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LES-PRE-20349
A64 -- Base Instructions (alphabetic order)

ADC: Add with Carry.
ADCS: Add with Carry, setting flags.

**ADD (extended register):** Add (extended register).
**ADD (immediate):** Add (immediate).
**ADD (shifted register):** Add (shifted register).
**ADDG:** Add with Tag.
**ADDS (extended register):** Add (extended register), setting flags.
**ADDS (immediate):** Add (immediate), setting flags.
**ADDS (shifted register):** Add (shifted register), setting flags.

ADR: Form PC-relative address.
ADR P: Form PC-relative address to 4KB page.

**AND (immediate):** Bitwise AND (immediate).
**AND (shifted register):** Bitwise AND (shifted register).
**ANDS (immediate):** Bitwise AND (immediate), setting flags.
**ANDS (shifted register):** Bitwise AND (shifted register), setting flags.

ASR (immediate): Arithmetic Shift Right (immediate): an alias of SBFM.
ASR (register): Arithmetic Shift Right (register): an alias of ASRV.

AT: Address Translate: an alias of SYS.

**AUTDA, AUTDZA:** Authenticate Data address, using key A.
**AUTDB, AUTDZB:** Authenticate Data address, using key B.
**AUTIA, AUTIA1716, AUTIASP, AUTIZA:** Authenticate Instruction address, using key A.
**AUTIB, AUTIB1716, AUTIBSP, AUTIBZ, AUTIZB:** Authenticate Instruction address, using key B.

**AXFlag:** Convert floating-point condition flags from ARM to external format.

B: Branch.
B.cond: Branch conditionally.
BFC: Bitfield Clear: an alias of BFM.
BFI: Bitfield Insert: an alias of BFM.

BFM: Bitfield Move.
BFXIL: Bitfield extract and insert at low end: an alias of BFM.

**BIC (shifted register):** Bitwise Bit Clear (shifted register).
**BICS (shifted register):** Bitwise Bit Clear (shifted register), setting flags.

BL: Branch with Link.
**BLR**: Branch with Link to Register.

**BLRAA, BLRAAZ, BLRAB, BLRABZ**: Branch with Link to Register, with pointer authentication.

**BR**: Branch to Register.

**BRAA, BRAAZ, BRAB, BRABZ**: Branch to Register, with pointer authentication.

**BRK**: Breakpoint instruction.

**BTI**: Branch Target Identification.

**CAS, CASA, CASAL, CASL**: Compare and Swap word or doubleword in memory.

**CASB, CASAB, CASALB, CASLB**: Compare and Swap byte in memory.

**CASH, CASAH, CASALH, CASLH**: Compare and Swap halfword in memory.

**CASP, CASPA, CASPAL, CASPL**: Compare and Swap Pair of words or doublewords in memory.

**CBNZ**: Compare and Branch on Nonzero.

**CBZ**: Compare and Branch on Zero.

**CCMN (immediate)**: Conditional Compare Negative (immediate).

**CCMN (register)**: Conditional Compare Negative (register).

**CCMP (immediate)**: Conditional Compare (immediate).

**CCMP (register)**: Conditional Compare (register).

**CFINV**: Invert PSTATE.C Carry Flag Flag Inversion.

**CFP**: Control Flow Prediction Restriction by Context: an alias of SYS.

**CINC**: Conditional Increment: an alias of CSINC.

**CINV**: Conditional Invert: an alias of CSINV.

**CLREX**: Clear Exclusive.

**CLS**: Count Leading Sign bits.

**CLZ**: Count Leading Zeros bits.

**CMN (extended register)**: Compare Negative (extended register): an alias of ADDS (extended register).

**CMN (immediate)**: Compare Negative (immediate): an alias of ADDS (immediate).

**CMN (shifted register)**: Compare Negative (shifted register): an alias of ADDS (shifted register).

**CMP (extended register)**: Compare (extended register): an alias of SUBS (extended register).

**CMP (immediate)**: Compare (immediate): an alias of SUBS (immediate).

**CMP (shifted register)**: Compare (shifted register): an alias of SUBS (shifted register).

**CMPP**: Compare with Tag: an alias of SUBPS.

**CNEG**: Conditional Negate: an alias of CSNEG.

**CPP**: Cache Prefetch Prediction Restriction by Context: an alias of SYS.

**CRC32B, CRC32H, CRC32W, CRC32X**: CRC32 checksum.

**CRC32CB, CRC32CH, CRC32CW, CRC32CX**: CRC32C checksum.

**CSDB**: Consumption of Speculative Data Barrier.

**CSEL**: Conditional Select.
CSET: Conditional Set: an alias of CSINC.
CSETM: Conditional Set Mask: an alias of CSINV.
CSINC: Conditional Select Increment.
CSINV: Conditional Select Invert.
CSNEG: Conditional Select Negation.
DC: Data Cache operation: an alias of SYS.
DCPS1: Debug Change PE State to EL1..
DCPS2: Debug Change PE State to EL2..
DCPS3: Debug Change PE State to EL3.
DMB: Data Memory Barrier.
DRPS: Debug restore process state.
DSB: Data Synchronization Barrier.
DVP: Data Value Prediction Restriction by Context: an alias of SYS.
EON (shifted register): Bitwise Exclusive OR NOT (shifted register).
EOR (immediate): Bitwise Exclusive OR (immediate).
EOR (shifted register): Bitwise Exclusive OR (shifted register).
ERET: Exception Return.
ERETAA, ERETAB: Exception Return, with pointer authentication.
ESB: Error Synchronization Barrier.
EXTR: Extract register.
GMI: Tag Mask Insert.
HINT: Hint instruction.
HLT: Halt instruction.
HVC: Hypervisor Call.
IC: Instruction Cache operation: an alias of SYS.
IRG: Insert Random Tag.
ISB: Instruction Synchronization Barrier.
LDADD, LDADDA, LDADDAL, LDADDL: Atomic add on word or doubleword in memory.
LDADDB, LDADDAB, LDADDALB, LDADDLB: Atomic add on byte in memory.
LDADDH, LDADDAH, LDADDALH, LDADDLH: Atomic add on halfword in memory.
LDAPR: Load-Acquire RCpc Register.
LDAPRB: Load-Acquire RCpc Register Byte.
LDAPRH: Load-Acquire RCpc Register Halfword.
LDAPUR: Load-Acquire RCpc Register (unscaled).
LDAPURB: Load-Acquire RCpc Register Byte (unscaled).
LDAPURH: Load-Acquire RCpc Register Halfword (unscaled).
**LDAPURSB**: Load-Acquire RCpc Register Signed Byte (unscaled).

**LDAPURSH**: Load-Acquire RCpc Register Signed Halfword (unscaled).

**LDAPURSW**: Load-Acquire RCpc Register Signed Word (unscaled).

**LDAR**: Load-Acquire Register.

**LDARH**: Load-Acquire Register Halfword.

**LDAXP**: Load-Acquire Exclusive Pair of Registers.

**LDAXR**: Load-Acquire Exclusive Register.

**LDAXRB**: Load-Acquire Exclusive Register Byte.

**LDAXRH**: Load-Acquire Exclusive Register Halfword.

**LDCLR, LDCLRA, LDCLRAL, LDCLRL**: Atomic bit clear on word or doubleword in memory.

**LDCLRB, LDCLRAB, LDCLRALB, LDCLRLB**: Atomic bit clear on byte in memory.

**LDCLRH, LDCLRAH, LDCLRALH, LDCLRLH**: Atomic bit clear on halfword in memory.

**LDEOR, LDEORA, LDEORAL, LDEORL**: Atomic exclusive OR on word or doubleword in memory.

**LDEORB, LDEORAB, LDEORALB, LDEORLB**: Atomic exclusive OR on byte in memory.

**LDEORH, LDEORAH, LDEORALH, LDEORLH**: Atomic exclusive OR on halfword in memory.

**LDG**: Load Allocation Tag.

**LDGV**: Load Allocation Tag.

**LDLAR**: Load LOAcquire Register.

**LDLARB**: Load LOAcquire Register Byte.

**LDLARH**: Load LOAcquire Register Halfword.

**LDNP**: Load Pair of Registers, with non-temporal hint.

**LDP**: Load Pair of Registers.

**LDPSW**: Load Pair of Registers Signed Word.

**LDR (immediate)**: Load Register (immediate).

**LDR (literal)**: Load Register (literal).

**LDR (register)**: Load Register (register).

**LDRAA, LDRAB**: Load Register, with pointer authentication.

**LDRB (immediate)**: Load Register Byte (immediate).

**LDRB (register)**: Load Register Byte (register).

**LDRH (immediate)**: Load Register Halfword (immediate).

**LDRH (register)**: Load Register Halfword (register).

**LDRSB (immediate)**: Load Register Signed Byte (immediate).

**LDRSB (register)**: Load Register Signed Byte (register).

**LDRSH (immediate)**: Load Register Signed Halfword (immediate).

**LDRSH (register)**: Load Register Signed Halfword (register).
LDRSW (immediate): Load Register Signed Word (immediate).

LDRSW (literal): Load Register Signed Word (literal).

LDRSW (register): Load Register Signed Word (register).

LDSET, LDSETA, LDSETAL, LDSETL: Atomic bit set on word or doubleword in memory.

LDSETB, LDSETAB, LDSETALB, LDSETLB: Atomic bit set on byte in memory.

LDSETH, LDSETAH, LDSETHL, LDSETLH: Atomic bit set on halfword in memory.

LDSMAX, LDSMAXA, LDSMAXAL, LDSMAXL: Atomic signed maximum on word or doubleword in memory.

LDSMAXB, LDSMAXAB, LDSMAXALB, LDSMAXLB: Atomic signed maximum on byte in memory.

LDSMAXH, LDSMAXAH, LDSMAXALH, LDSMAXLH: Atomic signed maximum on halfword in memory.

LDSMIN, LDSMINA, LDSMINAL, LDSMINL: Atomic signed minimum on word or doubleword in memory.

LDSMINB, LDSMINAB, LDSMINALB, LDSMINLB: Atomic signed minimum on byte in memory.

LDSMINH, LDSMINAH, LDSMINALH, LDSMINLH: Atomic signed minimum on halfword in memory.

LDTR: Load Register (unprivileged).

LDTRB: Load Register Byte (unprivileged).

LDTRH: Load Register Halfword (unprivileged).

LDTRSB: Load Register Signed Byte (unprivileged).

LDTRSH: Load Register Signed Halfword (unprivileged).

LDTRSW: Load Register Signed Word (unprivileged).

LDMAX, LDMAXA, LDMAXAL, LDMAXL: Atomic unsigned maximum on word or doubleword in memory.

LDMAXB, LDMAXAB, LDMAXALB, LDMAXLB: Atomic unsigned maximum on byte in memory.

LDMAXH, LDMAXAH, LDMAXALH, LDMAXLH: Atomic unsigned maximum on halfword in memory.

LDMIN, LDMINA, LDMINAL, LDMINL: Atomic unsigned minimum on word or doubleword in memory.

LDMINB, LDMINAB, LDMINALB, LDMINLB: Atomic unsigned minimum on byte in memory.

LDMINH, LDMINAH, LDMINALH, LDMINLH: Atomic unsigned minimum on halfword in memory.

LDUR: Load Register (unscaled).

LDURB: Load Register Byte (unscaled).

LDURH: Load Register Halfword (unscaled).

LDURSB: Load Register Signed Byte (unscaled).

LDURSH: Load Register Signed Halfword (unscaled).

LDURSW: Load Register Signed Word (unscaled).

LDXP: Load Exclusive Pair of Registers.

LDXR: Load Exclusive Register.

LDXRB: Load Exclusive Register Byte.

LDXRH: Load Exclusive Register Halfword.

LSL (immediate): Logical Shift Left (immediate); an alias of UBFM.

LSL (register): Logical Shift Left (register); an alias of LSLV.
LSLV: Logical Shift Left Variable.

LSR (immediate): Logical Shift Right (immediate): an alias of UBFM.

LSR (register): Logical Shift Right (register): an alias of LSRV.

LSRV: Logical Shift Right Variable.

MADD: Multiply-Add.

MNEG: Multiply-Negate: an alias of MSUB.

MOV (bitmask immediate): Move (bitmask immediate): an alias of ORR (immediate).

MOV (inverted wide immediate): Move (inverted wide immediate): an alias of MOVN.


MOV (to/from SP): Move between register and stack pointer: an alias of ADD (immediate).

MOV (wide immediate): Move (wide immediate): an alias of MOVZ.

MOVK: Move wide with keep.

MOVN: Move wide with NOT.

MOVZ: Move wide with zero.

MRS: Move System Register.

MSR (immediate): Move immediate value to Special Register.

MSR (register): Move general-purpose register to System Register.

MSUB: Multiply-Subtract.

MUL: Multiply: an alias of MADD.

MVN: Bitwise NOT: an alias of ORN (shifted register).


NEGS: Negate, setting flags: an alias of SUBS (shifted register).

NGC: Negate with Carry: an alias of SBC.

NGCS: Negate with Carry, setting flags: an alias of SBCS.

NOP: No Operation.

ORN (shifted register): Bitwise OR NOT (shifted register).

ORR (immediate): Bitwise OR (immediate).

ORR (shifted register): Bitwise OR (shifted register).

PACDA, PACDZA: Pointer Authentication Code for Data address, using key A.

PACDB, PACDZB: Pointer Authentication Code for Data address, using key B.

PACGA: Pointer Authentication Code, using Generic key.

PACIA, PACIA1716, PACIASP, PACIAZ, PACIZA: Pointer Authentication Code for Instruction address, using key A.

PACIB, PACIB1716, PACIBSP, PACIBZ, PACIZB: Pointer Authentication Code for Instruction address, using key B.

PRFM (immediate): Prefetch Memory (immediate).

PRFM (literal): Prefetch Memory (literal).

PRFM (register): Prefetch Memory (register).
**PRFM (unscaled offset):** Prefetch Memory (unscaled offset).

**PSB CSYNC:** Profiling Synchronization Barrier.

**PSSBB:** Physical Speculative Store Bypass Barrier.

**RBIT:** Reverse Bits.

**RET:** Return from subroutine.

**RETTA, RETAB:** Return from subroutine, with pointer authentication.

**REV:** Reverse Bytes.

**REV16:** Reverse bytes in 16-bit halfwords.

**REV32:** Reverse bytes in 32-bit words.

**REV64:** Reverse Bytes: an alias of REV.

**RMIF:** Rotate, Mask Insert Flags.

**ROR (immediate):** Rotate right (immediate): an alias of EXTR.

**ROR (register):** Rotate Right (register): an alias of RORV.

**RORV:** Rotate Right Variable.

**SB:** Speculation Barrier.

**SBC:** Subtract with Carry.

**SBCS:** Subtract with Carry, setting flags.

**SBFIZ:** Signed Bitfield Insert in Zero: an alias of SBFM.

**SBFM:** Signed Bitfield Move.

**SBFX:** Signed Bitfield Extract: an alias of SBFM.

**SDIV:** Signed Divide.

**SELT8, SETF16:** Evaluation of 8 or 16 bit flag values.

**SEV:** Send Event.

**SEVL:** Send Event Local.

**SMADDL:** Signed Multiply-Add Long.

**SMC:** Secure Monitor Call.

**SMNEGL:** Signed Multiply-Negate Long: an alias of SMSUBL.

**SMSUBL:** Signed Multiply-Subtract Long.

**SMULH:** Signed Multiply High.

**SMULL:** Signed Multiply Long: an alias of SMADDL.

**SSBB:** Speculative Store Bypass Barrier.

**ST2G:** Store Allocation Tags.

**STADD, STADDL:** Atomic add on word or doubleword in memory, without return: an alias of LDADD, LDADDA, LDADDAL, LDADDL.

**STADDB, STADDLB:** Atomic add on byte in memory, without return: an alias of LDADDB, LDADDAB, LDADDALB, LDADDLB.

**STADDH, STADDLH:** Atomic add on halfword in memory, without return: an alias of LDADDH, LDADDAH, LDADDALH, LDADDLH.

**STCLR, STCLRL:** Atomic bit clear on word or doubleword in memory, without return: an alias of LDCLR, LDCLRA, LDCLRAL, LDCLRL.
STCLRB, STCLRLB: Atomic bit clear on byte in memory, without return: an alias of LDCLRB, LDCLRAB, LDCLRALB, LDCLRLB.

STCLRH, STCLRLH: Atomic bit clear on halfword in memory, without return: an alias of LDCLRH, LDCLRAH, LDCLRALH, LDCLRLH.

STEOR, STEORL: Atomic exclusive OR on word or doubleword in memory, without return: an alias of LDEOR, LDEORA, LDEORAL, LDEORL.

STEORB, STEORLB: Atomic exclusive OR on byte in memory, without return: an alias of LDEORB, LDEORAB, LDEORALB, LDEORLB.

STEORH, STEORLH: Atomic exclusive OR on halfword in memory, without return: an alias of LDEORH, LDEORAH, LDEORALH, LDEORLH.

STG: Store Allocation Tag.

STGP: Store Allocation Tag and Pair of registers.

STGV: Store Tag Vector.

STLR: Store LORelease Register.

STLLRB: Store LORelease Register Byte.

STLLRH: Store LORelease Register Halfword.

STL: Store-Release Register.

STLRB: Store-Release Register Byte.

STLRH: Store-Release Register Halfword.

STLUR: Store-Release Register (unscaled).

STLURB: Store-Release Register Byte (unscaled).

STLURH: Store-Release Register Halfword (unscaled).

STLXP: Store-Release Exclusive Pair of registers.

STLXR: Store-Release Exclusive Register.

STLXRB: Store-Release Exclusive Register Byte.

STLXRH: Store-Release Exclusive Register Halfword.

STNP: Store Pair of Registers, with non-temporal hint.

STP: Store Pair of Registers.

STR (immediate): Store Register (immediate).

STR (register): Store Register (register).

STRB (immediate): Store Register Byte (immediate).

STRB (register): Store Register Byte (register).

STRH (immediate): Store Register Halfword (immediate).

STRH (register): Store Register Halfword (register).

STSET, STSETL: Atomic bit set on word or doubleword in memory, without return: an alias of LDSET, LDSETA, LDSETAL, LDSETL.

STSETB, STSETLB: Atomic bit set on byte in memory, without return: an alias of LDSETB, LDSETAB, LDSETALB, LDSETLB.

STSETH, STSETLH: Atomic bit set on halfword in memory, without return: an alias of LDSETH, LDSETAH, LDSETALH, LDSETLH.

STSMAX, STSMAXL: Atomic signed maximum on word or doubleword in memory, without return: an alias of LDSMAX, LDSMAXA, LDSMAXAL, LDSMAXL.

STSMAXB, STSMAXLB: Atomic signed maximum on byte in memory, without return: an alias of LDSMAXB, LDSMAXAB, LDSMAXALB, LDSMAXLB.
STSMAXH, STSMAXLH: Atomic signed maximum on halfword in memory, without return: an alias of LDSMAXH, LDSMAXAH, LDSMAXALH, LDSMAXLH.

STSMIN, STSMINL: Atomic signed minimum on word or doubleword in memory, without return: an alias of LDSMIN, LDSMINA, LDSMINAL, LDSMINL.

STSMINB, STSMINLB: Atomic signed minimum on byte in memory, without return: an alias of LDSMINB, LDSMINAB, LDSMINALB, LDSMINLB.

STSMINH, STSMINLH: Atomic signed minimum on halfword in memory, without return: an alias of LDSMINH, LDSMINAH, LDSMINALH, LDSMINLH.

STTR: Store Register (unprivileged).

STTRB: Store Register Byte (unprivileged).

STTRH: Store Register Halfword (unprivileged).

STUMAX, STUMAXL: Atomic unsigned maximum on word or doubleword in memory, without return: an alias of LDUMAX, LDUMAXA, LDUMAXAL, LDUMAXL.

STUMAXB, STUMAXLB: Atomic unsigned maximum on byte in memory, without return: an alias of LDUMAXB, LDUMAXAB, LDUMAXALB, LDUMAXLB.

STUMAXH, STUMAXLH: Atomic unsigned maximum on halfword in memory, without return: an alias of LDUMAXH, LDUMAXAH, LDUMAXALH, LDUMAXLH.

STUMIN, STUMINL: Atomic unsigned minimum on word or doubleword in memory, without return: an alias of LDUMIN, LDUMINA, LDUMINAL, LDUMINL.

STUMINB, STUMINLB: Atomic unsigned minimum on byte in memory, without return: an alias of LDUMINB, LDUMINAB, LDUMINALB, LDUMINLB.

STUMINH, STUMINLH: Atomic unsigned minimum on halfword in memory, without return: an alias of LDUMINH, LDUMINAH, LDUMINALH, LDUMINLH.

STUR: Store Register (unscaled).

STURB: Store Register Byte (unscaled).

STURH: Store Register Halfword (unscaled).

STXP: Store Exclusive Pair of registers.

STXR: Store Exclusive Register.

STXRB: Store Exclusive Register Byte.

STXRH: Store Exclusive Register Halfword.

STZ2G: Store Allocation Tags, Zeroing.

STZG: Store Allocation Tag, Zeroing.

SUB (extended register): Subtract (extended register).

SUB (immediate): Subtract (immediate).

SUB (shifted register): Subtract (shifted register).

SUBG: Subtract with Tag.

SUBP: Subtract Pointer.

SUBPS: Subtract Pointer, setting Flags.

SUBS (extended register): Subtract (extended register), setting flags.

SUBS (immediate): Subtract (immediate), setting flags.

SUBS (shifted register): Subtract (shifted register), setting flags.
SVC: Supervisor Call.

**SWP, SWPA, SWPAL, SWPL**: Swap word or doubleword in memory.

**SWPB, SWPAB, SWPALB, SWPLB**: Swap byte in memory.

**SWPH, SWPAH, SWPALH, SWPLH**: Swap halfword in memory.

SXTB: Signed Extend Byte: an alias of SBFM.

SXTH: Sign Extend Halfword: an alias of SBFM.

SXTW: Sign Extend Word: an alias of SBFM.

**SYS**: System instruction.

**SYSL**: System instruction with result.

**TBNZ**: Test bit and Branch if Nonzero.

**TBZ**: Test bit and Branch if Zero.

TLBI: TLB Invalidate operation: an alias of SYS.

**TSB CSYNC**: Trace Synchronization Barrier.

TST (immediate): Test bits (immediate): an alias of ANDS (immediate).


**UBFIZ**: Unsigned Bitfield Insert in Zero: an alias of UBFM.

**UBFM**: Unsigned Bitfield Move.

**UBFX**: Unsigned Bitfield Extract: an alias of UBFM.

**UDP**: Permanently Undefined.

UDIV: Unsigned Divide.

**UMADDL**: Unsigned Multiply-Add Long.

**UMNEGL**: Unsigned Multiply-Negate Long: an alias of UMSUBL.

**UMSUBL**: Unsigned Multiply-Subtract Long.

UMULH: Unsigned Multiply High.

UMULL: Unsigned Multiply Long: an alias of UMADDL.

UXTB: Unsigned Extend Byte: an alias of UBFM.

UXTH: Unsigned Extend Halfword: an alias of UBFM.

**WFE**: Wait For Event.

**WFI**: Wait For Interrupt.

**XAFlag**: Convert floating-point condition flags from external format to ARM format.

**XPACD, XPACI, XPACLRI**: Strip Pointer Authentication Code.

**YIELD**: YIELD.
A64 -- SIMD and Floating-point Instructions (alphabetic order)

ABS: Absolute value (vector).
ADD (vector): Add (vector).
ADDHN, ADDHN2: Add returning High Narrow.
ADDP (scalar): Add Pair of elements (scalar).
ADDP (vector): Add Pairwise (vector).
ADDV: Add across Vector.
AESD: AES single round decryption.
AESE: AES single round encryption.
AESIMC: AES inverse mix columns.
AESMC: AES mix columns.
AND (vector): Bitwise AND (vector).
BCAX: Bit Clear and XOR.
BIC (vector, immediate): Bitwise bit Clear (vector, immediate).
BIF: Bitwise Insert if False.
BIT: Bitwise Insert if True.
BSL: Bitwise Select.
CLS (vector): Count Leading Sign bits (vector).
CLZ (vector): Count Leading Zero bits (vector).
CMEQ (register): Compare bitwise Equal (vector).
CMEQ (zero): Compare bitwise Equal to zero (vector).
CMGE (register): Compare signed Greater than or Equal (vector).
CMGE (zero): Compare signed Greater than or Equal to zero (vector).
CMGT (register): Compare signed Greater than (vector).
CMGT (zero): Compare signed Greater than zero (vector).
CMHI (register): Compare unsigned Higher (vector).
CMHS (register): Compare unsigned Higher or Same (vector).
CMLE (zero): Compare signed Less than or Equal to zero (vector).
CMLT (zero): Compare signed Less than zero (vector).
CMTST: Compare bitwise Test bits nonzero (vector).
CNT: Population Count per byte.
DUP (element): Duplicate vector element to vector or scalar.
DUP (general): Duplicate general-purpose register to vector.
EOR (vector): Bitwise Exclusive OR (vector).

EOR3: Three-way Exclusive OR.

EXT: Extract vector from pair of vectors.

FABD: Floating-point Absolute Difference (vector).

FABS (scalar): Floating-point Absolute value (scalar).

FABS (vector): Floating-point Absolute value (vector).

FACGE: Floating-point Absolute Compare Greater than or Equal (vector).

FACGT: Floating-point Absolute Compare Greater than (vector).

FADD (scalar): Floating-point Add (scalar).

FADD (vector): Floating-point Add (vector).

FADDP (scalar): Floating-point Add Pair of elements (scalar).

FADDP (vector): Floating-point Add Pairwise (vector).

FCADD: Floating-point Complex Add.

FCCMP: Floating-point Conditional quiet Compare (scalar).

FCCMPE: Floating-point Conditional signaling Compare (scalar).

FCMEQ (register): Floating-point Compare Equal (vector).

FCMEQ (zero): Floating-point Compare Equal to zero (vector).

FCMGE (register): Floating-point Compare Greater than or Equal (vector).

FCMGE (zero): Floating-point Compare Greater than or Equal to zero (vector).

FCMGT (register): Floating-point Compare Greater than (vector).

FCMGT (zero): Floating-point Compare Greater than zero (vector).

FCMLA: Floating-point Complex Multiply Accumulate.

FCMLA (by element): Floating-point Complex Multiply Accumulate (by element).

FCMLE (zero): Floating-point Compare Less than or Equal to zero (vector).

FCMLT (zero): Floating-point Compare Less than zero (vector).

FCMP: Floating-point quiet Compare (scalar).

FCMP: Floating-point signaling Compare (scalar).

FCSEL: Floating-point Conditional Select (scalar).

FCVT: Floating-point Convert precision (scalar).

FCVTAS (scalar): Floating-point Convert to Signed integer, rounding to nearest with ties to Away (scalar).

FCVTAS (vector): Floating-point Convert to Signed integer, rounding to nearest with ties to Away (vector).

FCVTAU (scalar): Floating-point Convert to Unsigned integer, rounding to nearest with ties to Away (scalar).

FCVTAU (vector): Floating-point Convert to Unsigned integer, rounding to nearest with ties to Away (vector).

FCVTL, FCVTL2: Floating-point Convert to higher precision Long (vector).

FCVTMS (scalar): Floating-point Convert to Signed integer, rounding toward Minus infinity (scalar).

FCVTMS (vector): Floating-point Convert to Signed integer, rounding toward Minus infinity (vector).
FCVTMU (scalar): Floating-point Convert to Unsigned integer, rounding toward Minus infinity (scalar).
FCVTMU (vector): Floating-point Convert to Unsigned integer, rounding toward Minus infinity (vector).
FCVTN, FCVTN2: Floating-point Convert to lower precision Narrow (vector).
FCVTNS (scalar): Floating-point Convert to Signed integer, rounding to nearest with ties to even (scalar).
FCVTNS (vector): Floating-point Convert to Signed integer, rounding to nearest with ties to even (vector).
FCVTNU (scalar): Floating-point Convert to Unsigned integer, rounding to nearest with ties to even (scalar).
FCVTNU (vector): Floating-point Convert to Unsigned integer, rounding to nearest with ties to even (vector).
FCVTPS (scalar): Floating-point Convert to Signed integer, rounding toward Plus infinity (scalar).
FCVTPS (vector): Floating-point Convert to Signed integer, rounding toward Plus infinity (vector).
FCVTPU (scalar): Floating-point Convert to Unsigned integer, rounding toward Plus infinity (scalar).
FCVTPU (vector): Floating-point Convert to Unsigned integer, rounding toward Plus infinity (vector).
FCVTXN, FCVTXN2: Floating-point Convert to lower precision Narrow, rounding to odd (vector).
FCVTZS (scalar, fixed-point): Floating-point Convert to Signed fixed-point, rounding toward Zero (scalar).
FCVTZS (vector, fixed-point): Floating-point Convert to Signed fixed-point, rounding toward Zero (vector).
FCVTZS (scalar, integer): Floating-point Convert to Signed integer, rounding toward Zero (scalar).
FCVTZS (vector, integer): Floating-point Convert to Signed integer, rounding toward Zero (vector).
FCVTZU (scalar, fixed-point): Floating-point Convert to Unsigned fixed-point, rounding toward Zero (scalar).
FCVTZU (scalar, integer): Floating-point Convert to Unsigned integer, rounding toward Zero (scalar).
FCVTZU (vector, fixed-point): Floating-point Convert to Unsigned fixed-point, rounding toward Zero (vector).
FCVTZU (vector, integer): Floating-point Convert to Unsigned integer, rounding toward Zero (vector).
FDIV (scalar): Floating-point Divide (scalar).
FDIV (vector): Floating-point Divide (vector).
FJCVTZS: Floating-point Javascript Convert to Signed fixed-point, rounding toward Zero.
FMADD: Floating-point fused Multiply-Add (scalar).
FMAX (scalar): Floating-point Maximum (scalar).
FMAX (vector): Floating-point Maximum (vector).
FMAXNM (scalar): Floating-point Maximum Number (scalar).
FMAXNM (vector): Floating-point Maximum Number (vector).
FMAXNMP (scalar): Floating-point Maximum Number of Pair of elements (scalar).
FMAXNMP (vector): Floating-point Maximum Number Pairwise (vector).
FMAXN MV: Floating-point Maximum Number across Vector.
FMAXP (scalar): Floating-point Maximum of Pair of elements (scalar).
FMAXP (vector): Floating-point Maximum Pairwise (vector).
FMAXV: Floating-point Maximum across Vector.
FMIN (scalar): Floating-point Minimum (scalar).
FMIN (vector): Floating-point minimum (vector).
FMINNM (scalar): Floating-point Minimum Number (scalar).
FMINNM (vector): Floating-point Minimum Number (vector).
FMINNMP (scalar): Floating-point Minimum Number of Pair of elements (scalar).
FMINNMP (vector): Floating-point Minimum Number Pairwise (vector).
FMINMV: Floating-point Minimum Number across Vector.
FMINP (scalar): Floating-point Minimum of Pair of elements (scalar).
FMINP (vector): Floating-point Minimum Pairwise (vector).
FMINV: Floating-point Minimum across Vector.
FMLA (by element): Floating-point fused Multiply-Add to accumulator (by element).
FMLA (vector): Floating-point fused Multiply-Add to accumulator (vector).
FMLAL, FMLAL2 (by element): Floating-point fused Multiply-Add Long to accumulator (by element).
FMLAL, FMLAL2 (vector): Floating-point fused Multiply-Add Long to accumulator (vector).
FML (by element): Floating-point Multiply-Subtract from accumulator (by element).
FML (vector): Floating-point Multiply-Subtract from accumulator (vector).
FMLSL, FMLSL2 (by element): Floating-point fused Multiply-Subtract Long from accumulator (by element).
FMLSL, FMLSL2 (vector): Floating-point fused Multiply-Subtract Long from accumulator (vector).
FMOV (general): Floating-point Move to or from general-purpose register without conversion.
FMOV (register): Floating-point Move register without conversion.
FMOV (scalar, immediate): Floating-point move immediate (scalar).
FMOV (vector, immediate): Floating-point move immediate (vector).
FMULX: Floating-point Multiply extended.
FMULX (by element): Floating-point Multiply extended (by element).
FMUL (by element): Floating-point Multiply (by element).
FMUL (scalar): Floating-point Multiply (scalar).
FMUL (vector): Floating-point Multiply (vector).
FRINT32X (scalar): Floating-point Round to 32-bit Integer, using current rounding mode (scalar).
FRINT32X (vector): Floating-point Round to 32-bit Integer, using current rounding mode (vector).
FRINT32Z (scalar): Floating-point Round to 32-bit Integer toward Zero (scalar).

FRINT32Z (vector): Floating-point Round to 32-bit Integer toward Zero (vector).

FRINT64X (scalar): Floating-point Round to 64-bit Integer, using current rounding mode (scalar).

FRINT64X (vector): Floating-point Round to 64-bit Integer, using current rounding mode (vector).

FRINT64Z (scalar): Floating-point Round to 64-bit Integer toward Zero (scalar).

FRINT64Z (vector): Floating-point Round to 64-bit Integer toward Zero (vector).

FRINTA (scalar): Floating-point Round to Integral, to nearest with ties to Away (scalar).

FRINTA (vector): Floating-point Round to Integral, to nearest with ties to Away (vector).

FRINTI (scalar): Floating-point Round to Integral, using current rounding mode (scalar).

FRINTI (vector): Floating-point Round to Integral, using current rounding mode (vector).

FRINTM (scalar): Floating-point Round to Integral, toward Minus infinity (scalar).

FRINTM (vector): Floating-point Round to Integral, toward Minus infinity (vector).

FRINTN (scalar): Floating-point Round to Integral, to nearest with ties to even (scalar).

FRINTN (vector): Floating-point Round to Integral, to nearest with ties to even (vector).

FRINTP (scalar): Floating-point Round to Integral, toward Plus infinity (scalar).

FRINTP (vector): Floating-point Round to Integral, toward Plus infinity (vector).

FRINTX (scalar): Floating-point Round to Integral exact, using current rounding mode (scalar).

FRINTX (vector): Floating-point Round to Integral exact, using current rounding mode (vector).

FRINTZ (scalar): Floating-point Round to Integral, toward Zero (scalar).

FRINTZ (vector): Floating-point Round to Integral, toward Zero (vector).

FRSQRTE: Floating-point Reciprocal Square Root Estimate.

FRSQRTS: Floating-point Reciprocal Square Root Step.

FSQRT (scalar): Floating-point Square Root (scalar).

FSQRT (vector): Floating-point Square Root (vector).

FSUB (scalar): Floating-point Subtract (scalar).

FSUB (vector): Floating-point Subtract (vector).

INS (element): Insert vector element from another vector element.

INS (general): Insert vector element from general-purpose register.

LD1 (multiple structures): Load multiple single-element structures to one, two, three, or four registers.

LD1 (single structure): Load one single-element structure to one lane of one register.

LD1R: Load one single-element structure and Replicate to all lanes (of one register).

LD2 (multiple structures): Load multiple 2-element structures to two registers.

LD2 (single structure): Load single 2-element structure to one lane of two registers.

LD2R: Load single 2-element structure and Replicate to all lanes of two registers.

LD3 (multiple structures): Load multiple 3-element structures to three registers.

LD3 (single structure): Load single 3-element structure to one lane of three registers.
A64 -- SIMD and Floating-point Instructions (alphabetic order)

**LD3R**: Load single 3-element structure and Replicate to all lanes of three registers.

**LD4 (multiple structures)**: Load multiple 4-element structures to four registers.

**LD4 (single structure)**: Load single 4-element structure to one lane of four registers.

**LD4R**: Load single 4-element structure and Replicate to all lanes of four registers.

**LDNP (SIMD&FP)**: Load Pair of SIMD&FP registers, with Non-temporal hint.

**LDP (SIMD&FP)**: Load Pair of SIMD&FP registers.

**LDR (immediate, SIMD&FP)**: Load SIMD&FP Register (immediate offset).

**LDR (literal, SIMD&FP)**: Load SIMD&FP Register (PC-relative literal).

**LDR (register, SIMD&FP)**: Load SIMD&FP Register (register offset).

**LDUR (SIMD&FP)**: Load SIMD&FP Register (unscaled offset).

**MLA (by element)**: Multiply-Add to accumulator (vector, by element).

**MLA (vector)**: Multiply-Add to accumulator (vector).

**MLS (by element)**: Multiply-Subtract from accumulator (vector, by element).

**MLS (vector)**: Multiply-Subtract from accumulator (vector).

**MOV (element)**: Move vector element to another vector element: an alias of INS (element).

**MOV (from general)**: Move general-purpose register to a vector element: an alias of INS (general).

**MOV (scalar)**: Move vector element to scalar: an alias of DUP (element).

**MOV (to general)**: Move vector element to general-purpose register: an alias of UMOV.

**MOV (vector)**: Move vector: an alias of ORR (vector, register).

**MOVI**: Move Immediate (vector).

**MUL (by element)**: Multiply (vector, by element).

**MUL (vector)**: Multiply (vector).

**MVN**: Bitwise NOT (vector): an alias of NOT.

**MVNI**: Move inverted Immediate (vector).

**NEG (vector)**: Negate (vector).

**NOT**: Bitwise NOT (vector).

**ORN (vector)**: Bitwise inclusive OR NOT (vector).

**ORR (vector, immediate)**: Bitwise inclusive OR (vector, immediate).

**ORR (vector, register)**: Bitwise inclusive OR (vector, register).

**PMUL**: Polynomial Multiply.

**PMULL, PMULL2**: Polynomial Multiply Long.

**RADDHN, RADDHN2**: Rounding Add returning High Narrow.

**RAXI**: Rotate and Exclusive OR.

**RBIT (vector)**: Reverse Bit order (vector).

**REV16 (vector)**: Reverse elements in 16-bit halfwords (vector).

**REV32 (vector)**: Reverse elements in 32-bit words (vector).
REV64: Reverse elements in 64-bit doublewords (vector).

RSHRN, RSHRN2: Rounding Shift Right Narrow (immediate).

RSUBHN, RSUBHN2: Rounding Subtract returning High Narrow.

SABA: Signed Absolute difference and Accumulate.

SABAL, SABAL2: Signed Absolute difference and Accumulate Long.

SABD: Signed Absolute Difference.

SABDL, SABDL2: Signed Absolute Difference Long.

SADALP: Signed Add and Accumulate Long Pairwise.

SADDL, SADDL2: Signed Add Long (vector).

SADDLP: Signed Add Long Pairwise.

SADDLV: Signed Add Long across Vector.

SADDW, SADDW2: Signed Add Wide.

SCVTF (scalar, fixed-point): Signed fixed-point Convert to Floating-point (scalar).

SCVTF (scalar, integer): Signed integer Convert to Floating-point (scalar).

SCVTF (vector, fixed-point): Signed fixed-point Convert to Floating-point (vector).

SCVTF (vector, integer): Signed integer Convert to Floating-point (vector).

SDOT (by element): Dot Product signed arithmetic (vector, by element).

SDOT (vector): Dot Product signed arithmetic (vector).

SHA1C: SHA1 hash update (choose).

SHA1H: SHA1 fixed rotate.

SHA1M: SHA1 hash update (majority).

SHA1P: SHA1 hash update (parity).

SHA1SU0: SHA1 schedule update 0.

SHA1SU1: SHA1 schedule update 1.

SHA256H: SHA256 hash update (part 1).

SHA256H2: SHA256 hash update (part 2).

SHA256SU0: SHA256 schedule update 0.

SHA256SU1: SHA256 schedule update 1.

SHA512H: SHA512 Hash update part 1.

SHA512H2: SHA512 Hash update part 2.

SHA512SU0: SHA512 Schedule Update 0.

SHA512SU1: SHA512 Schedule Update 1.

SHADD: Signed Halving Add.

SHL: Shift Left (immediate).

SHLL, SHLL2: Shift Left Long (by element size).

SHRN, SHRN2: Shift Right Narrow (immediate).
SHSUB: Signed Halving Subtract.
SLI: Shift Left and Insert (immediate).
SM3PARTW1: SM3PARTW1.
SM3PARTW2: SM3PARTW2.
SM3SS1: SM3SS1.
SM3TT1A: SM3TT1A.
SM3TT1B: SM3TT1B.
SM3TT2A: SM3TT2A.
SM3TT2B: SM3TT2B.
SM4E: SM4 Encode.
SM4EKEY: SM4 Key.
SMAX: Signed Maximum (vector).
SMAXP: Signed Maximum Pairwise.
SMAXV: Signed Maximum across Vector.
SMIN: Signed Minimum (vector).
SMINP: Signed Minimum Pairwise.
SMINV: Signed Minimum across Vector.
SMLSL, SMLSL2 (by element): Signed Multiply-Subtract Long (vector, by element).
SMOV: Signed Move vector element to general-purpose register.
SQABS: Signed saturating Absolute value.
SQADD: Signed saturating Add.
SQDMLSL, SQDMLSL2 (by element): Signed saturating Doubling Multiply-Subtract Long (by element).
SQDMULH (by element): Signed saturating Doubling Multiply returning High half (by element).
SQDMULH (vector): Signed saturating Doubling Multiply returning High half.
SQDMULL, SQDMULL2 (by element): Signed saturating Doubling Multiply Long (by element).
SQNEG: Signed saturating Negate.
SQRDMLAH (by element): Signed Saturating Rounding Doubling Multiply Accumulate returning High Half (by element).
**A64 -- SIMD and Floating-point Instructions (alphabetic order)**

**SQRDMLAH (vector):** Signed Saturating Rounding Doubling Multiply Accumulate returning High Half (vector).

**SQRDMLSH (by element):** Signed Saturating Rounding Doubling Multiply Subtract returning High Half (by element).

**SQRDMLSH (vector):** Signed Saturating Rounding Doubling Multiply Subtract returning High Half (vector).

**SQRDMULH (by element):** Signed saturating Rounding Doubling Multiply returning High half (by element).

**SQRDMULH (vector):** Signed saturating Rounding Doubling Multiply returning High half.

**SQRSHL:** Signed saturating Rounding Shift Left (register).

**SQRSHRN, SQRSHRN2:** Signed saturating Rounded Shift Right Narrow (immediate).

**SQRSHRUN, SQRSHRUN2:** Signed saturating Rounded Shift Right Unsigned Narrow (immediate).

**SQSHEL (immediate):** Signed saturating Shift Left (immediate).

**SQSHEL (register):** Signed saturating Shift Left (register).

**SQSHELU:** Signed saturating Shift Left Unsigned (immediate).

**SQSHRN, SQSHRN2:** Signed saturating Shift Right Narrow (immediate).

**SQSHRUN, SQSHRUN2:** Signed saturating Shift Right Unsigned Narrow (immediate).

**SQSUB:** Signed saturating Subtract.

**SQXTN, SQXTN2:** Signed saturating extract Narrow.

**SQXTUN, SQXTUN2:** Signed saturating extract Unsigned Narrow.

**SRHADD:** Signed Rounding Halving Add.

**SRI:** Shift Right and Insert (immediate).

**SRSHL:** Signed Rounding Shift Left (register).

**SRSHR:** Signed Rounding Shift Right (immediate).

**SRSRA:** Signed Rounding Shift Right and Accumulate (immediate).

**SSHLL, SSHLL2:** Signed Shift Left Long (immediate).

**SSHR:** Signed Shift Right (immediate).

**SSRA:** Signed Shift Right and Accumulate (immediate).

**SSUBL, SSUBL2:** Signed Subtract Long.

**SSUBW, SSUBW2:** Signed Subtract Wide.

**ST1 (multiple structures):** Store multiple single-element structures from one, two, three, or four registers.

**ST1 (single structure):** Store a single-element structure from one lane of one register.

**ST2 (multiple structures):** Store multiple 2-element structures from two registers.

**ST2 (single structure):** Store single 2-element structure from one lane of two registers.

**ST3 (multiple structures):** Store multiple 3-element structures from three registers.

**ST3 (single structure):** Store single 3-element structure from one lane of three registers.

**ST4 (multiple structures):** Store multiple 4-element structures from four registers.

**ST4 (single structure):** Store single 4-element structure from one lane of four registers.

**STNP (SIMD&FP):** Store Pair of SIMD&FP registers, with Non-temporal hint.
STP (SIMD&FP): Store Pair of SIMD&FP registers.
STR (immediate, SIMD&FP): Store SIMD&FP register (immediate offset).
STR (register, SIMD&FP): Store SIMD&FP register (register offset).
STUR (SIMD&FP): Store SIMD&FP register (unscaled offset).
SUB (vector): Subtract (vector).
SUBHN, SUBHN2: Subtract returning High Narrow.
SUQADD: Signed saturating Accumulate of Unsigned value.
TBL: Table vector Lookup.
TBX: Table vector lookup extension.
TRN1: Transpose vectors (primary).
TRN2: Transpose vectors (secondary).
UABA: Unsigned Absolute difference and Accumulate.
UABAL, UABAL2: Unsigned Absolute difference and Accumulate Long.
UABD: Unsigned Absolute Difference (vector).
UABDL, UABDL2: Unsigned Absolute Difference Long.
UADALP: Unsigned Add and Accumulate Long Pairwise.
UADDL, UADDL2: Unsigned Add Long (vector).
UADLP: Unsigned Add Long Pairwise.
UADLV: Unsigned sum Long across Vector.
UADDW, UADDW2: Unsigned Add Wide.
UCVTF (scalar, fixed-point): Unsigned fixed-point Convert to Floating-point (scalar).
UCVTF (scalar, integer): Unsigned integer Convert to Floating-point (scalar).
UCVTF (vector, fixed-point): Unsigned fixed-point Convert to Floating-point (vector).
UCVTF (vector, integer): Unsigned integer Convert to Floating-point (vector).
UDOT (by element): Dot Product unsigned arithmetic (vector, by element).
UDOT (vector): Dot Product unsigned arithmetic (vector).
UHADD: Unsigned Halving Add.
UHSUB: Unsigned Halving Subtract.
UMAX: Unsigned Maximum (vector).
UMAXP: Unsigned Maximum Pairwise.
UMAXV: Unsigned Maximum across Vector.
UMIN: Unsigned Minimum (vector).
UMINP: Unsigned Minimum Pairwise.
UMINV: Unsigned Minimum across Vector.

UMLSL, UMLSL2 (by element): Unsigned Multiply-Subtract Long (vector, by element).

UMLSL, UMLSL2 (vector): Unsigned Multiply-Subtract Long (vector).

UMOV: Unsigned Move vector element to general-purpose register.

UMULL, UMULL2 (by element): Unsigned Multiply Long (vector, by element).

UMULL, UMULL2 (vector): Unsigned Multiply long (vector).

UQADD: Unsigned saturating Add.

UQRSHL: Unsigned saturating Rounding Shift Left (register).

UQRSHRN, UQRSHRN2: Unsigned saturating Rounded Shift Right Narrow (immediate).

UQSHL (immediate): Unsigned saturating Shift Left (immediate).

UQSHL (register): Unsigned saturating Shift Left (register).

UQSHRN, UQSHRN2: Unsigned saturating Shift Right Narrow (immediate).

UQSUB: Unsigned saturating Subtract.

UQXTN, UQXTN2: Unsigned saturating extract Narrow.

URECPE: Unsigned Reciprocal Estimate.

URHADD: Unsigned Rounding Halving Add.

URSHL: Unsigned Rounding Shift Left (register).

URSHR: Unsigned Rounding Shift Right (immediate).

URSQRT: Unsigned Reciprocal Square Root Estimate.

URSR: Unsigned Rounding Shift Right and Accumulate (immediate).

USSH: Unsigned Shift Left (register).

USHLL, USHLL2: Unsigned Shift Left Long (immediate).

USHR: Unsigned Shift Right (immediate).

USQA: Unsigned saturating Accumulate of Signed value.

USRA: Unsigned Shift Right and Accumulate (immediate).

USUBL, USUBL2: Unsigned Subtract Long.

USUBW, USUBW2: Unsigned Subtract Wide.


UZP: Unzip vectors (primary).

UZP2: Unzip vectors (secondary).

XAR: Exclusive OR and Rotate.

XTN, XTN2: Extract Narrow.

ZIP: Zip vectors (primary).

ZIP2: Zip vectors (secondary).
ABS

Absolute value (vector). This instruction calculates the absolute value of each vector element in the source SIMD&FP register, puts the result into a vector, and writes the vector to the destination SIMD&FP register.

Depending on the settings in the \texttt{CPACR\_EL1}, \texttt{CPTR\_EL2}, and \texttt{CPTR\_EL3} registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

It has encodings from 2 classes: \texttt{Scalar} and \texttt{Vector}

### Scalar

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</tbody>
</table>
```

\texttt{Scalar \textit{ABS}<V><d>, <V><n>}

```
integer d = UInt(Rd);
integer n = UInt(Rn);

if size != '11' then UNDEFINED;
integer esize = 8 <<if size = '11' then ReservedValue()::<V>

integer esize = 8 <<UInt(size);
integer datasize = esize;
integer elements = 1;
boolean neg = (U == '1');
```

### Vector

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</tbody>
</table>
```

\texttt{Vector \textit{ABS}<Vd>.<T>, <Vn>.<T>}

```
integer d = UInt(Rd);
integer n = UInt(Rn);

if size:Q == '110' then UNDEFINED;
integer esize = 8 <<if size:Q == '110' then ReservedValue()::<V>

integer esize = 8 <<UInt(size);
integer datasize = if Q == '1' then 128 else 64;
integer elements = datasize DIV esize;
boolean neg = (U == '1');
```

### Assembler Symbols

\texttt{<V>}

Is a width specifier, encoded in "size":

```
<table>
<thead>
<tr>
<th>size</th>
<th>&lt;V&gt;</th>
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</thead>
<tbody>
<tr>
<td>0x</td>
<td>RESERVED</td>
</tr>
<tr>
<td>10</td>
<td>RESERVED</td>
</tr>
<tr>
<td>11</td>
<td>D</td>
</tr>
</tbody>
</table>
```

\texttt{<d>}

Is the number of the SIMD&FP destination register, encoded in the "Rd" field.

\texttt{<n>}

Is the number of the SIMD&FP source register, encoded in the "Rn" field.
<Vd> Is the name of the SIMD&FP destination register, encoded in the "Rd" field.

<T> Is an arrangement specifier, encoded in “size-Q”:

<table>
<thead>
<tr>
<th>size</th>
<th>Q</th>
<th>&lt;T&gt;</th>
</tr>
</thead>
<tbody>
<tr>
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<td>8B</td>
</tr>
<tr>
<td>00</td>
<td>1</td>
<td>16B</td>
</tr>
<tr>
<td>01</td>
<td>0</td>
<td>4H</td>
</tr>
<tr>
<td>01</td>
<td>1</td>
<td>8H</td>
</tr>
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<td>10</td>
<td>0</td>
<td>2S</td>
</tr>
<tr>
<td>10</td>
<td>1</td>
<td>4S</td>
</tr>
<tr>
<td>11</td>
<td>0</td>
<td>RESERVED</td>
</tr>
<tr>
<td>11</td>
<td>1</td>
<td>2D</td>
</tr>
</tbody>
</table>

<Vn> Is the name of the SIMD&FP source register, encoded in the "Rn" field.

Operation

```c
CheckFPAdvSIMDEnabled64();
bits(datasize) operand = V[n];
bits(datasize) result;
integer element;
for e = 0 to elements-1
    element = SInt(Elem[operand, e, esize]);
    if neg then
        element = -element;
    else
        element = Abs(element);
    Elem[result, e, esize] = element<esize-1:0>;
V[d] = result;
```

Operational information

If PSTATE.DIT is 1:

- The execution time of this instruction is independent of:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
- The response of this instruction to asynchronous exceptions does not vary based on:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.

Internal version only: isa v30.25 v29.05 AdvSIMD v27.01 v26.0 pseudocode v85-xml-00bet8_rc3e35f ; Build timestamp: 2018-09-13 13:50:45

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ADD (extended register)

Add (extended register) adds a register value and a sign or zero-extended register value, followed by an optional left shift amount, and writes the result to the destination register. The argument that is extended from the <Rm> register can be a byte, halfword, word, or doubleword.

32-bit (sf == 0)

ADD <Wd|WSP>, <Wn|WSP>, <Wm>{, <extend> {#<amount>}}

64-bit (sf == 1)

ADD <Xd|SP>, <Xn|SP>, <R><m>{, <extend> {#<amount>}}

Assembler Symbols

| <Wd|WSP> | Is the 32-bit name of the destination general-purpose register or stack pointer, encoded in the "Rd" field. |
| <Wn|WSP> | Is the 32-bit name of the first source general-purpose register or stack pointer, encoded in the "Rn" field. |
| <Wm> | Is the 32-bit name of the second general-purpose source register, encoded in the "Rm" field. |
| <Xd|SP> | Is the 64-bit name of the destination general-purpose register or stack pointer, encoded in the "Rd" field. |
| <Xn|SP> | Is the 64-bit name of the first source general-purpose register or stack pointer, encoded in the "Rn" field. |
| <R> | Is a width specifier, encoded in "option": |
| option | <R> |
| 00x | W |
| 010 | W |
| x11 | X |
| 10x | W |
| 110 | W |

| <m> | Is the number [0-30] of the second general-purpose source register or the name ZR (31), encoded in the "Rm" field. |
| <extend> | For the 32-bit variant: is the extension to be applied to the second source operand, encoded in "option": |
| option | <extend> |
| 000 | UXTB |
| 001 | UXTH |
| 010 | LSL|UXTW |
| 011 | UXTX |
| 100 | SXTB |
| 101 | SXTH |
| 110 | SXTW |
| 111 | SXTX |

If "Rd" or "Rn" is '11111' (WSP) and "option" is '010' then LSL is preferred, but may be omitted when "imm3" is '000'. In all other cases <extend> is required and must be UXTW when "option" is '010'.

For the 64-bit variant: is the extension to be applied to the second source operand, encoded in "option":

integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rm);
integer datasize = if sf == '1' then 64 else 32;
boolean sub_op = (op == '1');
boolean setflags = (S == '1');
ExtendType extend_type = DecodeRegExtend(option);
integer shift = UInt(imm3);
if shift > 4 then UNDEFINED; if shift > 4 then ReservedValue();
<table>
<thead>
<tr>
<th>option</th>
<th>&lt;extend&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>000</td>
<td>UXTB</td>
</tr>
<tr>
<td>001</td>
<td>UXTH</td>
</tr>
<tr>
<td>010</td>
<td>UXTW</td>
</tr>
<tr>
<td>011</td>
<td>LSL</td>
</tr>
<tr>
<td>100</td>
<td>SXTB</td>
</tr>
<tr>
<td>101</td>
<td>SXTH</td>
</tr>
<tr>
<td>110</td>
<td>SXTW</td>
</tr>
<tr>
<td>111</td>
<td>SXTX</td>
</tr>
</tbody>
</table>

If "Rd" or "Rn" is '11111' (SP) and "option" is '011' then LSL is preferred, but may be omitted when "imm3" is '000'. In all other cases <extend> is required and must be UXTX when "option" is '011'.

<amount>

Is the left shift amount to be applied after extension in the range 0 to 4, defaulting to 0, encoded in the "imm3" field. It must be absent when <extend> is absent, is required when <extend> is LSL, and is optional when <extend> is present but not LSL.

Operation

```plaintext
bits(datasize) result;
bits(datasize) operand1 = if n == 31 then SP[] else X[n];
bits(datasize) operand2 = ExtendReg(m, extend_type, shift);
bits(4) nzcv;
bit carry_in;
if sub_op then
    operand2 = NOT(operand2);
carry_in = '1';
else
    carry_in = '0';
(result, nzcv) = AddWithCarry(operand1, operand2, carry_in);
if setflags then
    PSTATE.<N,Z,C,V> = nzcv;
if d == 31 && !setflags then
    SP[] = result;
else
    X[d] = result;
```

Operational information

If PSTATE.DIT is 1:

- The execution time of this instruction is independent of:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
- The response of this instruction to asynchronous exceptions does not vary based on:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
ADD (immediate)

Add (immediate) adds a register value and an optionally-shifted immediate value, and writes the result to the destination register.

This instruction is used by the alias MOV (to/from SP).

32-bit (sf == 0)

ADD <Wd|WSP>, <Wn|WSP>, #<imm>, <shift>

64-bit (sf == 1)

ADD <Xd|SP>, <Xn|SP>, #<imm>, <shift>

integer d = UInt(Rd);
integer n = UInt(Rn);
integer datasize = if sf == '1' then 64 else 32;
boolean sub_op = (op == '1');
boolean setflags = (S == '1');
bits(datasize) imm;

case shift of
  when '00' imm = ZeroExtend(imm12, datasize);
  when '01' imm = ZeroExtend(imm12 : Zeros(12), datasize);
  when '10' SEE "ADDG, SUBG";
  when '11' when '1x' ReservedValue();

Assembler Symbols

<Wd|WSP> Is the 32-bit name of the destination general-purpose register or stack pointer, encoded in the "Rd" field.
<Wn|WSP> Is the 32-bit name of the source general-purpose register or stack pointer, encoded in the "Rn" field.
<Xd|SP> Is the 64-bit name of the destination general-purpose register or stack pointer, encoded in the "Rd" field.
<Xn|SP> Is the 64-bit name of the source general-purpose register or stack pointer, encoded in the "Rn" field.
<imm> Is an unsigned immediate, in the range 0 to 4095, encoded in the "imm12" field.
<shift> Is the optional left shift to apply to the immediate, defaulting to LSL #0 and encoded in "shift<0>":

<table>
<thead>
<tr>
<th>shift&lt;0&gt;</th>
<th>&lt;shift&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>LSL #0</td>
</tr>
<tr>
<td>10</td>
<td>LSL #12</td>
</tr>
<tr>
<td>1x</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

Alias Conditions

<table>
<thead>
<tr>
<th>Alias</th>
<th>Is preferred when</th>
</tr>
</thead>
<tbody>
<tr>
<td>MOV (to/from SP)</td>
<td>shift == '00' &amp;&amp; imm12 == '000000000000' &amp;&amp; (Rd == '11111'</td>
</tr>
</tbody>
</table>
Operation

bits(datasize) result;
bites(datasize) operand1 = if n == 31 then $sp[]$ else $x[n]$;
bites(datasize) operand2 = imm;
bites(4) nzcv;
bit carry_in;

if sub_op then
  operand2 = NOT(operand2);
  carry_in = '1';
else
  carry_in = '0';

(result, nzcv) = AddWithCarry(operand1, operand2, carry_in);

if setflags then
  PSTATE.<N,Z,C,V> = nzcv;
if d == 31 && !setflags then
  $sp[] = result;
else
  $x[d] = result;

Operational information

If PSTATE.DIT is 1:
  • The execution time of this instruction is independent of:
    ◦ The values of the data supplied in any of its registers.
    ◦ The values of the NZCV flags.
  • The response of this instruction to asynchronous exceptions does not vary based on:
    ◦ The values of the data supplied in any of its registers.
    ◦ The values of the NZCV flags.

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ADD (shifted register)

ADD (shifted register) adds a register value and an optionally-shifted register value, and writes the result to the destination register.

<table>
<thead>
<tr>
<th>sf</th>
<th>0</th>
<th>0</th>
<th>1</th>
<th>0</th>
<th>1</th>
<th>shift</th>
<th>0</th>
<th>Rm</th>
<th>imm6</th>
<th>Rn</th>
<th>Rd</th>
</tr>
</thead>
</table>

op S

32-bit (sf == 0)

ADD <Wd>, <Wn>, <Wm>{, <shift> #<amount>}

64-bit (sf == 1)

ADD <Xd>, <Xn>, <Xm>{, <shift> #<amount>}

integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rm);
integer datasize = if sf == '1' then 64 else 32;
boolean sub_op = (op == '1');
boolean setflags = (S == '1');
if shift == '11' then UNDEFINED;
if sf == '0' && imm6<5> == '1' then UNDEFINED;

if shift == '11' then
ReservedValue();
if sf == '0' && imm6<5> == '1' then ReservedValue();

ShiftType shift_type = DecodeShift(shift);
integer shift_amount = UInt(imm6);

Assembler Symbols

<Wd> Is the 32-bit name of the general-purpose destination register, encoded in the "Rd" field.

<Wn> Is the 32-bit name of the first general-purpose source register, encoded in the "Rn" field.

<Wm> Is the 32-bit name of the second general-purpose source register, encoded in the "Rm" field.

<Xd> Is the 64-bit name of the general-purpose destination register, encoded in the "Rd" field.

<Xn> Is the 64-bit name of the first general-purpose source register, encoded in the "Rn" field.

<Xm> Is the 64-bit name of the second general-purpose source register, encoded in the "Rm" field.

<shift> Is the optional shift type to be applied to the second source operand, defaulting to LSL and encoded in “shift”:

<table>
<thead>
<tr>
<th>shift</th>
<th>&lt;shift&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>LSL</td>
</tr>
<tr>
<td>01</td>
<td>LSR</td>
</tr>
<tr>
<td>10</td>
<td>ASR</td>
</tr>
<tr>
<td>11</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

<amount> For the 32-bit variant: is the shift amount, in the range 0 to 31, defaulting to 0 and encoded in the "imm6" field.
For the 64-bit variant: is the shift amount, in the range 0 to 63, defaulting to 0 and encoded in the "imm6" field.
Operation

```
bits(datasize) result;
bits(datasize) operand1 = X[n];
bits(datasize) operand2 = ShiftReg(m, shift_type, shift_amount);
bits(4) nzcv;
bit carry_in;
if sub_op then
    operand2 = NOT(operand2);
carry_in = '1';
else
    carry_in = '0';

(result, nzcv) = AddWithCarry(operand1, operand2, carry_in);
if setflags then
    PSTATE.<N,Z,C,V> = nzcv;
X[d] = result;
```

Operational information

If PSTATE.DIT is 1:

- The execution time of this instruction is independent of:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
- The response of this instruction to asynchronous exceptions does not vary based on:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.

Internal version only: isa v30.25 v29.05, AdvSIMD v27.01 v26.0, pseudocode v85-xml-008c88_rc3333 ; Build timestamp: 2018-09-13T13:2018-06-16T09:04:45

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ADD (vector)

Add (vector). This instruction adds corresponding elements in the two source SIMD&FP registers, places the results into a vector, and writes the vector to the destination SIMD&FP register.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

It has encodings from 2 classes: Scalar and Vector

Scalar

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9  | 8  | 7  | 6  | 5  | 4  | 3  | 2  | 1  | 0  |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0  | 1  | 0  | 1  | 1  | 1  | 1  | 0  | size| 1  | Rm | 1  | 0  | 0  | 0  | 0  | 1  | Rn | Rd |

Scalar

ADD <V><d>, <V><n>, <V><m>

integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rm);
if size != '11' then UNDEFINED;
integer esize = 8 << if size != '11' then ReservedValue();
integer datasize = esize;
integer elements = 1;
boolean sub_op = (U == '1');

Vector

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9  | 8  | 7  | 6  | 5  | 4  | 3  | 2  | 1  | 0  |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0  | Q | 0  | 0  | 1  | 1  | 1  | 0  | size| 1  | Rm | 1  | 0  | 0  | 0  | 0  | 1  | Rn | Rd |

Vector

ADD <Vd>.<T>, <Vn>.<T>, <Vm>.<T>

integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rm);
if size:Q == '110' then UNDEFINED;
integer esize = 8 << if size:Q == '110' then ReservedValue();
integer esize = 8 << if Q == '1' then ReservedValue();
integer datasize = if Q == '1' then 128 else 64;
integer elements = datasize DIV esize;
boolean sub_op = (U == '1');

Assembler Symbols

<table>
<thead>
<tr>
<th>&lt;V&gt;</th>
<th>Is a width specifier, encoded in &quot;size&quot;:</th>
</tr>
</thead>
<tbody>
<tr>
<td>size</td>
<td>&lt;V&gt;</td>
</tr>
<tr>
<td>0x</td>
<td>RESERVED</td>
</tr>
<tr>
<td>10</td>
<td>RESERVED</td>
</tr>
<tr>
<td>11</td>
<td>D</td>
</tr>
</tbody>
</table>

<d> Is the number of the SIMD&FP destination register, in the "Rd" field.

<n> Is the number of the first SIMD&FP source register, encoded in the "Rn" field.
Is the number of the second SIMD&FP source register, encoded in the "Rm" field.

Is the name of the SIMD&FP destination register, encoded in the "Rd" field.

Is an arrangement specifier, encoded in "size:Q":

<table>
<thead>
<tr>
<th>size</th>
<th>Q</th>
<th>&lt;T&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>0</td>
<td>8B</td>
</tr>
<tr>
<td>00</td>
<td>1</td>
<td>16B</td>
</tr>
<tr>
<td>01</td>
<td>0</td>
<td>4H</td>
</tr>
<tr>
<td>01</td>
<td>1</td>
<td>8H</td>
</tr>
<tr>
<td>10</td>
<td>0</td>
<td>2S</td>
</tr>
<tr>
<td>10</td>
<td>1</td>
<td>4S</td>
</tr>
<tr>
<td>11</td>
<td>0</td>
<td>RESERVED</td>
</tr>
<tr>
<td>11</td>
<td>1</td>
<td>2D</td>
</tr>
</tbody>
</table>

Is the name of the first SIMD&FP source register, encoded in the "Rn" field.

Is the name of the second SIMD&FP source register, encoded in the "Rm" field.

**Operation**

```plaintext
CheckFPAdvSIMDEnabled64();
bias(dataSize) operand1 = V[n];
bias(dataSize) operand2 = V[m];
bias(dataSize) result;
bias(elemSize) element1;
bias(elemSize) element2;
for e = 0 to elements-1
    element1 = Elem[operand1, e, elemSize];
    element2 = Elem[operand2, e, elemSize];
    if sub_op then
        Elem[result, e, elemSize] = element1 - element2;
    else
        Elem[result, e, elemSize] = element1 + element2;
V[d] = result;
```

**Operational information**

If PSTATE.DIT is 1:

- The execution time of this instruction is independent of:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
- The response of this instruction to asynchronous exceptions does not vary based on:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.


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**ADDG**

Add with Tag adds an immediate value scaled by the Tag granule to the address in the source register, modifies the Logical Address Tag of the address using an immediate value, and writes the result to the destination register. Tags specified in GCR_EL1.Exclude are excluded from the possible outputs when modifying the Logical Address Tag.

**Integer**

(ARMv8.5)

```
<table>
<thead>
<tr>
<th></th>
<th>31</th>
<th>30</th>
<th>29</th>
<th>28</th>
<th>27</th>
<th>26</th>
<th>25</th>
<th>24</th>
<th>23</th>
<th>22</th>
<th>21</th>
<th>20</th>
<th>19</th>
<th>18</th>
<th>17</th>
<th>16</th>
<th>15</th>
<th>14</th>
<th>13</th>
<th>12</th>
<th>11</th>
<th>10</th>
<th>9</th>
<th>8</th>
<th>7</th>
<th>6</th>
<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
```

- **uimm6**
- **uimm4**
- **Xn**
- **Xd**

**Integer**

ADDG <Xd|SP>, <Xn|SP>, #<uimm6>, #<uimm4>

```plaintext
integer d = UInt(Xd);
integer n = UInt(Xn);
bits(4) tag_offset = uimm4;
bits(64) offset = LSL(ZeroExtend(uimm6, 64), LOG2_TAG_GRANULE);
boolean ADD = TRUE;
```

**Assembler Symbols**

- `<Xd|SP>` is the 64-bit name of the destination general-purpose register or stack pointer, encoded in the "Xd" field.
- `<Xn|SP>` is the 64-bit name of the source general-purpose register or stack pointer, encoded in the "Xn" field.
- `<uimm6>` is an unsigned immediate, a multiple of 16 in the range 0 to 1008, encoded in the "uimm6" field.
- `<uimm4>` is an unsigned immediate, in the range 0 to 15, encoded in the "uimm4" field.

**Operation**

```plaintext
bits(64) operand1 = if n == 31 then SP[] else X[n];
bits(4) start_tag = AllocationTagFromAddress(operand1);
bits(16) exclude = GCR_EL1.Exclude;
bits(64) result;
bits(4) rtag;
if AllocationTagAccessIsEnabled() then
  rtag = ChooseNonExcludedTag(start_tag, tag_offset, exclude);
else
  rtag = '0000';
if ADD then
  (result, -) = AddWithCarry(operand1, offset, '0');
else
  (result, -) = AddWithCarry(operand1, NOT(offset), '1');
result = AddressWithAllocationTag(result, rtag);
if d == 31 then
  SP[] = result;
else
  X[d] = result;
```

---

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ADDHN, ADDHN2

Add returning High Narrow. This instruction adds each vector element in the first source SIMD&FP register to the corresponding vector element in the second source SIMD&FP register, places the most significant half of the result into a vector, and writes the vector to the lower or upper half of the destination SIMD&FP register.

The results are truncated. For rounded results, see RADDHN.

The ADDHN instruction writes the vector to the lower half of the destination register and clears the upper half, while the ADDHN2 instruction writes the vector to the upper half of the destination register without affecting the other bits of the register.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

```
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9  | 8  | 7  | 6  | 5  | 4  | 3  | 2  | 1  | 0   |
|-----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| Q   | 0  | 0  | 1  | 1  | 1  | 1  | size | 1  | Rm | 0  | 1  | 0  | 0  | 0  | Rn | Rd |
| U   | o1 |
```

Three registers, not all the same type

ADDHN[2] <Vd>,<Tb>, <Vn>,<Ta>, <Vm>.<Ta>

```java
integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rm);

if size == '11' then UNDEFINED;
integer esize = 8 <<<if size == '11' then ReservedValue();
integer esize = 0 <<<Int(size);
integer datasize = 64;
integer part = UInt(Q);
integer elements = datasize DIV esize;

boolean sub_op = (o1 == '1');
boolean round = (U == '1');
```

Assembler Symbols

2  

Is the second and upper half specifier. If present it causes the operation to be performed on the upper 64 bits of the registers holding the narrower elements, and is encoded in “Q”:

```
<table>
<thead>
<tr>
<th>Q</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>[absent]</td>
</tr>
<tr>
<td>1</td>
<td>[present]</td>
</tr>
</tbody>
</table>
```

<Vd>  

Is the name of the SIMD&FP destination register, encoded in the “Rd” field.

<Tb>  

Is an arrangement specifier, encoded in “size:Q”:

```
<table>
<thead>
<tr>
<th>size</th>
<th>Q</th>
<th>&lt;Tb&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>0</td>
<td>8H</td>
</tr>
<tr>
<td>00</td>
<td>1</td>
<td>16B</td>
</tr>
<tr>
<td>01</td>
<td>0</td>
<td>4H</td>
</tr>
<tr>
<td>01</td>
<td>1</td>
<td>8H</td>
</tr>
<tr>
<td>10</td>
<td>0</td>
<td>2S</td>
</tr>
<tr>
<td>10</td>
<td>1</td>
<td>4S</td>
</tr>
<tr>
<td>11</td>
<td>x</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>
```

<Vn>  

Is the name of the first SIMD&FP source register, encoded in the “Rn” field.

<Ta>  

Is an arrangement specifier, encoded in “size”:

```
<table>
<thead>
<tr>
<th>size</th>
<th>&lt;Ta&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>8H</td>
</tr>
<tr>
<td>01</td>
<td>4S</td>
</tr>
<tr>
<td>10</td>
<td>2D</td>
</tr>
<tr>
<td>11</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>
```
Operation

```c
CheckFPAdvSIMDEnabled64();
bits(2*datasize) operand1 = V[n];
bits(2*datasize) operand2 = V[m];
bits(datasize) result;
integer round_const = if round then 1 << (esize - 1) else 0;
bv(2*esize) element1;
bv(2*esize) element2;
bv(2*esize) sum;
for e = 0 to elements-1
  element1 = Elem[operand1, e, 2*esize];
  element2 = Elem[operand2, e, 2*esize];
  if sub_op then
    sum = element1 - element2;
  else
    sum = element1 + element2;
  sum = sum + round_const;
  Elem[result, e, esize] = sum<2*esize-1:esize>;
Vpart[d, part] = result;
```

Operational information

If PSTATE.DIT is 1:

- The execution time of this instruction is independent of:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
- The response of this instruction to asynchronous exceptions does not vary based on:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
ADDP (scalar)

Add Pair of elements (scalar). This instruction adds two vector elements in the source SIMD&FP register and writes the scalar result into the destination SIMD&FP register.

Depending on the settings in the `CPACR_EL1`, `CPTR_EL2`, and `CPTR_EL3` registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

### Advanced SIMD

ADDP <V><d>, <Vn>.<T>

```plaintext
integer d = UInt(Rd);
integer n = UInt(Rn);
if size != '11' then UNDEFINED;
integer esize = 8 << (if size !! '11' then ReservedValue());
integer datasize = esize * 2;
integer elements = 2;
ReduceOp op = ReduceOp_ADD;
```

### Assembler Symbols

- **<V>**
  - Is the destination width specifier, encoded in "size":
  ```plaintext
  size     <V>
  0x       RESERVED
  10       RESERVED
  11       D
  ```

- **<d>**
  - Is the number of the SIMD&FP destination register, encoded in the "Rd" field.

- **<Vn>**
  - Is the name of the SIMD&FP source register, encoded in the "Rn" field.

- **<T>**
  - Is the source arrangement specifier, encoded in "size":
  ```plaintext
  size     <T>
  0x       RESERVED
  10       RESERVED
  11       2D
  ```

### Operation

```plaintext
CheckFPAdvSIMDEnabled64();
bits(datasize) operand = V[n];
V[d] = Reduce(op, operand, esize);
```

### Operational Information

If PSTATE.DIT is 1:
- The execution time of this instruction is independent of:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
- The response of this instruction to asynchronous exceptions does not vary based on:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
ADDP (vector)

Add Pairwise (vector). This instruction creates a vector by concatenating the vector elements of the first source SIMD&FP register after the vector elements of the second source SIMD&FP register, reads each pair of adjacent vector elements from the concatenated vector, adds each pair of values together, places the result into a vector, and writes the vector to the destination SIMD&FP register.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

Three registers of the same type

ADDP <Vd>.<T>, <Vn>.<T>, <Vm>.<T>

integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rm);
if size:Q == '110' then UNDEFINED;
integer esize = 8 << if size:Q == '110' then ReservedValue();
integer esize = 8 << UInt(size);
integer datasize = if Q == '1' then 128 else 64;
integer elements = datasize DIV esize;

Assembler Symbols

<Vd> Is the name of the SIMD&FP destination register, encoded in the "Rd" field.
<T> Is an arrangement specifier, encoded in “size:Q”:

<table>
<thead>
<tr>
<th>size</th>
<th>Q</th>
<th>&lt;T&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>0</td>
<td>8B</td>
</tr>
<tr>
<td>00</td>
<td>1</td>
<td>16B</td>
</tr>
<tr>
<td>01</td>
<td>0</td>
<td>4H</td>
</tr>
<tr>
<td>01</td>
<td>1</td>
<td>8H</td>
</tr>
<tr>
<td>10</td>
<td>0</td>
<td>2S</td>
</tr>
<tr>
<td>10</td>
<td>1</td>
<td>4S</td>
</tr>
<tr>
<td>11</td>
<td>0</td>
<td>RESERVED</td>
</tr>
<tr>
<td>11</td>
<td>1</td>
<td>2D</td>
</tr>
</tbody>
</table>

<Vn> Is the name of the first SIMD&FP source register, encoded in the "Rn" field.
<Vm> Is the name of the second SIMD&FP source register, encoded in the "Rm" field.

Operation

CheckFPAdvSIMDEnabled64();
bits(datasize) operand1 = \[V\][n];
bits(datasize) operand2 = \[V\][m];
bits(datasize) result;
bits(2*datasize) concat = operand2:operand1;
bits(esize) element1;
bits(esize) element2;
for e = 0 to elements-1
    element1 = Elem[concat, 2*e, esize];
    element2 = Elem[concat, (2*e)+1, esize];
    Elem[result, e, esize] = element1 + element2;
\[V\][d] = result;
Operational information

If PSTATE.DIT is 1:

- The execution time of this instruction is independent of:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
- The response of this instruction to asynchronous exceptions does not vary based on:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
ADDS (extended register)

Add (extended register), setting flags, adds a register value and a sign or zero-extended register value, followed by an optional left shift amount, and writes the result to the destination register. The argument that is extended from the <Rm> register can be a byte, halfword, word, or doubleword. It updates the condition flags based on the result.

This instruction is used by the alias **CMN (extended register)**.

### Assembler Symbols

- **<Wd>** Is the 32-bit name of the general-purpose destination register, encoded in the "Rd" field.
- **<Wn|WSP>** Is the 32-bit name of the first source general-purpose register or stack pointer, encoded in the "Rn" field.
- **<Wm>** Is the 32-bit name of the second general-purpose source register, encoded in the "Rm" field.
- **<Xd>** Is the 64-bit name of the general-purpose destination register, encoded in the "Rd" field.
- **<Xn|SP>** Is the 64-bit name of the first source general-purpose register or stack pointer, encoded in the "Rn" field.
- **<R>** Is a width specifier, encoded in "option":

<table>
<thead>
<tr>
<th>option</th>
<th>&lt;R&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00x</td>
<td>W</td>
</tr>
<tr>
<td>010</td>
<td>W</td>
</tr>
<tr>
<td>x11</td>
<td>X</td>
</tr>
<tr>
<td>10x</td>
<td>W</td>
</tr>
<tr>
<td>110</td>
<td>W</td>
</tr>
</tbody>
</table>

- **<m>** Is the number [0-30] of the second general-purpose source register or the name ZR (31), encoded in the "Rm" field.
- **<extend>** For the 32-bit variant: is the extension to be applied to the second source operand, encoded in "option":

<table>
<thead>
<tr>
<th>option</th>
<th>&lt;extend&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>000</td>
<td>UXTB</td>
</tr>
<tr>
<td>001</td>
<td>UXTH</td>
</tr>
<tr>
<td>010</td>
<td>LSL</td>
</tr>
<tr>
<td>011</td>
<td>UXTX</td>
</tr>
<tr>
<td>100</td>
<td>SXTB</td>
</tr>
<tr>
<td>101</td>
<td>SXTH</td>
</tr>
<tr>
<td>110</td>
<td>SXTW</td>
</tr>
<tr>
<td>111</td>
<td>SXTX</td>
</tr>
</tbody>
</table>
If "Rn" is '11111' (WSP) and "option" is '010' then LSL is preferred, but may be omitted when "imm3" is '000'. In all other cases <extend> is required and must be UXTW when "option" is '010'.

For the 64-bit variant: is the extension to be applied to the second source operand, encoded in “option”:

<table>
<thead>
<tr>
<th>option</th>
<th>&lt;extend&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>000</td>
<td>UXTB</td>
</tr>
<tr>
<td>001</td>
<td>UXTH</td>
</tr>
<tr>
<td>010</td>
<td>UXTW</td>
</tr>
<tr>
<td>011</td>
<td>LSL</td>
</tr>
<tr>
<td>100</td>
<td>SXTB</td>
</tr>
<tr>
<td>101</td>
<td>SXTH</td>
</tr>
<tr>
<td>110</td>
<td>SXTW</td>
</tr>
<tr>
<td>111</td>
<td>SXTX</td>
</tr>
</tbody>
</table>

If "Rn" is '11111' (SP) and "option" is '011' then LSL is preferred, but may be omitted when "imm3" is '000'. In all other cases <extend> is required and must be UXTX when "option" is '011'.

<amount> Is the left shift amount to be applied after extension in the range 0 to 4, defaulting to 0, encoded in the “imm3” field. It must be absent when <extend> is absent, is required when <extend> is LSL, and is optional when <extend> is present but not LSL.

Alias Conditions

<table>
<thead>
<tr>
<th>Alias</th>
<th>Is preferred when</th>
</tr>
</thead>
<tbody>
<tr>
<td>CMN (extended register)</td>
<td>Rd == '11111'</td>
</tr>
</tbody>
</table>

Operation

```c
bits(datasize) result;
bits(datasize) operand1 = if n == 31 then SP[] else X[n];
bits(datasize) operand2 = ExtendReg(m, extend_type, shift);
bits(4) nzcv;
bit carry_in;

if sub_op then
    operand2 = NOT(operand2);
    carry_in = '1';
else
    carry_in = '0';

(result, nzcv) = AddWithCarry(operand1, operand2, carry_in);

if setflags then
    PSTATE.<N,Z,C,V> = nzcv;

if d == 31 && !setflags then
    SP[] = result;
else
    X[d] = result;
```

Operational information

If PSTATE.DIT is 1:

- The execution time of this instruction is independent of:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
- The response of this instruction to asynchronous exceptions does not vary based on:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
ADDS (immediate)

Add (immediate), setting flags, adds a register value and an optionally-shifted immediate value, and writes the result to the destination register. It updates the condition flags based on the result.

This instruction is used by the alias CMN (immediate).

### 32-bit (sf == 0)

ADDS <Wd>, <Wn|WSP>, #<imm>{, <shift>}

### 64-bit (sf == 1)

ADDS <Xd>, <Xn|SP>, #<imm>{, <shift>}

```plaintext
integer d = UInt(Rd);
integer n = UInt(Rn);
integer datasize = if sf == '1' then 64 else 32;
boolean sub_op = (op == '1');
boolean setflags = (S == '1');
bites(datasize) imm;

case shift of
  when '00' imm = ZeroExtend(imm12, datasize);
  when '01' imm = ZeroExtend(imm12 : Zeros(12), datasize);
  when '10' SEE "ADDG, SUBG";
  when '11' when '1x' ReservedValue();
```

**Assembler Symbols**

- `<Wd>` Is the 32-bit name of the general-purpose destination register, encoded in the "Rd" field.
- `<Wn|WSP>` Is the 32-bit name of the source general-purpose register or stack pointer, encoded in the "Rn" field.
- `<Xd>` Is the 64-bit name of the general-purpose destination register, encoded in the "Rd" field.
- `<Xn|SP>` Is the 64-bit name of the source general-purpose register or stack pointer, encoded in the "Rn" field.
- `<imm>` Is an unsigned immediate, in the range 0 to 4095, encoded in the "imm12" field.
- `<shift>` Is the optional left shift to apply to the immediate, defaulting to LSL #0 and encoded in "shift<0>":

<table>
<thead>
<tr>
<th>shift&lt;0&gt;</th>
<th>&lt;shift&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0b0</td>
<td>LSL #0</td>
</tr>
<tr>
<td>1b1</td>
<td>LSL #12</td>
</tr>
<tr>
<td>1b1</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

**Alias Conditions**

<table>
<thead>
<tr>
<th>Alias</th>
<th>Is preferred when</th>
</tr>
</thead>
<tbody>
<tr>
<td>CMN (immediate)</td>
<td>Rd == '11111'</td>
</tr>
</tbody>
</table>
Operation

```plaintext
bits(datasize) result;
bits(datasize) operand1 = if n == 31 then SP[] else X[n];
bits(datasize) operand2 = imm;
bits(4) nzcv;
bit carry_in;
if sub_op then
    operand2 = NOT(operand2);
    carry_in = '1';
else
    carry_in = '0';
(result, nzcv) = AddWithCarry(operand1, operand2, carry_in);
if setflags then
    PSTATE.<N,Z,C,V> = nzcv;
if d == 31 && !setflags then
    SP[] = result;
else
    X[d] = result;
```

Operational information

If PSTATE.DIT is 1:

- The execution time of this instruction is independent of:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
- The response of this instruction to asynchronous exceptions does not vary based on:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
ADDS (shifted register)

Add (shifted register), setting flags, adds a register value and an optionally-shifted register value, and writes the result to the destination register. It updates the condition flags based on the result.

This instruction is used by the alias `CMN (shifted register)`. 

32-bit (sf == 0)

ADDS \(<Wd>, <Wn>, <Wm>\), \(<shift> \#<amount>\) 

64-bit (sf == 1)

ADDS \(<Xd>, <Xn>, <Xm>\), \(<shift> \#<amount>\) 

\[
\begin{align*}
\text{integer } d &= \text{UInt}(Rd); \\
\text{integer } n &= \text{UInt}(Rn); \\
\text{integer } m &= \text{UInt}(Rm); \\
\text{integer } \text{datasize} &= \text{if } sf == '1' \text{ then } 64 \text{ else } 32; \\
\text{boolean } \text{sub_op} &= \langle op == '1' \rangle; \\
\text{boolean } \text{setflags} &= \langle S == '1' \rangle; \\
\text{if } \text{shift} == '11' \text{ then } \text{UNDEFINED}; \\
\text{if } sf == '0' \&\& \text{imm6}<5> == '1' \text{ then } \text{UNDEFINED}; \\
\text{if } \text{shift} == '11' \text{ then } \text{ReservedValue}(); \\
\text{if } sf == '0' \&\& \text{imm6}<5> == '1' \text{ then } \text{ReservedValue}(); \\
\text{ShiftType } \text{shift_type} &= \text{DecodeShift}(\text{shift}); \\
\text{integer } \text{shift_amount} &= \text{UInt}(\text{imm6}); \\
\end{align*}
\]

Assembler Symbols

- \(<Wd>\):\ Is the 32-bit name of the general-purpose destination register, encoded in the "Rd" field.
- \(<Wn>\):\ Is the 32-bit name of the first general-purpose source register, encoded in the "Rn" field.
- \(<Wm>\):\ Is the 32-bit name of the second general-purpose source register, encoded in the "Rm" field.
- \(<Xd>\):\ Is the 64-bit name of the general-purpose destination register, encoded in the "Rd" field.
- \(<Xn>\):\ Is the 64-bit name of the first general-purpose source register, encoded in the "Rn" field.
- \(<Xm>\):\ Is the 64-bit name of the second general-purpose source register, encoded in the "Rm" field.
- \(<shift>\):\ Is the optional shift type to be applied to the second source operand, defaulting to LSL and encoded in “shift”:

\[
\begin{array}{c|c}
\text{shift} & \text{shift} \\
\hline
00 & \text{LSL} \\
01 & \text{LSR} \\
10 & \text{ASR} \\
11 & \text{RESERVED} \\
\end{array}
\]

- \(<amount>\):\ For the 32-bit variant: is the shift amount, in the range 0 to 31, defaulting to 0 and encoded in the "imm6" field.
- For the 64-bit variant: is the shift amount, in the range 0 to 63, defaulting to 0 and encoded in the "imm6" field.
Alias Conditions

<table>
<thead>
<tr>
<th>Alias</th>
<th>Is preferred when</th>
</tr>
</thead>
<tbody>
<tr>
<td>CMN (shifted register)</td>
<td>Rd == '11111'</td>
</tr>
</tbody>
</table>

Operation

```c
bits(datasize) result;
bits(datasize) operand1 = X[n];
bits(datasize) operand2 = ShiftReg(m, shift_type, shift_amount);
bits(4) nzcv;
bit carry_in;

if sub_op then
    operand2 = NOT(operand2);
carry_in = '1';
else
    carry_in = '0';

(result, nzcv) = AddWithCarry(operand1, operand2, carry_in);

if setflags then
    PSTATE.<N,Z,C,V> = nzcv;

X[d] = result;
```

Operational information

If PSTATE.DIT is 1:

- The execution time of this instruction is independent of:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
- The response of this instruction to asynchronous exceptions does not vary based on:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
ADDV

Add across Vector. This instruction adds every vector element in the source SIMD&FP register together, and writes the scalar result to the destination SIMD&FP register.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

Advanced SIMD

ADDV <V><d>, <Vn>.<T>

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th>size</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th>Rn</th>
<th></th>
<th></th>
<th>Rd</th>
</tr>
</thead>
<tbody>
<tr>
<td>31</td>
<td>30</td>
<td>29</td>
<td>28</td>
<td>27</td>
<td>26</td>
<td>25</td>
<td>24</td>
<td>23</td>
<td>22</td>
<td>21</td>
<td>20</td>
<td>19</td>
<td>18</td>
<td>17</td>
<td>16</td>
<td>15</td>
<td>14</td>
<td>13</td>
</tr>
</tbody>
</table>

integer d = UInt(Rd);
integer n = UInt(Rn);

if size:Q == '100' then UNDEFINED;
if size == '11' then UNDEFINED;

integer esize = 8 << if size:Q == '100' then ReservedValue(1);
if size == '11' then ReservedValue(1);

integer esize = 8 << UInt(size);
integer datasize = if Q == '1' then 128 else 64;
integer elements = datasize DIV esize;

ReduceOp op = ReduceOp_ADD;

Assembler Symbols

<V> Is the destination width specifier, encoded in “size”:

<table>
<thead>
<tr>
<th>size</th>
<th>&lt;V&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>B</td>
</tr>
<tr>
<td>01</td>
<td>H</td>
</tr>
<tr>
<td>10</td>
<td>S</td>
</tr>
<tr>
<td>11</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

<d> Is the number of the SIMD&FP destination register, encoded in the "Rd" field.

<Vn> Is the name of the SIMD&FP source register, encoded in the "Rn" field.

<T> Is an arrangement specifier, encoded in “size:Q”:

<table>
<thead>
<tr>
<th>size</th>
<th>Q</th>
<th>&lt;T&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>0</td>
<td>8B</td>
</tr>
<tr>
<td>00</td>
<td>1</td>
<td>16B</td>
</tr>
<tr>
<td>01</td>
<td>0</td>
<td>4H</td>
</tr>
<tr>
<td>01</td>
<td>1</td>
<td>8H</td>
</tr>
<tr>
<td>10</td>
<td>0</td>
<td>RESERVED</td>
</tr>
<tr>
<td>10</td>
<td>1</td>
<td>4S</td>
</tr>
<tr>
<td>11</td>
<td>x</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

Operation

CheckFPAdvSIMDEnabled64();
bits(datasize) operand = V[n];
V[d] = Reduce(op, operand, esize);

Operational information

If PSTATE.DIT is 1:
• The execution time of this instruction is independent of:
  ◦ The values of the data supplied in any of its registers.
  ◦ The values of the NZCV flags.

• The response of this instruction to asynchronous exceptions does not vary based on:
  ◦ The values of the data supplied in any of its registers.
  ◦ The values of the NZCV flags.
AESD

AES single round decryption.

31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
0 1 0 0 1 1 0 0 0 0 1 0 0 0 0 0 1 0 1 1 0

Advanced SIMD

AESD <Vd>.16B, <Vn>.16B

integer d = UInt(Rd);
integer n = UInt(Rn);
if !HaveAESExt() then UNDEFINED;
boolean decrypt = (D == '1');

Assembler Symbols

<Vd> Is the name of the SIMD&FP source and destination register, encoded in the "Rd" field.
<Vn> Is the name of the second SIMD&FP source register, encoded in the "Rn" field.

Operation

AArch64.CheckFPAdvSIMDEnabled();

bits(128) operand1 = V[d];
bits(128) operand2 = V[n];
bits(128) result;
result = operand1 EOR operand2;
if decrypt then
    result = AESInvSubBytes(AESInvShiftRows(result));
else
    result = AESSubBytes(AESShiftRows(result));

V[d] = result;

Operational information

If PSTATE.DIT is 1:
- The execution time of this instruction is independent of:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
- The response of this instruction to asynchronous exceptions does not vary based on:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
AESE

AES single round encryption.

Advanced SIMD

AESE <Vd>.16B, <Vn>.16B

<table>
<thead>
<tr>
<th>D</th>
<th>Rn</th>
<th>Rd</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
</tbody>
</table>

integer d = UInt(Rd);
integer n = UInt(Rn);
if !HaveAESExt() then UNDEFINED;

boolean decrypt = (D == '1');
()

boolean decrypt = (D == '1');

Assembler Symbols

<Vd> Is the name of the SIMD&FP source and destination register, encoded in the "Rd" field.
<Vn> Is the name of the second SIMD&FP source register, encoded in the "Rn" field.

Operation

AArch64.CheckFPAdvSIMDEnabled();

bits(128) operand1 = V[d];
bits(128) operand2 = V[n];
bits(128) result;
result = operand1 EOR operand2;
if decrypt then
    result = AESInvSubBytes(AESInvShiftRows(result));
else
    result = AESSubBytes(AESShiftRows(result));

V[d] = result;

Operational information

If PSTATE.DIT is 1:

- The execution time of this instruction is independent of:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
- The response of this instruction to asynchronous exceptions does not vary based on:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
AESIMC

AES inverse mix columns.

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|-----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0   | 1  | 0  | 1  | 1  | 0  | 0  | 0  | 1  | 0  | 1  | 0  | 0  | 0  | 1  | 1  | 1  | 0  | Rn  | Rd  |

D

Advanced SIMD

AESIMC <Vd>.16B, <Vn>.16B

integer d = UInt(Rd);
integer n = UInt(Rn);
if !HaveAESExt() then UNDEFINED;
boolean decrypt = (D == '1'); if decrypt then UnallocatedEncoding();

boolean decrypt = (D == '1');

Assembler Symbols

<Vd> Is the name of the SIMD&FP destination register, encoded in the "Rd" field.
<Vn> Is the name of the SIMD&FP source register, encoded in the "Rn" field.

Operation

AArch64.CheckFPAdvSIMDEnabled();

bits(128) operand = V[n];
bits(128) result;
if decrypt then
    result = AESInvMixColumns(operand);
else
    result = AESMixColumns(operand);
V[d] = result;

Operational information

If PSTATE.DIT is 1:

- The execution time of this instruction is independent of:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
- The response of this instruction to asynchronous exceptions does not vary based on:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
AESMC

AES mix columns.

Advanced SIMD

AESMC <Vd>.16B, <Vn>.16B

```plaintext
integer d = UInt(Rd);
integer n = UInt(Rn);
if !HaveAESExt() then UNDEFINED;
boolean decrypt = (D == '1');
boolean decrypt = (D == '1');

Assembler Symbols

<Vd> Is the name of the SIMD&FP destination register, encoded in the "Rd" field.
<Vn> Is the name of the SIMD&FP source register, encoded in the "Rn" field.

Operation

AArch64.CheckFPAdvSIMDEnabled();

bits(128) operand = V[n];
bits(128) result;
if decrypt then
    result = AESInvMixColumns(operand);
else
    result = AESMixColumns(operand);
V[d] = result;

Operational information

If PSTATE.DIT is 1:
• The execution time of this instruction is independent of:
  ◦ The values of the data supplied in any of its registers.
  ◦ The values of the NZCV flags.
• The response of this instruction to asynchronous exceptions does not vary based on:
  ◦ The values of the data supplied in any of its registers.
  ◦ The values of the NZCV flags.
AND (immediate)

Bitwise AND (immediate) performs a bitwise AND of a register value and an immediate value, and writes the result to the destination register.

### 32-bit (sf == 0 && N == 0)

AND <Wd|WSP>, <Wn>, #<imm>

### 64-bit (sf == 1)

AND <Xd|SP>, <Xn>, #<imm>

```plaintext
integer d = UInt(Rd);
integer n = UInt(Rn);
integer datasize = if sf == '1' then 64 else 32;
boolean setflags;
LogicalOp op;
case opc of
  when '00' op = LogicalOp_AND; setflags = FALSE;
  when '01' op = LogicalOp_ORR; setflags = FALSE;
  when '10' op = LogicalOp_EOR; setflags = FALSE;
  when '11' op = LogicalOp_AND; setflags = TRUE;

bits(datasize) imm;
if sf == '0' && N != '0' then UNDEFINED;
(imm, -) = if sf == '0' && N != '0' then ReservedValue();
(imm, -) = DecodeBitMasks(N, imms, immr, TRUE);
```

### Assembler Symbols

- `<Wd|WSP>`: Is the 32-bit name of the destination general-purpose register or stack pointer, encoded in the "Rd" field.
- `<Wn>`: Is the 32-bit name of the general-purpose source register, encoded in the "Rn" field.
- `<Xd|SP>`: Is the 64-bit name of the destination general-purpose register or stack pointer, encoded in the "Rd" field.
- `<Xn>`: Is the 64-bit name of the general-purpose source register, encoded in the "Rn" field.
- `<imm>`: For the 32-bit variant: is the bitmask immediate, encoded in "imms:immr".
  - For the 64-bit variant: is the bitmask immediate, encoded in "N:imms:immr".
bits(datasize) result;
bits(datasize) operand1 = X[n];
bits(datasize) operand2 = imm;

case op of
    when LogicalOp_AND result = operand1 AND operand2;
    when LogicalOp_ORR result = operand1 OR  operand2;
    when LogicalOp_EOR result = operand1 EOR operand2;

if setflags then
    PSTATE.<N,Z,C,V> = result<datasize-1>:IsZeroBit(result):'00';

if d == 31 && !setflags then
    SP[] = result;
else
    X[d] = result;

Operational information

If PSTATE.DIT is 1:

- The execution time of this instruction is independent of:
  
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.

- The response of this instruction to asynchronous exceptions does not vary based on:
  
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.

Internal version only: isa v30.25, AdvSIMD v27.01, pseudocode v85-xml-00e8_rc3.0.5; Build timestamp: 2018-09-13T13:2018-09-16T09:04:45

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Bitwise AND (shifted register) performs a bitwise AND of a register value and an optionally-shifted register value, and writes the result to the destination register.

32-bit (sf == 0)

AND <Wd>, <Wn>, <Wm>!, <shift> #<amount>

64-bit (sf == 1)

AND <Xd>, <Xn>, <Xm>!, <shift> #<amount>

integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rm);
integer datasize = if sf == '1' then 64 else 32;
boolean setflags;
LogicalOp op;
case opc of
  when '00' op = LogicalOp_AND; setflags = FALSE;
  when '01' op = LogicalOp_ORR; setflags = FALSE;
  when '10' op = LogicalOp_EOR; setflags = FALSE;
  when '11' op = LogicalOp_AND; setflags = TRUE;
if sf == '0' && imm6<5> == '1' then UNDEFINED;if sf == '0' && imm6<5> == '1' then
ReservedValue();
ShiftType shift_type = DecodeShift(shift);
integer shift_amount = UInt(imm6);
boolean invert = (N == '1');

Assembler Symbols

<Wd> Is the 32-bit name of the general-purpose destination register, encoded in the "Rd" field.
<Wn> Is the 32-bit name of the first general-purpose source register, encoded in the "Rn" field.
<Wm> Is the 32-bit name of the second general-purpose source register, encoded in the "Rm" field.
<Xd> Is the 64-bit name of the general-purpose destination register, encoded in the "Rd" field.
<Xn> Is the 64-bit name of the first general-purpose source register, encoded in the "Rn" field.
<Xm> Is the 64-bit name of the second general-purpose source register, encoded in the "Rm" field.
<shift> Is the optional shift to be applied to the final source, defaulting to LSL and encoded in "shift":

<table>
<thead>
<tr>
<th>shift</th>
<th>&lt;shift&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>LSL</td>
</tr>
<tr>
<td>01</td>
<td>LSR</td>
</tr>
<tr>
<td>10</td>
<td>ASR</td>
</tr>
<tr>
<td>11</td>
<td>ROR</td>
</tr>
</tbody>
</table>

<amount> For the 32-bit variant: is the shift amount, in the range 0 to 31, defaulting to 0 and encoded in the "imm6" field.
For the 64-bit variant: is the shift amount, in the range 0 to 63, defaulting to 0 and encoded in the "imm6" field,
Operation

```c
bits(datasize) operand1 = X[n];
bits(datasize) operand2 = ShiftReg(m, shift_type, shift_amount);
if invert then operand2 = NOT(operand2);

case op of
    when LogicalOp_AND result = operand1 AND operand2;
    when LogicalOp.ORR result = operand1 OR operand2;
    when LogicalOp.EOR result = operand1 EOR operand2;
if setflags then
    PSTATE.<N,Z,C,V> = result<datasize-1>:IsZeroBit(result):'00';
X[d] = result;
```

Operational information

If PSTATE.DIT is 1:
- The execution time of this instruction is independent of:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
- The response of this instruction to asynchronous exceptions does not vary based on:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
**ANDS (immediate)**

Bitwise AND (immediate), setting flags, performs a bitwise AND of a register value and an immediate value, and writes the result to the destination register. It updates the condition flags based on the result.

This instruction is used by the alias `TST (immediate)`.

<table>
<thead>
<tr>
<th>sf</th>
<th>immr</th>
<th>imms</th>
<th>Rn</th>
<th>Rd</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

**32-bit (sf == 0 && N == 0)**

Ands <Wd>, <Wn>, #<imm>

**64-bit (sf == 1)**

Ands <Xd>, <Xn>, #<imm>

```plaintext
integer d = UInt(Rd);
integer n = UInt(Rn);
integer datasize = if sf == '1' then 64 else 32;
boolean setflags;
LogicalOp op;
case opc of
  when '00' op = LogicalOp_AND; setflags = FALSE;
  when '01' op = LogicalOp_OR; setflags = FALSE;
  when '10' op = LogicalOp_XOR; setflags = FALSE;
  when '11' op = LogicalOp_AND; setflags = TRUE;
bits(datasize) imm;
if sf == '0' && N != '0' then UNDEFINED;
(imm, -) = if sf == '0' && N != '0' then ReservedValue();
(imm, -) = DecodeBitMasks(N, imms, immr, TRUE);
```

**Assembler Symbols**

- `<Wd>` Is the 32-bit name of the general-purpose destination register, encoded in the "Rd" field.
- `<Wn>` Is the 32-bit name of the general-purpose source register, encoded in the "Rn" field.
- `<Xd>` Is the 64-bit name of the general-purpose destination register, encoded in the "Rd" field.
- `<Xn>` Is the 64-bit name of the general-purpose source register, encoded in the "Rn" field.
- `<imm>` For the 32-bit variant: is the bitmask immediate, encoded in "imms:immr".
  For the 64-bit variant: is the bitmask immediate, encoded in "N:imms:immr".

**Alias Conditions**

<table>
<thead>
<tr>
<th>Alias</th>
<th>Is preferred when</th>
</tr>
</thead>
<tbody>
<tr>
<td>TST (immediate)</td>
<td>Rd == '11111'</td>
</tr>
</tbody>
</table>
Operation

```c
bits(datasize) result;
bits(datasize) operand1 = X[n];
bits(datasize) operand2 = imm;

case op of
    when LogicalOp_AND result = operand1 AND operand2;
    when LogicalOp_ORR result = operand1 OR  operand2;
    when LogicalOp_EOR result = operand1 EOR operand2;

if setflags then
    PSTATE.<N,Z,C,V> = result<datasize-1>:IsZeroBit(result):'00';

if d == 31 && !setflags then
    SP[] = result;
else
    X[d] = result;
```

Operational information

If PSTATE.DIT is 1:
- The execution time of this instruction is independent of:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
- The response of this instruction to asynchronous exceptions does not vary based on:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.

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ANDS (shifted register)

Bitwise AND (shifted register), setting flags, performs a bitwise AND of a register value and an optionally-shifted register value, and writes the result to the destination register. It updates the condition flags based on the result.

This instruction is used by the alias TST (shifted register).

<table>
<thead>
<tr>
<th>sf</th>
<th>1 1 0 1 0 1 0 0</th>
<th>shift</th>
<th>0</th>
<th>Rm</th>
<th>imm6</th>
<th>Rn</th>
<th>Rd</th>
</tr>
</thead>
<tbody>
<tr>
<td>opc</td>
<td>N</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

32-bit (sf == 0)

ANDS <Wd>, <Wn>, <Wm>{, <shift> #<amount>}

64-bit (sf == 1)

ANDS <Xd>, <Xn>, < Xm>{, <shift> #<amount>}

integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rm);
integer datasize = if sf == '1' then 64 else 32;
boolean setflags;
LogicalOp op;
case opc of
  when '00' op = LogicalOp AND; setflags = FALSE;
  when '01' op = LogicalOp ORR; setflags = FALSE;
  when '10' op = LogicalOp EOR; setflags = FALSE;
  when '11' op = LogicalOp AND; setflags = TRUE;
if sf == '0' && imm6<5> == '1' then UNDEFINED; if sf == '1' && imm6<5> == '1' then
ReservedValue();
ShiftType shift_type = DecodeShift(shift);
integer shift_amount = UInt(imm6);
boolean invert = (N == '1');

Assembler Symbols

<Wd> Is the 32-bit name of the general-purpose destination register, encoded in the "Rd" field.
<Wn> Is the 32-bit name of the first general-purpose source register, encoded in the "Rn" field.
<Wm> Is the 32-bit name of the second general-purpose source register, encoded in the "Rm" field.
Xd> Is the 64-bit name of the general-purpose destination register, encoded in the "Rd" field.
<Xn> Is the 64-bit name of the first general-purpose source register, encoded in the "Rn" field.
<Xm> Is the 64-bit name of the second general-purpose source register, encoded in the "Rm" field.
<shift> Is the optional shift to be applied to the final source, defaulting to LSL and encoded in "shift":

<table>
<thead>
<tr>
<th>shift</th>
<th>&lt;shift&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>LSL</td>
</tr>
<tr>
<td>01</td>
<td>LSR</td>
</tr>
<tr>
<td>10</td>
<td>ASR</td>
</tr>
<tr>
<td>11</td>
<td>ROR</td>
</tr>
</tbody>
</table>

<amount> For the 32-bit variant: is the shift amount, in the range 0 to 31, defaulting to 0 and encoded in the "imm6" field.
For the 64-bit variant: is the shift amount, in the range 0 to 63, defaulting to 0 and encoded in the "imm6" field.
## Alias Conditions

<table>
<thead>
<tr>
<th>Alias</th>
<th>Is preferred when</th>
</tr>
</thead>
<tbody>
<tr>
<td>TST (shifted register)</td>
<td>Rd == '11111'</td>
</tr>
</tbody>
</table>

### Operation

```plaintext
bits(datasize) operand1 = X[n];
bits(datasize) operand2 = ShiftReg(m, shift_type, shift_amount);
if invert then operand2 = NOT(operand2);

case op of
  when LogicalOp_AND result = operand1 AND operand2;
  when LogicalOp_ORR result = operand1 OR operand2;
  when LogicalOp_EOR result = operand1 EOR operand2;
if setflags then
  PSTATE.<N,Z,C,V> = result<datasize-1>:IsZeroBit(result):'00';
X[d] = result;
```

### Operational information

If PSTATE.DIT is 1:

- The execution time of this instruction is independent of:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
- The response of this instruction to asynchronous exceptions does not vary based on:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.

Internal version only: isa v30.25 v29.05, AdvSIMD v27.01 v26.0, pseudocode v85-xml-00bet8_rc3; Build timestamp: 2018-09-13T13:2018-06-16T04:45

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AUTDA, AUTDZA

Authenticate Data address, using key A. This instruction authenticates a data address, using a modifier and key A.

The address is in the general-purpose register that is specified by <Xd>.

The modifier is:

- In the general-purpose register or stack pointer that is specified by <Xn|SP> for AUTDA.
- The value zero, for AUTDZA.

If the authentication passes, the upper bits of the address are restored to enable subsequent use of the address. If the authentication fails, the upper bits are corrupted and any subsequent use of the address results in a Translation fault.

### Integer (ARMv8.3)

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 1  | 1  | 0  | 1  | 0  | 1  | 0  | 1  | 0  | 0  | 0  | 0  | 1  | 0  | 0  | Z | 1  | 1  | 0  | 0  | 0  | 0  | 0  | 0  | 1  | 0  | 0  |

### AUTDA (Z == 0)

AUTDA <Xd>, <Xn|SP>

### AUTDZA (Z == 1 && Rn == 11111)

AUTDZA <Xd>

```java
boolean source_is_sp = FALSE;
integer d = UInt(Rd);
integer n = UInt(Rn);
if !HavePACExt() then
    UNDEFINED;
if Z == '0' then // AUTDA
    if n == 31 then source_is_sp = TRUE;
else // AUTDZA
    if n != 31 then UNDEFINED();
if Z == '0' then // AUTDA
    if n == 31 then source_is_sp = TRUE;
else // AUTDZA
    if n != 31 then UnallocatedEncoding();
```

### Assembler Symbols

- `<Xd>` Is the 64-bit name of the general-purpose destination register, encoded in the "Rd" field.
- `<Xn|SP>` Is the 64-bit name of the general-purpose source register or stack pointer, encoded in the "Rn" field.

### Operation

```java
if source_is_sp then
    X[d] = AuthDA(X[d], SP());
else
    X[d] = AuthDA(X[d], X[n]);
```

Internal version only: isa v30.25, AdvSIMD v27.01, pseudocode v85-xml-00bet8_rc3v25; Build timestamp: 2018-09-13T13:20:45Z; Copyright © 2010-2018 ARM Limited or its affiliates. All rights reserved. This document is Non-Confidential.
AUTDB, AUTDZB

Authenticate Data address, using key B. This instruction authenticates a data address, using a modifier and key B. The address is in the general-purpose register that is specified by \(<Xd>\).

The modifier is:

- In the general-purpose register or stack pointer that is specified by \(<Xn|SP>\) for AUTDB.
- The value zero, for AUTDZB.

If the authentication passes, the upper bits of the address are restored to enable subsequent use of the address. If the authentication fails, the upper bits are corrupted and any subsequent use of the address results in a Translation fault.

### Integer (ARMv8.3)

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 1  | 1  | 0  | 1  | 0  | 1  | 0  | 1  | 0  | 0  | 0  | 0  | 0  | 1  | 0  | 0  | Z  | 1  | 1  | 1  | |  |  |  |  |  |  |  | Rn |  | Rd |

### AUTDB (Z == 0)

AUTDB \(<Xd>, <Xn|SP>\)

### AUTDZB (Z == 1 && Rn == 1111)

AUTDZB \(<Xd>\)

```plaintext
boolean source_is_sp = FALSE;
integer d = UInt(Rd);
integer n = UInt(Rn);
if !HavePACExt() then UNDEFINED;
if Z == '0' then // AUTDB
    if n == 31 then source_is_sp = TRUE;
else // AUTDZB
    if n != 31 then UNDEFINED();
if Z == '0' then // AUTDB
    if n == 31 then source_is_sp = TRUE;
else // AUTDZB
    if n != 31 then UnallocatedEncoding();
```

### Assembler Symbols

- \(<Xd>\) Is the 64-bit name of the general-purpose destination register, encoded in the "Rd" field.
- \(<Xn|SP>\) Is the 64-bit name of the general-purpose source register or stack pointer, encoded in the "Rn" field.

### Operation

```plaintext
if source_is_sp then
    \(X[d] = \text{AuthDB}(X[d], \text{SP})\);
else
    \(X[d] = \text{AuthDB}(X[d], X[n])\);
```

---

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AUTIA, AUTIA1716, AUTIASP, AUTIAZ, AUTIZA

Authenticate Instruction address, using key A. This instruction authenticates an instruction address, using a modifier and key A.

The address is:
- In the general-purpose register that is specified by \( <Xd> \) for AUTIA and AUTIZA.
- In X17, for AUTIA1716.
- In X30, for AUTIASP and AUTIAZ.

The modifier is:
- In the general-purpose register or stack pointer that is specified by \( <Xn|SP> \) for AUTIA.
- The value zero, for AUTIZA and AUTIAZ.
- In X16, for AUTIA1716.
- In SP, for AUTIASP.

If the authentication passes, the upper bits of the address are restored to enable subsequent use of the address. If the authentication fails, the upper bits are corrupted and any subsequent use of the address results in a Translation fault.

It has encodings from 2 classes: Integer and System

### Integer (ARMv8.3)

<table>
<thead>
<tr>
<th>31</th>
<th>30</th>
<th>29</th>
<th>28</th>
<th>27</th>
<th>26</th>
<th>25</th>
<th>24</th>
<th>23</th>
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<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
</tr>
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<tbody>
<tr>
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<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>Z</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>Rn</td>
<td>Rd</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### AUTIA (Z == 0)

AUTIA \( <Xd> \), \( <Xn|SP> \)

### AUTIZA (Z == 1 & Rn == 1111)

AUTIZA \( <Xd> \)

```java
boolean source_is_sp = FALSE;
integer d = UInt(Rd);
integer n = UInt(Rn);
if !HavePACExt() then UNDEFINED;
if Z == '0' then // AUTIA
    if n == 31 then source_is_sp = TRUE;
else // AUTIZA
    if n != 31 then UNDEFINED;() then UnallocatedEncoding();
if Z == '0' then // AUTIA
    if n == 31 then source_is_sp = TRUE;
else // AUTIZA
    if n != 31 then UnallocatedEncoding();
```

### System (ARMv8.3)

<table>
<thead>
<tr>
<th>31</th>
<th>30</th>
<th>29</th>
<th>28</th>
<th>27</th>
<th>26</th>
<th>25</th>
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<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
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<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>x</td>
<td>1</td>
<td>0</td>
<td>x</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

CRm | op2
integer d;
integer n;
boolean source_is_sp = FALSE;

case CRm:op2 of
  when '0011 100' // AUTIAZ
    d = 30;
    n = 31;
  when '0011 101' // AUTIASP
    d = 30;
    source_is_sp = TRUE;
  when '0001 100' // AUTIA1716
    d = 17;
    n = 16;
  when '0001 000' SEE "PACIA";
  when '0001 010' SEE "PACIB";
  when '0001 110' SEE "AUTIB";
  when '0011 00x' SEE "PACIA";
  when '0011 01x' SEE "PACIB";
  when '0011 11x' SEE "AUTIB";
  when '0000 111' SEE "XPACLRI";
  otherwise SEE "HINT";

Assembler Symbols

<Xd> Is the 64-bit name of the general-purpose destination register, encoded in the "Rd" field.

<Xn|SP> Is the 64-bit name of the general-purpose source register or stack pointer, encoded in the "Rn" field.

Operation

if HavePACExt () then
  if source_is_sp then
    X[d] = AuthIA(X[d], SP[]);
  else
    X[d] = AuthIA(X[d], X[n]);
AUTIB, AUTIB1716, AUTIBSP, AUTIBZ, AUTIZB

Authenticate Instruction address, using key B. This instruction authenticates an instruction address, using a modifier and key B.

The address is:
- In the general-purpose register that is specified by <Xd> for AUTIB and AUTIZB.
- In X17, for AUTIB1716.
- In X30, for AUTIBSP and AUTIBZ.

The modifier is:
- In the general-purpose register or stack pointer that is specified by <Xn|SP> for AUTIB.
- The value zero, for AUTIZB and AUTIBZ.
- In X16, for AUTIB1716.
- In SP, for AUTIBSP.

If the authentication passes, the upper bits of the address are restored to enable subsequent use of the address. If the authentication fails, the upper bits are corrupted and any subsequent use of the address results in a Translation fault.

It has encodings from 2 classes: Integer and System.

Integer
(ARMv8.3)

```
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 1  | 1  | 0  | 1  | 0  | 1  | 0  | 1  | 1  | 0  | 0  | 0  | 0  | 0  | 1  | 0  | 0  | Z | 1 | 0 | 1 | Rn | Rd |
```

AUTIB (Z == 0)

AUTIB <Xd>, <Xn|SP>

AUTIZB (Z == 1 && Rn == 1111)

AUTIZB <Xd>

```java
boolean source_is_sp = FALSE;
integer d = Uint(Rd);
integer n = Uint(Rn);
if !HavePACExt() then
    UNDEFINED;
if Z == '0' then // AUTIB
    if n == 31 then source_is_sp = TRUE;
else // AUTIZB
    if n != 31 then UNDEFINED(); thenUnallocatedEncoding();
if Z == '1' then // AUTIB
    if n == 31 then source_is_sp = TRUE;
else // AUTIZB
    if n != 31 then UnallocatedEncoding();
```

System
(ARMv8.3)

```
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 1  | 1  | 0  | 1  | 0  | 1  | 0  | 0  | 0  | 0  | 0  | 1  | 1  | 0  | 0  | 1  | 0  | 0  | 0  | 1  | 0  | 0  | x | 1  | 1  | 1  | 1  | 1  | x |
```

CRm op2
integer \( d \);
integer \( n \);
boolean source_is_sp = FALSE;

\[
\text{case CRm:op2 of}
\begin{align*}
\text{when '0011 110' // AUTIBZ} & \quad d = 30; \\
& \quad n = 31; \\
\text{when '0011 111' // AUTIBSP} & \quad d = 30; \\
& \quad \text{source_is_sp = TRUE;} \\
\text{when '0001 110' // AUTIB1716} & \quad d = 17; \\
& \quad n = 16; \\
\text{when '0001 000' SEE "PACIA";} & \\
\text{when '0001 010' SEE "PACIB";} & \\
\text{when '0001 100' SEE "AUTIA";} & \\
\text{when '0011 00x' SEE "PACIA";} & \\
\text{when '0011 01x' SEE "PACIB";} & \\
\text{when '0011 10x' SEE "AUTIA";} & \\
\text{when '0000 111' SEE "XPACLRI"};
\end{align*}
\]

**Asmmler Symbols**

\(<Xd>\) Is the 64-bit name of the general-purpose destination register, encoded in the "Rd" field.

\(<Xn|SP>\) Is the 64-bit name of the general-purpose source register or stack pointer, encoded in the "Rn" field.

**Operation**

\[
\text{if HavePACExt () then}
\begin{align*}
\text{if source_is_sp then} & \quad X[d] = \text{AuthIB}(X[d], \text{SP}); \\
\text{else} & \quad X[d] = \text{AuthIB}(X[d], X[n]);
\end{align*}
\]

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AXFlag

Convert floating-point condition flags from ARM to external format. This instruction converts the state of the PSTATE.{N,Z,C,V} flags from a form representing the result of an ARM floating-point scalar compare instruction to an alternative representation required by some software.

System
(ARMv8.5)

\[
\begin{array}{cccccccccccccccccccc}
1 & 1 & 0 & 1 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & (0) & (0) & (0) & 0 & 1 & 0 & 1 & 1 & 1 & 1 & 1
\end{array}
\]

C	Rm

System

AXFlag

if !HaveFlagFormatExt() then UNDEFINED;

Operation

\[
\begin{align*}
\text{bit } N &= '0'; \\
\text{bit } Z &= \text{PSTATE.Z OR PSTATE.V;} \\
\text{bit } C &= \text{PSTATE.C AND NOT(PSTATE.V);} \\
\text{bit } V &= '0'; \\
\text{PSTATE.N} &= N; \\
\text{PSTATE.Z} &= Z; \\
\text{PSTATE.C} &= C; \\
\text{PSTATE.V} &= V;
\end{align*}
\]

Internal version only: isa v30.25, AdvSIMD v27.01, pseudocode v85-xml-00be8_rc3; Build timestamp: 2018-09-13T13:04

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B.cond

Branch conditionally to a label at a PC-relative offset, with a hint that this is not a subroutine call or return.

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0  | 1  | 0  | 1  | 0  | 1  | 0  | imm19 | 0  | 0  | 0  | 0  | imm19 | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | cond |

19-bit signed PC-relative branch offset

B.<cond> <label>

```assembly
bits(64) offset = SignExtend(imm19:'00', 64);
bits(4) condition = cond;
```

Assembler Symbols

<cond> Is one of the standard conditions, encoded in the "cond" field in the standard way.

<label> Is the program label to be conditionally branched to. Its offset from the address of this instruction, in the range +/-1MB, is encoded as "imm19" times 4.

Operation

```assembly
if ConditionHolds(condition) then
    BranchTo(PC[]) + offset, BranchType_DIR, BranchType_JMP;
```

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Branch causes an unconditional branch to a label at a PC-relative offset, with a hint that this is not a subroutine call or return.

```
0 0 0 1 0 1
imm26
```

**26-bit signed PC-relative branch offset**

```python
B <label>

BranchType branch_type = if op == '1' then BranchType_DIRCALL else BranchType_DIRJMP;
bits(64) offset = SignExtend(imm26:'00', 64);

Assembler Symbols

<label> Is the program label to be unconditionally branched to. Its offset from the address of this instruction, in the range +/-128MB, is encoded as “imm26” times 4.

Operation

```python
if branch_type == BranchType_DIRCALL then X[30] = PC[] + 4;
BranchTo(PC[] + offset, branch_type);
```

Internal version only: isa v30.25,v29.05, AdvSIMD v27.01,v26.0, pseudocode v85-xml-00bet8_rc39632 ; Build timestamp: 2018-09-13T13:04 2018-06-16T09:04:45

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BCAX

Bit Clear and Exclusive OR performs a bitwise AND of the 128-bit vector in a source SIMD&FP register and the complement of the vector in another source SIMD&FP register, then performs a bitwise exclusive OR of the resulting vector and the vector in a third source SIMD&FP register, and writes the result to the destination SIMD&FP register.

This instruction is implemented only when ARMv8.2-SHA is implemented.

Advanced SIMD
(ARMv8.2)

|   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| 31| 30| 29| 28| 27| 26| 25| 24| 23| 22| 21| 20| 19| 18| 17| 16| 15| 14| 13| 12| 11| 10| 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 1 | Rm | 0 | Ra | Rn | Rd |

Advanced SIMD

BCAX <Vd>.16B, <Vn>.16B, <Vm>.16B, <Va>.16B

if !HaveSHA3Ext() then UNDEFINED;

integer d = UnallocatedEncoding();
integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rm);
integer a = UInt(Ra);

Assembler Symbols

<Vd> Is the name of the SIMD&FP destination register, encoded in the "Rd" field.
<Vn> Is the name of the first SIMD&FP source register, encoded in the "Rn" field.
<Vm> Is the name of the second SIMD&FP source register, encoded in the "Rm" field.
<Va> Is the name of the third SIMD&FP source register, encoded in the "Ra" field.

Operation

AArch64.CheckFPAdvSIMDEnabled();

bits(128) Vm = V[m];
bits(128) Vn = V[n];
bits(128) Va = V[a];
V[d] = Vn EOR (Vm AND NOT(Va));

Operational information

If PSTATE.DIT is 1:

• The execution time of this instruction is independent of:
  ◦ The values of the data supplied in any of its registers.
  ◦ The values of the NZCV flags.

• The response of this instruction to asynchronous exceptions does not vary based on:
  ◦ The values of the data supplied in any of its registers.
  ◦ The values of the NZCV flags.

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BFM

Bitfield Move is usually accessed via one of its aliases, which are always preferred for disassembly. If \(<\text{imms}>\) is greater than or equal to \(<\text{immr}>\), this copies a bitfield of \(<\text{imms}>-<\text{immr}>+1\) bits starting from bit position \(<\text{immr}>\) in the source register to the least significant bits of the destination register. If \(<\text{imms}>\) is less than \(<\text{immr}>\), this copies a bitfield of \(<\text{imms}>+1\) bits from the least significant bits of the source register to bit position \((\text{regsize}-<\text{immr}>)\) of the destination register, where \(\text{regsize}\) is the destination register size of 32 or 64 bits. In both cases the other bits of the destination register remain unchanged.

This instruction is used by the aliases \(\text{BFC}, \text{BFI}, \text{and BFXIL}\).
For the 64-bit variant: is the right rotate amount, in the range 0 to 63, encoded in the "immr" field.

For the 32-bit variant: is the leftmost bit number to be moved from the source, in the range 0 to 31, encoded in the "imms" field.

For the 64-bit variant: is the leftmost bit number to be moved from the source, in the range 0 to 63, encoded in the "imms" field.

### Alias Conditions

<table>
<thead>
<tr>
<th>Alias</th>
<th>Is preferred when</th>
</tr>
</thead>
<tbody>
<tr>
<td>BFC</td>
<td>Rn == '11111' &amp;&amp; UInt(imms) &lt; UInt(immr)</td>
</tr>
<tr>
<td>BFI</td>
<td>Rn != '11111' &amp;&amp; UInt(imms) &lt; UInt(immr)</td>
</tr>
<tr>
<td>BFXIL</td>
<td>UInt(imms) &gt;= UInt(immr)</td>
</tr>
</tbody>
</table>

### Operation

\[
\begin{align*}
\text{bits}(\text{datasize}) \ dst &= \text{if inzero then } \text{Zeros()} \text{ else } X[d]; \\
\text{bits}(\text{datasize}) \ src &= X[n]; \\
\end{align*}
\]

// perform bitfield move on low bits
\[
\begin{align*}
\text{bits}(\text{datasize}) \ bot &= (\text{dst AND NOT(wmask)}) \text{ OR } (\text{ROR(src, R) AND wmask}); \\
\end{align*}
\]

// determine extension bits (sign, zero or dest register)
\[
\begin{align*}
\text{bits}(\text{datasize}) \ top &= \text{if extend then } \text{Replicate}(\text{src<}$S$)$) \text{ else } \text{dst}; \\
\end{align*}
\]

// combine extension bits and result bits
\[
X[d] = (\text{top AND NOT(tmask)}) \text{ OR } (\text{bot AND tmask});
\]

### Operational information

If PSTATE.DIT is 1:
- The execution time of this instruction is independent of:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
- The response of this instruction to asynchronous exceptions does not vary based on:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
BIC (vector, immediate)

Bitwise bit Clear (vector, immediate). This instruction reads each vector element from the destination SIMD&FP register, performs a bitwise AND between each result and the complement of an immediate constant, places the result into a vector, and writes the vector to the destination SIMD&FP register.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
0 | Q 1 0 1 1 1 0 0 0 0 | a | b | c | x | x | x | 1 | 0 | d | e | f | g | h | Rd
op cmode

16-bit (cmode == 10x1)

BIC <Vd>.<T>, #<imm8>{, LSL <amount>}

32-bit (cmode == 0x1)

BIC <Vd>.<T>, #<imm8>{, LSL <amount>}

integer rd = UInt(Rd);
integer datasize = if Q == '1' then 128 else 64;
bits(datasize) imm;
bits(64) imm64;

ImmediateOp operation;
case cmode:op of
  when '0xx00' operation = ImmediateOp_MOVI;
  when '0xx01' operation = ImmediateOp_MVNI;
  when '0xx10' operation = ImmediateOp_ORR;
  when '0xx11' operation = ImmediateOp_BIC;
  when '10x00' operation = ImmediateOp_MOVI;
  when '10x01' operation = ImmediateOp_MVNI;
  when '10x10' operation = ImmediateOp_ORR;
  when '10x11' operation = ImmediateOp_BIC;
  when '110x0' operation = ImmediateOp_MOVI;
  when '110x1' operation = ImmediateOp_MVNI;
  when '1110x' operation = ImmediateOp_MOVI;
  when '11110' operation = ImmediateOp_MOVI;
  when '11111'
  // FMOV Dn,#imm is in main FP instruction set
  if Q == '0' then UNDEFINED;
  operation = if Q == '0' then UnallocatedEncoding();
  operation = ImmediateOp_MOVI;

imm64 = AdvSIMDExpandImm(op, cmode, a:b:c:d:e:f:g:h);
imm = Replicate(imm64, datasize DIV 64);

Assembler Symbols

<Vd> Is the name of the SIMD&FP register, encoded in the "Rd" field.
<T> For the 16-bit variant: is an arrangement specifier, encoded in “Q”:

| Q |<T>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>4H</td>
</tr>
<tr>
<td>1</td>
<td>8H</td>
</tr>
</tbody>
</table>

For the 32-bit variant: is an arrangement specifier, encoded in “Q”:
Is an 8-bit immediate encoded in "a:b:c:d:e:f:g:h".

For the 16-bit variant: is the shift amount encoded in "cmode<1>":

<table>
<thead>
<tr>
<th>cmode&lt;1&gt;</th>
<th>&lt;amount&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1</td>
<td>8</td>
</tr>
</tbody>
</table>

defaulting to 0 if LSL is omitted.

For the 32-bit variant: is the shift amount encoded in "cmode<2:1>":

<table>
<thead>
<tr>
<th>cmode&lt;2:1&gt;</th>
<th>&lt;amount&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>0</td>
</tr>
<tr>
<td>01</td>
<td>8</td>
</tr>
<tr>
<td>10</td>
<td>16</td>
</tr>
<tr>
<td>11</td>
<td>24</td>
</tr>
</tbody>
</table>

defaulting to 0 if LSL is omitted.

Operation

```c
CheckFPAdvSIMDEnabled64();
bits(datasize) operand;
bits(datasize) result;

case operation of
  when ImmediateOp_MOVI
    result = imm;
  when ImmediateOp_MVNI
    result = NOT(imm);
  when ImmediateOp_ORR
    operand = V[rd];
    result = operand OR imm;
  when ImmediateOp_BIC
    operand = V[rd];
    result = operand AND NOT(imm);

V[rd] = result;
```

Operational information

If PSTATE.DIT is 1:

- The execution time of this instruction is independent of:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
- The response of this instruction to asynchronous exceptions does not vary based on:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
BIC (shifted register)

Bitwise Bit Clear (shifted register) performs a bitwise AND of a register value and the complement of an optionally-shifted register value, and writes the result to the destination register.

<table>
<thead>
<tr>
<th>sf</th>
<th>000001</th>
<th>Rm</th>
<th>imm6</th>
<th>Rn</th>
<th>Rd</th>
</tr>
</thead>
<tbody>
<tr>
<td>opc</td>
<td></td>
<td>N</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

32-bit (sf == 0)

BIC <Wd>, <Wn>, <Wm>{, <shift> #<amount>}

64-bit (sf == 1)

BIC <Xd>, <Xn>, <Xm>{, <shift> #<amount>}

```plaintext
integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rm);
integer datasize = if sf == 1 then 64 else 32;
boolean setflags;
LogicalOp op;
case opc of
  when '00' op = LogicalOp AND; setflags = FALSE;
  when '01' op = LogicalOp ORR; setflags = FALSE;
  when '10' op = LogicalOp EOR; setflags = FALSE;
  when '11' op = LogicalOp AND; setflags = TRUE;

if sf == '0' && imm6<5> == '1' then UNDEFINED;

ReservedValue();

ShiftType shift_type = DecodeShift(shift);
integer shift_amount = UInt(imm6);
boolean invert = (N == '1');
```

Assembler Symbols

- <Wd> Is the 32-bit name of the general-purpose destination register, encoded in the "Rd" field.
- <Wn> Is the 32-bit name of the first general-purpose source register, encoded in the "Rn" field.
- <Wm> Is the 32-bit name of the second general-purpose source register, encoded in the "Rm" field.
- <Xd> Is the 64-bit name of the general-purpose destination register, encoded in the "Rd" field.
- <Xn> Is the 64-bit name of the first general-purpose source register, encoded in the "Rn" field.
- <Xm> Is the 64-bit name of the second general-purpose source register, encoded in the "Rm" field.
- <shift> Is the optional shift to be applied to the final source, defaulting to LSL and encoded in "shift":

<table>
<thead>
<tr>
<th>shift</th>
<th>&lt;shift&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>LSL</td>
</tr>
<tr>
<td>01</td>
<td>LSR</td>
</tr>
<tr>
<td>10</td>
<td>ASR</td>
</tr>
<tr>
<td>11</td>
<td>ROR</td>
</tr>
</tbody>
</table>

- <amount> For the 32-bit variant: is the shift amount, in the range 0 to 31, defaulting to 0 and encoded in the "imm6" field.
  For the 64-bit variant: is the shift amount, in the range 0 to 63, defaulting to 0 and encoded in the "imm6" field,
Operation

```plaintext
bits(datasize) operand1 = X[n];
bits(datasize) operand2 = ShiftReg(m, shift_type, shift_amount);
if invert then operand2 = NOT(operand2);

case op of
    when LogicalOp_AND result = operand1 AND operand2;
    when LogicalOp_ORR result = operand1 OR operand2;
    when LogicalOp_EOR result = operand1 EOR operand2;

if setflags then
    PSTATE.<N,Z,C,V> = result<datasize-1>:IsZeroBit(result):'00';

X[d] = result;
```

Operational information

If PSTATE.DIT is 1:

- The execution time of this instruction is independent of:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
- The response of this instruction to asynchronous exceptions does not vary based on:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
BICS (shifted register)

Bitwise Bit Clear (shifted register), setting flags, performs a bitwise AND of a register value and the complement of an optionally-shifted register value, and writes the result to the destination register. It updates the condition flags based on the result.

<table>
<thead>
<tr>
<th>sf</th>
<th>1 1 0 1 0 1 0</th>
<th>shift</th>
<th>1</th>
<th>Rm</th>
<th>imm6</th>
<th>Rn</th>
<th>Rd</th>
</tr>
</thead>
<tbody>
<tr>
<td>opc</td>
<td>shift_type = DecodeShift(shift); integer shift_amount = UInt(Imm6); boolean invert = (N == '1');</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**32-bit (sf == 0)**

BICS <Wd>, <Wn>, <Wm>{, <shift> #<amount>}

**64-bit (sf == 1)**

BICS <Xd>, <Xn>, <Xm>{, <shift> #<amount>}

integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rm);
integer datasize = if sf == '1' then 64 else 32;
boolean setflags;
LogicalOp op;
case opc of
  when '00' op = LogicalOp AND; setflags = FALSE;
  when '01' op = LogicalOp ORR; setflags = FALSE;
  when '10' op = LogicalOp EOR; setflags = FALSE;
  when '11' op = LogicalOp AND; setflags = TRUE;

if sf == '0' && imm6<5> == '1' then UNDEFINED; if sf == '0' && imm6<5> == '1' then ReservedValue();

Assembler Symbols

<Wd> Is the 32-bit name of the general-purpose destination register, encoded in the "Rd" field.
<Wn> Is the 32-bit name of the first general-purpose source register, encoded in the "Rn" field.
<Wm> Is the 32-bit name of the second general-purpose source register, encoded in the "Rm" field.
<Xd> Is the 64-bit name of the general-purpose destination register, encoded in the "Rd" field.
<Xn> Is the 64-bit name of the first general-purpose source register, encoded in the "Rn" field.
<Xm> Is the 64-bit name of the second general-purpose source register, encoded in the "Rm" field.
<shift> Is the optional shift to be applied to the final source, defaulting to LSL and encoded in “shift”:

<table>
<thead>
<tr>
<th>shift</th>
<th>&lt;shift&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>LSL</td>
</tr>
<tr>
<td>01</td>
<td>LSR</td>
</tr>
<tr>
<td>10</td>
<td>ASR</td>
</tr>
<tr>
<td>11</td>
<td>ROR</td>
</tr>
</tbody>
</table>

<amount> For the 32-bit variant: is the shift amount, in the range 0 to 31, defaulting to 0 and encoded in the "imm6" field.
For the 64-bit variant: is the shift amount, in the range 0 to 63, defaulting to 0 and encoded in the "imm6" field,
Operation

```plaintext
bits(datasize) operand1 = X[n];
bits(datasize) operand2 = ShiftReg(m, shift_type, shift_amount);
if invert then operand2 = NOT(operand2);

case op of
    when LogicalOp_AND result = operand1 AND operand2;
    when LogicalOp_ORR result = operand1 OR operand2;
    when LogicalOp_EOR result = operand1 EOR operand2;

if setflags then
    PSTATE.<N,Z,C,V> = result<datasize-1>:IsZeroBit(result):'00';

X[d] = result;
```

Operational information

If PSTATE.DIT is 1:

- The execution time of this instruction is independent of:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
- The response of this instruction to asynchronous exceptions does not vary based on:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
Branch with Link branches to a PC-relative offset, setting the register X30 to PC+4. It provides a hint that this is a subroutine call.

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9  | 8  | 7  | 6  | 5  | 4  | 3  | 2  | 1  | 0  |
|----|----|----|----|----|----|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|
| 1  | 0  | 0  | 1  | 0  | 1  | \_ | \_ | \_ | \_ | \_ | \_ | \_ | \_ | \_ | \_ | \_ | \_ | \_ | \_ | \_ | \_ | \_ | \_ | \_ | \_ | \_ | \_ | \_ | \_ |

26-bit signed PC-relative branch offset

```python
BL <label>

BranchType branch_type = if op == '1' then BranchType_DIRCALL BranchType_CALL else BranchType_DIRBranchType_JMP;

bits(64) offset = SignExtend(imm26:'00', 64);

Assembler Symbols

<label> Is the program label to be unconditionally branched to. Its offset from the address of this instruction, in the range +/-128MB, is encoded as "imm26" times 4.

Operation

if branch_type == BranchType_DIRCALL BranchType_CALL then X[30] = PC[] + 4;

BranchTo(PC[] + offset, branch_type);
```
BLR

Branch with Link to Register calls a subroutine at an address in a register, setting register X30 to PC+4.

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9  | 8  | 7  | 6  | 5  | 4  | 3  | 2  | 1  | 0  |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 1  | 1  | 0  | 1  | 1  | 0  | 0  | 0  | 1  | 1  | 1  | 1  | 1  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  |

BLR <Xn>

integer n = UInt(Rn);
BranchType branch_type;
integer m = UInt(Rm);
boolean pac = (A == '1');
boolean use_key_a = (M == '0');
boolean source_is_sp = ((Z == '1') && (m == 31));

if !pac && m != 0 then
    UNDEFINED;
elsif pac && !HavePACExt() then
    UNDEFINED;

case op of
    when '00' branch_type = BranchType_INDIR;
    when '01' branch_type = BranchType_JMP;
    when '10' branch_type = BranchType_CALL;
    when '11' branch_type = BranchType_RET;
    otherwise UNDEFINED;

if pac then
    if Z == '0' && m != 31 then
        UNDEFINED;
    if branch_type == BranchType_RET then
        if n != 31 then UNDEFINED;
    n = 30;
    source_is_sp = TRUE;

Assembler Symbols

<Xn> Is the 64-bit name of the general-purpose register holding the address to be branched to, encoded in the "Rn" field.
Operation

bits(64) target = X[n];
case branch_type of
    when if pac then
        bits(64) modifier = if source_is_sp then BranchType_INDIR
            if !InGuardedPage then
                if n == 16 || n == 17 then
                    BTypeNext = '01';
                else
                    BTypeNext = '11';
            else
                BTypeNext = '01';
            when BranchType_INDCALL
                BTypeNext = '10';
            when BranchType_RET
                BTypeNext = '00';
    if pac then
        bits(64) modifier = if source_is_sp then SP[] else X[m];
            if use_key_a then
                target = AuthIA(target, modifier);
            else
                target = AuthIB(target, modifier);
        if branch_type == BranchType_INDCALL BranchType_CALL then X[30] = PC[] + 4;
        BranchTo(target, branch_type);

Internal version only: isa v30.25 v29.05, AdvSIMD v27.01 v26.0, pseudocode v85-xml-00bet8_rc3 v35.3; Build timestamp: 2018-09-13T13:2018-06-16T09:4545

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**BLRAA, BLRAAZ, BLRAB, BLRABZ**

Branch with Link to Register, with pointer authentication. This instruction authenticates the address in the general-purpose register that is specified by `<Xn>`, using a modifier and the specified key, and calls a subroutine at the authenticated address, setting register X30 to PC+4.

The modifier is:

- In the general-purpose register or stack pointer that is specified by `<Xm|SP>` for BLRAA and BLRAB.
- The value zero, for BLRAAZ and BLRABZ.

Key A is used for BLRAA and BLRAAZ, and key B is used for BLRAB and BLRABZ.

If the authentication passes, the PE continues execution at the target of the branch. If the authentication fails, a Translation fault is generated. The authenticated address is not written back to the general-purpose register.

**Integer**

*(ARMv8.3)*

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 1  | 1  | 0  | 1  | 0  | 1  | Z  | 0  | 0  | 1  | 1  | 1  | 1  | 1  | 0  | 0  | 0  | 0  | 1  | M  | Rn | Rm |

<table>
<thead>
<tr>
<th>op</th>
<th>A</th>
</tr>
</thead>
</table>

**(new)**
Key A, zero modifier (Z == 0 && M == 0 && Rm == 11111)

BLRAAZ <Xn>

Key A, register modifier (Z == 1 && M == 0)

BLRAA <Xn>, <Xm|SP>

Key B, zero modifier (Z == 0 && M == 1 && Rm == 11111)

BLRABZ <Xn>

Key B, register modifier (Z == 1 && M == 1)

BLRAB <Xn>, <Xm|SP>

integer n = UInt(Rn);
BranchType branch_type;
integer m = UInt(Rm);
boolean pac = (A == '1');
boolean use_key_a = (M == '0');
boolean source_is_sp = ((Z == '1') && (m == 31));

if !pac && m != 0 then UNDEFINED;
elsif pac && ! if !pac && m != 0 then UnallocatedEncoding();
elsif pac && ! HavePACExt() then UNDEFINED;

case op of
  when '00' branch_type = BranchType_INDIR; UnallocatedEncoding();
  when '01' branch_type = BranchType_JMP;
  when '10' branch_type = BranchType_CALL;
  when '11' branch_type = BranchType_RET;
  otherwise UNDEFINED;

if pac then
  if Z == '0' && m != 31 then UNDEFINED;
  if branch_type == otherwise UnallocatedEncoding();
  if pac then
    if Z == '0' && m != 31 then UnallocatedEncoding();
    if branch_type == BranchType_RET then
      if n != 31 then UnallocatedEncoding();
      if n != 31 then UNDEFINED;
      n = 30;
      source_is_sp = TRUE;

Assembler Symbols

<Xn> Is the 64-bit name of the general-purpose register holding the address to be branched to, encoded in the "Rn" field.
<Xm|SP> Is the 64-bit name of the general-purpose source register or stack pointer holding the modifier, encoded in the "Rm" field.
Operation

```plaintext
bits(64) target = X[n];
case branch_type of
  when if pac then
    bits(64) modifier = if source_is_sp then BranchType_INDIR
      if InGuardedPage then
        if n == 16 || n == 17 then BTypeNext = '01';
      else
        BTypeNext = '11';
    else
      BTypeNext = '01';
    when BranchType_INDCALL
      BTypeNext = '10';
    when BranchType_RET
      BTypeNext = '00';
  if pac then
    bits(64) modifier = if source_is_sp then SP[] else X[m];
    if use_key_a then
      target = AuthIA(target, modifier);
    else
      target = AuthIB(target, modifier);
  if branch_type == BranchType_INDCALL BranchType_CALL then X[30] = PC[] + 4;
BranchTo(target, branch_type);
```


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Branch to Register branches unconditionally to an address in a register, with a hint that this is not a subroutine return.

integer <Xn>

```plaintext
int n = UInt(Rn);
BranchType branch_type;
int m = UInt(Rm);
boolean pac = (A == '1');
boolean use_key_a = (M == '0');
boolean source_is_sp = ((Z == '1') && (m == 31));

if !pac && m != 0 then
    UNDEFINED;
elsif pac && !
    UnallocatedEncoding();
elsif pac && !HavePACExt() then
    UNDEFINED;

  case op of
    when '00' branch_type = BranchType_INDIR;
    when '01' branch_type = BranchType_JMP;
    when '10' branch_type = BranchType_CALL;
    when '11' branch_type = BranchType_RET;
    otherwise UNDEFINED;

  if pac then
    if Z == '0' && m != 31 then
        UNDEFINED;
    if branch_type == BranchType_RET then
        if n != 31 then
            UNDEFINED;
        n = 30;
        source_is_sp = TRUE;
```

Assembler Symbols

<Xn> Is the 64-bit name of the general-purpose register holding the address to be branched to, encoded in the "Rn" field.
Operation

```plaintext
bits(64) target = X[n];
case branch_type of
  when if pac then
    bits(64) modifier = if source_is_sp then BranchType_INDIR
      if InGuardedPage then
        if n == 16 || n == 17 then
          BTypeNext = '01';
        else
          BTypeNext = '11';
      else
        BTypeNext = '01';
      when BranchType_INDCALL
        BTypeNext = '10';
      when BranchType_RET
        BTypeNext = '00';
  if pac then
    bits(64) modifier = if source_is_sp then SP[] else X[m];
    if use_key_a then
      target = AuthIA(target, modifier);
    else
      target = AuthIB(target, modifier);
    if branch_type == BranchType_INDCALL BranchType_CALL then X[30] = PC[] + 4;
    BranchTo(target, branch_type);
```

Internal version only: isa v30.25, AdvSIMD v27.01, pseudocode v85-xml-00bet8_rc3v35; Build timestamp: 2018-09-13T13:2018-06-16T09:45

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BRAA, BRAAZ, BRAB, BRABZ

Branch to Register, with pointer authentication. This instruction authenticates the address in the general-purpose register that is specified by <Xn>, using a modifier and the specified key, and branches to the authenticated address.

The modifier is:

- In the general-purpose register or stack pointer that is specified by <Xm|SP> for BRAA and BRAB.
- The value zero, for BRAAZ and BRABZ.

Key A is used for BRAA and BRAAZ, and key B is used for BRAB and BRABZ.

If the authentication passes, the PE continues execution at the target of the branch. If the authentication fails, a Translation fault is generated.

The authenticated address is not written back to the general-purpose register.

**Integer**

(ARMv8.3)

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 1  | 1  | 0  | 1  | 0  | 1  | 1  | Z  | 0  | 0  | 0  | 1  | 1  | 1  | 1  | 0  | 0  | 0  | 0  | 1  | M  | Rn |   |   | Rm |

op A
Key A, zero modifier \((Z == 0 \&\& M == 0 \&\& Rm == 1111)\)

```
BRAAZ <Xn>
```

Key A, register modifier \((Z == 1 \&\& M == 0)\)

```
BRAA <Xn>, <Xm|SP>
```

Key B, zero modifier \((Z == 0 \&\& M == 1 \&\& Rm == 1111)\)

```
BRABZ <Xn>
```

Key B, register modifier \((Z == 1 \&\& M == 1)\)

```
BRAB <Xn>, <Xm|SP>
```

```plaintext
integer n = UInt(Rn);
BranchType branch_type;
integer m = UInt(Rm);
boolean pac = (A == '1');
boolean use_key_a = (M == '0');
boolean source_is_sp = ((Z == '1') \&\& (m == 31));

if !pac \&\& m != 0 then
  UNDEFINED;
elsif pac \&\& !if !pac \&\& m != 0 then UnallocatedEncoding();
elsif pac \&\& !HavePACExt() then
  UNDEFINED;

case op of
  when '00' branch_type = BranchType_INDIR();
  when '01' branch_type = BranchType_JMP();
  when '10' branch_type = BranchType_CALL();
  when '11' branch_type = BranchType_RET();
  otherwise UNDEFINED;

if pac then
  if Z == '0' \&\& m != 31 then
    UNDEFINED;
    if branch_type == otherwise UnallocatedEncoding();

if pac then
  if Z == '0' \&\& m != 31 then
    UnallocatedEncoding();
    if branch_type == BranchType_RET then
      if n != 31 then UnallocatedEncoding() then
        if n != 31 then UNDEFINED;
  n = 30;
  source_is_sp = TRUE;
```

**Assembler Symbols**

\(<Xn>\) Is the 64-bit name of the general-purpose register holding the address to be branched to, encoded in the "Rn" field.

\(<Xm|SP>\) Is the 64-bit name of the general-purpose source register or stack pointer holding the modifier, encoded in the "Rm" field.
Operation

bits(64) target = X[n];
case branch_type of
  when if pac then
    bits(64) modifier = if source_is_sp then BranchType_INDIR
      if InGuardedPage then
        if n == 16 || n == 17 then
          BTypeNext = '01';
        else
          BTypeNext = '11';
      else
        BTypeNext = '01';
      when BranchType_INDCALL
        BTypeNext = '10';
      when BranchType_RET
        BTypeNext = '00';
if pac then
  bits(64) modifier = if source_is_sp then SP[] else X[m];
  if use_key_a then
target = AuthIA(target, modifier);
else
target = AuthIB(target, modifier);
if branch_type == BranchType_INDCALLBranchType_CALL then X[30] = PC[] + 4;
BranchTo(target, branch_type);


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Breakpoint instruction generates a Breakpoint Instruction exception. The PE records the exception in `ESR_ELx`, using the EC value 0x3c, and captures the value of the immediate argument in `ESR_ELx.ISS`.

### System

```
System

BRK #<imm>
```

```
<table>
<thead>
<tr>
<th>bits(16) comment</th>
<th>imm16</th>
</tr>
</thead>
<tbody>
<tr>
<td>imm16</td>
<td>0 0 0 0</td>
</tr>
</tbody>
</table>
```

### Assembler Symbols

```
<imm>
```

Is a 16-bit unsigned immediate, in the range 0 to 65535, encoded in the "imm16" field.

### Operation

```
AArch64.SoftwareBreakpoint(comment);
```


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BTI

Branch Target Identification. A BTI instruction is used to guard against the execution of instructions which are not the intended target of a branch.

Outside of a guarded memory region, a BTI instruction executes as a NOP. Within a guarded memory region while PSTATE.BTYPE != 0b00, a BTI instruction compatible with the current value of PSTATE.BTYPE will not generate a Branch Target Exception and will allow execution of subsequent instructions within the memory region.

The operand <targets> passed to a BTI instruction determines the values of PSTATE.BTYPE which the BTI instruction is compatible with. Within a guarded memory region, while PSTATE.BTYPE != 0b00, all instructions will generate a Branch Target Exception, other than BRK, BTI, HLT, PACIASP, and PACIBSP, which may not. See the individual instructions for details.

**System**

(ARMv8.5)

```
System HintOp op;
```

```
case CRm:op2 of
  when '0000 000' op = SystemHintOp_NOP;
  when '0000 001' op = SystemHintOp_YIELD;
  when '0000 010' op = SystemHintOp_WFE;
  when '0000 011' op = SystemHintOp_WFI;
  when '0000 100' op = SystemHintOp_SEV;
  when '0000 101' op = SystemHintOp_SEVL;
  when '0000 111'  // Instruction executes as NOP
    see "XPACLRI";
  when '0001 xxx'  // Instruction executes as NOP
    see "PACIA1716, PACIB1716, AUTIA1716, AUTIB1716";
  when '0010 000'  // Instruction executes as NOP
    if !HaveRASExt() then EndOfInstruction();
    op = SystemHintOp_ESB;
  when '0010 001'  // Instruction executes as NOP
    if !HaveStatisticalProfiling() then EndOfInstruction();
    op = SystemHintOp_PSB;
  when '0010 010'  // Instruction executes as NOP
    if !HaveSelfHostedTrace() then EndOfInstruction();
    op = SystemHintOp_TSB;
  when '0010 100'  // Instruction executes as NOP
    op = SystemHintOp_CSDB;
  when '0011 xxx'  // Instruction executes as NOP
    see "PACIAZ, PACIASP, PACIBZ, PACIBSP, AUTIAZ, AUTIASP, AUTIBZ, AUTIBSP";
  when '0100 xx0'  // Instruction executes as NOP
    op = SystemHintOp_BTI;
    BTypeCompatible = BTypeCompatible_BTI(op2<2:1>);
  when '0101 xx0'
    op = SystemHintOp_CSDB;
    BTypeCompatible = BTypeCompatible_BTI(op2<2:1>);
  when '0110 xx0'
    op = SystemHintOp_TSB;
    BTypeCompatible = BTypeCompatible_BTI(op2<2:1>);
  when '0111 xxx'
    see "PACIAZ, PACIASP, PACIBZ, PACIBSP, AUTIAZ, AUTIASP, AUTIBZ, AUTIBSP";
  when '1000 xx0'
    op = SystemHintOp_BTI;
    BTypeCompatible = BTypeCompatible_BTI(op2<2:1>);
  otherwise EndOfInstruction();
```

### Assembler Symbols

<targets> Is the type of indirection, encoded in "op2<2:1>":

**BTI**

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Operation

```c
case op of
  when SystemHintOp_YIELDHint_Yield();

  when SystemHintOp_WFE
    if IsEventRegisterSet() then
      ClearEventRegister();
    else
      if PSTATE_EL == EL0 then
        // Check for traps described by the OS which may be EL1 or EL2.
        AArch64.CheckForWFXTrap(EL1, TRUE);
      if EL2Enabled() && PSTATE_EL IN {EL0, EL1} && !IsInHost() then
        // Check for traps described by the Hypervisor.
        AArch64.CheckForWFXTrap(EL2, TRUE);
      if HaveEL(EL3) && PSTATE_EL != EL3 then
        // Check for traps described by the Secure Monitor.
        AArch64.CheckForWFXTrap(EL3, TRUE);
      WaitForEvent();
    if !InterruptPending() then
      if PSTATE_EL == EL0 then
        // Check for traps described by the OS which may be EL1 or EL2.
        AArch64.CheckForWFXTrap(EL1, FALSE);
      if EL2Enabled() && PSTATE_EL IN {EL0, EL1} && !IsInHost() then
        // Check for traps described by the Hypervisor.
        AArch64.CheckForWFXTrap(EL2, FALSE);
      if HaveEL(EL3) && PSTATE_EL != EL3 then
        // Check for traps described by the Secure Monitor.
        AArch64.CheckForWFXTrap(EL3, FALSE);
      WaitForInterrupt();
    when SystemHintOp_WFI
     when SystemHintOp_SEVSSendEvent();

  when SystemHintOp_SEVLSendEventLocal();

  when SystemHintOp_ESBSynchronizeErrors();
    AArch64.ESBOperation();
    if EL2Enabled() && PSTATE_EL IN {EL0, EL1} then
      AArch64.vESBOperation();
      TakeUnmaskedSErrorInterruptions();
  when SystemHintOp_PSBProfilingSynchronizationBarrier();

  when SystemHintOp_TSB
    TraceSynchronizationBarrier();

  when SystemHintOp_CSDBConsumptionOfSpeculativeDataBarrier();

  when SystemHintOp_BTI
    BTypeNext = '00';
  otherwise // do nothing
```
CAS, CASA, CASAL, CASL

Compare and Swap word or doubleword in memory reads a 32-bit word or 64-bit doubleword from memory, and compares it against the value held in a first register. If the comparison is equal, the value in a second register is written to memory. If the write is performed, the read and write occur atomically such that no other modification of the memory location can take place between the read and write.

- CASA and CASAL load from memory with acquire semantics.
- CASL and CASAL store to memory with release semantics.
- CAS has no memory ordering requirements.

For more information about memory ordering semantics see Load-Acquire, Store-Release.

For information about memory accesses see Load/Store addressing modes.

The architecture permits that the data read clears any exclusive monitors associated with that location, even if the compare subsequently fails.

If the instruction generates a synchronous Data Abort, the register which is compared and loaded, that is \(<Ws>\), or \(<Xs>\), is restored to the value held in the register before the instruction was executed.

No offset

(ARMv8.1)

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 |  9 |  8 |  7 |  6 |  5 |  4 |  3 |  2 |  1 |  0 |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 1  | x  | 0  | 0  | 1  | 0  | 0  | 1  | L  | 1  | Rs | o0 | 1  | 1  | 1  | 1  | Rn |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |

size
32-bit CAS (size == 10 & L == 0 & o0 == 0)

   CAS <Ws>, <Wt>, [<Xn|SP>{,#0}]

32-bit CASA (size == 10 & L == 1 & o0 == 0)

   CASA <Ws>, <Wt>, [<Xn|SP>{,#0}]

32-bit CASAL (size == 10 & L == 1 & o0 == 1)

   CASAL <Ws>, <Wt>, [<Xn|SP>{,#0}]

32-bit CASL (size == 10 & L == 0 & o0 == 1)

   CASL <Ws>, <Wt>, [<Xn|SP>{,#0}]

64-bit CAS (size == 11 & L == 0 & o0 == 0)

   CAS <Xs>, <Xt>, [<Xn|SP>{,#0}]

64-bit CASA (size == 11 & L == 1 & o0 == 0)

   CASA <Xs>, <Xt>, [<Xn|SP>{,#0}]

64-bit CASAL (size == 11 & L == 1 & o0 == 1)

   CASAL <Xs>, <Xt>, [<Xn|SP>{,#0}]

64-bit CASL (size == 11 & L == 0 & o0 == 1)

   CASL <Xs>, <Xt>, [<Xn|SP>{,#0}]

if !HaveAtomicExt() then UNDEFINED;

integer n = UInt(Rn);
integer t = UInt(Rt);
integer s = UInt(Rs);

integer datasize = 8 << UInt(size);
integer regsize = if datasize == 64 then 64 else 32;
AccType ldacctype = if L == '1' then AccType_ORDEREDATOMICRW else AccType_ATOMICRW;
AccType stacctype = if o0 == '1' then AccType_ORDEREDATOMICRW else AccType_ATOMICRW;

Assembler Symbols

<Ws> Is the 32-bit name of the general-purpose register to be compared and loaded, encoded in the "Rs" field.
<Wt> Is the 32-bit name of the general-purpose register to be conditionally stored, encoded in the "Rt" field.
<Xs> Is the 64-bit name of the general-purpose register to be compared and loaded, encoded in the "Rs" field.
<Xt> Is the 64-bit name of the general-purpose register to be conditionally stored, encoded in the "Rt" field.
<Xn|SP> Is the 64-bit name of the general-purpose base register or stack pointer, encoded in the "Rn" field.
Operation

bits(64) address;
bits(datasize) comparevalue;
bits(datasize) newvalue;
bits(datasize) data;

if comparevalue = HaveMTEExt() then
    SetNotTagCheckedInstruction(n == 31);

comparevalue = X[s];
newvalue = X[t];
if n == 31 then
    CheckSPAlignment();
    address = SP[];
else
    address = X[n];

// All observers in the shareability domain observe the
// following load and store atomically.
data = Mem[address, datasize DIV 8, ldacctype];
if data == comparevalue then
    Mem[address, datasize DIV 8, stacctype] = newvalue;
X[s] = ZeroExtend(data, regsize);
CASB, CASAB, CASALB, CASLB

Compare and Swap byte in memory reads an 8-bit byte from memory, and compares it against the value held in a first register. If the comparison
is equal, the value in a second register is written to memory. If the write is performed, the read and write occur atomically such that no other
modification of the memory location can take place between the read and write.

- CASAB and CASALB load from memory with acquire semantics.
- CASLB and CASALB store to memory with release semantics.
- CASB has no memory ordering requirements.

For more information about memory ordering semantics see Load-Acquire, Store-Release.
For information about memory accesses see Load/Store addressing modes.

The architecture permits that the data read clears any exclusive monitors associated with that location, even if the compare subsequently fails.
If the instruction generates a synchronous Data Abort, the register which is compared and loaded, that is <Ws>, is restored to the values held in
the register before the instruction was executed.

No offset
(ARMv8.1)

| 31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0 |
|--------------------------------------------------|--------|--------|
| 0 0 0 0 1 0 0 0 1 L 1 | Rs o0 1 1 1 1 1 | Rn | Rt |
| size |

CASAB (L == 1 && o0 == 0)

CASAB <Ws>, <Wt>, [Xn|SP]{,#0}

CASALB (L == 1 && o0 == 1)

CASALB <Ws>, <Wt>, [Xn|SP]{,#0}

CASB (L == 0 && o0 == 0)

CASB <Ws>, <Wt>, [Xn|SP]{,#0}

CASLB (L == 0 && o0 == 1)

CASLB <Ws>, <Wt>, [Xn|SP]{,#0}

if !HaveAtomicExt() then UNDEFINED;
integer n = Unt(Rn);
integer t = Unt(Rt);
integer s = Unt(Rs);

integer datasize = 8 << Unt(size);
integer regsise = if datasize == 64 then 64 else 32;
AccType ldacctype = if L == '1' then AccType ORDEREDATOMICRW else AccType ATOMICRW;
AccType stacctype = if o0 == '1' then AccType ORDEREDATOMICRW else AccType ATOMICRW;

Assembler Symbols

<Ws> Is the 32-bit name of the general-purpose register to be compared and loaded, encoded in the "Rs" field.
<Wt> Is the 32-bit name of the general-purpose register to be conditionally stored, encoded in the "Rt" field.
<Xn|SP> Is the 64-bit name of the general-purpose base register or stack pointer, encoded in the "Rn" field.
Operation

```c
bits(64) address;
bites(datasize) comparevalue;
bites(datasize) newvalue;
bites(datasize) data;

if comparevalue == HaveMTEExt() then
    SetNotTagCheckedInstruction(n == 31);

comparevalue = X[s];
newvalue = X[t];

if n == 31 then
    CheckSPAlignment();
    address = SP[];
else
    address = X[n];

// All observers in the shareability domain observe the
// following load and store atomically.
data = Mem[address, datasize DIV 8, ldacctype];
if data == comparevalue then
    Mem[address, datasize DIV 8, stacctype] = newvalue;

X[s] = ZeroExtend(data, regsize);
```

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CASH, CASAH, CASALH, CASLH

Compare and Swap halfword in memory reads a 16-bit halfword from memory, and compares it against the value held in a first register. If the comparison is equal, the value in a second register is written to memory. If the write is performed, the read and write occur atomically such that no other modification of the memory location can take place between the read and write.

- CASAH and CASALH load from memory with acquire semantics.
- CASLH and CASALH store to memory with release semantics.
- CAS has no memory ordering requirements.

For more information about memory ordering semantics see Load-Acquire, Store-Release. For information about memory accesses see Load/Store addressing modes.

The architecture permits that the data read clears any exclusive monitors associated with that location, even if the compare subsequently fails. If the instruction generates a synchronous Data Abort, the register which is compared and loaded, that is <Ws>, is restored to the values held in the register before the instruction was executed.

No offset
(ARMv8.1)

<table>
<thead>
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</tbody>
</table>

CASAH (L == 1 && o0 == 0)

CASAH <Ws>, <Wt>, [<Xn|SP>{,#0}]

CASALH (L == 1 && o0 == 1)

CASALH <Ws>, <Wt>, [<Xn|SP>{,#0}]

CASH (L == 0 && o0 == 0)

CASH <Ws>, <Wt>, [<Xn|SP>{,#0}]

CASLH (L == 0 && o0 == 1)

CASLH <Ws>, <Wt>, [<Xn|SP>{,#0}]

if !HaveAtomicExt() then UNDEFINED:

| integer n = 4 then UnallocatedEncoding(); |

integer n = UInt(Rn);
integer t = UInt(Rt);
integer s = UInt(Rs);

integer datasize = 8 << UInt(size);
integer regsize = if datasize == 64 then 64 else 32;
AccType ldacctype = if L == '1' then AccType ORDEREDATOMICRW else AccType_ATOMICRW;
AccType stacctype = if o0 == '1' then AccType ORDEREDATOMICRW else AccType_ATOMICRW;

Assembler Symbols

<Ws> Is the 32-bit name of the general-purpose register to be compared and loaded, encoded in the "Rs" field.

<Wt> Is the 32-bit name of the general-purpose register to be conditionally stored, encoded in the "Rt" field.

<Xn|SP> Is the 64-bit name of the general-purpose base register or stack pointer, encoded in the "Rn" field.
Operation

```c
bits(64) address;
bits(datasize) comparevalue;
bits(datasize) newvalue;
bits(datasize) data;

if comparevalue = HaveMTEExt() then
    SetNotTagCheckedInstruction(n == 31);

comparevalue = X[s];
newvalue = X[t];

if n == 31 then
    CheckSPAlignment();
    address = SP[];
else
    address = X[n];

// All observers in the shareability domain observe the
// following load and store atomically.
data = Mem[address, datasize DIV 8, ldacctype];
if data == comparevalue then
    Mem[address, datasize DIV 8, stacctype] = newvalue;

X[s] = ZeroExtend(data, regsize);
```

Internal version only: isa v30.25, AdvSIMD v27.01, pseudocode v85-xml-00bet8_rc3b5; Build timestamp: 2018-09-13T13:20:45

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CASP, CASPA, CASPAL, CASPL

Compare and Swap Pair of words or doublewords in memory reads a pair of 32-bit words or 64-bit doublewords from memory, and compares them against the values held in the first pair of registers. If the comparison is equal, the values in the second pair of registers are written to memory. If the writes are performed, the reads and writes occur atomically such that no other modification of the memory location can take place between the reads and writes.

- CASPA and CASPAL load from memory with acquire semantics.
- CASPL and CASPAL store to memory with release semantics.
- CAS has no memory ordering requirements.

For more information about memory ordering semantics see Load-Acquire, Store-Release.

For information about memory accesses see Load/Store addressing modes.

The architecture permits that the data read clears any exclusive monitors associated with that location, even if the compare subsequently fails. If the instruction generates a synchronous Data Abort, the registers which are compared and loaded, that is <Ws> and <W(s+1)>, or <Xs> and <X(s+1)>, are restored to the values held in the registers before the instruction was executed.

No offset

(ARMv8.1)

```
| 31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0 |
|-----------------------|-----------------|-----------------|-----------------|-----------------|
| 0 sz 0 0 1 0 0 0 0 L 1 | Rs o0 1 1 1 1 1   | Rn               | Rt               |
|                      |                 |                 |                 |
|                      |                 |                 | Rt2              |
```
32-bit CASP (sz == 0 & L == 0 & o0 == 0)

CASP <Ws>, <W(s+1)>, <Wt>, <W(t+1)>, [<X|SP>],

32-bit CASPA (sz == 0 & L == 1 & o0 == 0)

CASP <Ws>, <W(s+1)>, <Wt>, <W(t+1)>, [<X|SP>],

32-bit CASPAL (sz == 0 & L == 1 & o0 == 1)

CASPAL <Ws>, <W(s+1)>, <Wt>, <W(t+1)>, [<X|SP>],

32-bit CASPL (sz == 0 & L == 0 & o0 == 1)

CASPL <Ws>, <W(s+1)>, <Wt>, <W(t+1)>, [<X|SP>],

64-bit CASP (sz == 1 & L == 0 & o0 == 0)

CASP <Xs>, <X(s+1)>, <Xt>, <X(t+1)>, [<X|SP>],

64-bit CASPA (sz == 1 & L == 1 & o0 == 0)

CASP <Xs>, <X(s+1)>, <Xt>, <X(t+1)>, [<X|SP>],

64-bit CASPAL (sz == 1 & L == 1 & o0 == 1)

CASPAL <Xs>, <X(s+1)>, <Xt>, <X(t+1)>, [<X|SP>],

64-bit CASPL (sz == 1 & L == 0 & o0 == 1)

CASPL <Xs>, <X(s+1)>, <Xt>, <X(t+1)>, [<X|SP>],

if !HaveAtomicExt() then UNDEFINED;
if Rs<0> == '1' then UNDEFINED;
if Rt<0> == '1' then UNDEFINED;
integer n = UInt(Rn);
integer t = UInt(Rt);
integer s = UInt(Rs);
integer datasize = 32 << UInt(sz);
integer regsize = datasize;
AccType ldacctype = if L == '1' then AccType_ORDERED_ATOMIC_RW
else AccType_ATOMIC_RW;
AccType stacctype = if o0 == '1' then AccType_ORDERED_ATOMIC_RW
else AccType_ATOMIC_RW;

Assembler Symbols

<Ws> Is the 32-bit name of the first general-purpose register to be compared and loaded, encoded in the "Rs" field. <Ws> must be an even-numbered register.

<W(s+1)> Is the 32-bit name of the second general-purpose register to be compared and loaded.

<Wt> Is the 32-bit name of the first general-purpose register to be conditionally stored, encoded in the "Rt" field. <Wt> must be an even-numbered register.

<W(t+1)> Is the 32-bit name of the second general-purpose register to be conditionally stored.

<Xs> Is the 64-bit name of the first general-purpose register to be compared and loaded, encoded in the "Rs" field. <Xs> must be an even-numbered register.
Is the 64-bit name of the second general-purpose register to be compared and loaded.

Is the 64-bit name of the first general-purpose register to be conditionally stored, encoded in the "Rt" field. <Xt> must be an even-numbered register.

Is the 64-bit name of the second general-purpose register to be conditionally stored.

Is the 64-bit name of the general-purpose base register or stack pointer, encoded in the "Rn" field.

Operation

```
bits(64) address;
bits(2*datasize) comparevalue;
bits(2*datasize) newvalue;
bits(2*datasize) data;

bits(datasize) s1 = X[s];
bits(datasize) s2 = X[s+1];
bits(datasize) t1 = X[t];
bits(datasize) t2 = X[t+1];

comparevalue = if BigEndian() then s1:s2 else s2:s1;
newvalue = if BigEndian() then t1:t2 else t2:t1;

if n == 31 then HaveMTEExt() then
    SetNotTagCheckedInstruction(n == 31);

if n == 31 then
    CheckSPAlignment();
else
    address = X[n];

// All observers in the shareability domain observe the
// following load and store atomically.
data = Mem[address, (2 * datasize) DIV 8, ldacctype];
if data == comparevalue then
    Mem[address, (2 * datasize) DIV 8, stacctype] = newvalue;

if BigEndian() then
    X[s] = ZeroExtend(data<2*datasize-1:datasize>, regsize);
    X[s+1] = ZeroExtend(data<datasize-1:0>, regsize);
else
    X[s] = ZeroExtend(data<2*datasize-1:0>, regsize);
    X[s+1] = ZeroExtend(data<2*datasize-1:datasize>, regsize);
```
CBNZ

Compare and Branch on Nonzero compares the value in a register with zero, and conditionally branches to a label at a PC-relative offset if the comparison is not equal. It provides a hint that this is not a subroutine call or return. This instruction does not affect the condition flags.

<table>
<thead>
<tr>
<th>sf</th>
<th>0</th>
<th>1</th>
<th>0</th>
<th>1</th>
<th>0</th>
<th>1</th>
</tr>
</thead>
<tbody>
<tr>
<td>op</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

### 32-bit (sf == 0)

```asm
CBNZ <Wt>, <label>
```

### 64-bit (sf == 1)

```asm
CBNZ <Xt>, <label>
```

```python
integer t = UInt(Rt);
integer datasize = if sf == '1' then 64 else 32;
boolean iszero = (op == '0');
bits(64) offset = SignExtend(imm19:'00', 64);
```

#### Assembler Symbols

- `<Wt>`: Is the 32-bit name of the general-purpose register to be tested, encoded in the "Rt" field.
- `<Xt>`: Is the 64-bit name of the general-purpose register to be tested, encoded in the "Rt" field.
- `<label>`: Is the program label to be conditionally branched to. Its offset from the address of this instruction, in the range +/-1MB, is encoded as "imm19" times 4.

#### Operation

```python
bits(datasize) operand1 = X[t];

if IsZero(operand1) == iszero then
    BranchTo(PC[] + offset, BranchType_DIR, BranchType_JMP);
```

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CBZ

Compare and Branch on Zero compares the value in a register with zero, and conditionally branches to a label at a PC-relative offset if the comparison is equal. It provides a hint that this is not a subroutine call or return. This instruction does not affect condition flags.

```
<table>
<thead>
<tr>
<th>sf</th>
<th>0</th>
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<th>1</th>
<th>0</th>
<th>0</th>
<th>imm19</th>
<th>op</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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</tbody>
</table>
```

32-bit (sf == 0)

\[ \text{CBZ} \ <Wt>, <label> \]

64-bit (sf == 1)

\[ \text{CBZ} \ <Xt>, <label> \]

```plaintext
integer t = \text{UInt}(Rt);
integer datasize = if sf == '1' then 64 else 32;
boolean iszero = (op == '0');
bits(64) offset = \text{SignExtend}(imm19:'00', 64);
```

Assembler Symbols

\(<Wt>\) Is the 32-bit name of the general-purpose register to be tested, encoded in the "Rt" field.

\(<Xt>\) Is the 64-bit name of the general-purpose register to be tested, encoded in the "Rt" field.

\(<\text{label}>\) Is the program label to be conditionally branched to. Its offset from the address of this instruction, in the range +/-1MB, is encoded as "imm19" times 4.

Operation

```plaintext
bits(datasize) operand1 = X[t];

if \text{IsZero}(operand1) == iszero then
    \text{BranchTo}(PC[]) + offset, \text{BranchType_DIR} or \text{BranchType_JMP};
```

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CFINV

Invert Carry Flag. This instruction inverts the value of the PSTATE.C flag.

System

(ARMv8.4)

31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
1 1 0 1 0 1 0 0 0 0 0 0 1 0 0 (0) (0) (0) (0) 0 0 0 1 1 1 1 1

CRm

Operation

PSTATE.C = NOT(PSTATE.C);

Operational information

If PSTATE.DIT is 1:

• The execution time of this instruction is independent of:
  ▪ The values of the data supplied in any of its registers.
  ▪ The values of the NZCV flags.

• The response of this instruction to asynchronous exceptions does not vary based on:
  ▪ The values of the data supplied in any of its registers.
  ▪ The values of the NZCV flags.
Control Flow Prediction Restriction by Context prevents control flow predictions that predict execution addresses, based on information gathered from earlier execution within a particular execution context, from allowing later speculative execution within that context to be observable through side-channels.

For more information, see CFP RCTX, Control Flow Prediction Restriction by Context.

This is an alias of SYS. This means:

- The encodings in this description are named to match the encodings of SYS.
- The description of SYS gives the operational pseudocode for this instruction.

```
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9  | 8  | 7  | 6  | 5  | 4  | 3  | 2  | 1  | 0  |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 1  | 1  | 0  | 1  | 0  | 1  | 0  | 0  | 0  | 0  | 0  | 1  | 0  | 1  | 0  | 0  | 1  | 1  | 0  | 0  | 1  | 1  | 1  | 0  | 0  | 1  | 1  | 0  |

L    op1    CRn    CRm    op2
```

System

CFP RCTX, <Xt>

is equivalent to

SYS #3, C8, C3, #4, <Xt>

and is always the preferred disassembly.

Assembler Symbols

<Xt> Is the 64-bit name of the general-purpose source register, encoded in the "Rt" field.

Operation

The description of SYS gives the operational pseudocode for this instruction.
CLS (vector)

Count Leading Sign bits (vector). This instruction counts the number of consecutive bits following the most significant bit that are the same as the most significant bit in each vector element in the source SIMD&FP register, places the result into a vector, and writes the vector to the destination SIMD&FP register. The count does not include the most significant bit itself.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

```
+-----------------------------------------------+---------------------+---------------------+
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9  | 8  | 7  | 6  | 5  | 4  | 3  | 2  | 1  | 0  |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0  | Q  | 0  | 1  | 1  | 1  | 0  | 0  | 0  | 0  | 0  | 0  | 1  | 0  | 0  | 1  | 0  | 0  | 0  | 1  | 0  | 0  | 0  | 1  | 0  |
```

U

Vector

CLS <Vd>.<T>, <Vn>.<T>

```
integer d = UInt(Rd);
integer n = UInt(Rn);

if size == '11' then UNDEFINED;
integer esize = 8 << if size == '11' then ReservedValue();
integer esize = 8 << UInt(size);
integer datasize = if Q == '1' then 128 else 64;
integer elements = datasize DIV esize;

CountOp countop = if U == '1' then CountOp_CLZ else CountOp_CLS;
```

Assembler Symbols

```
<Vd> Is the name of the SIMD&FP destination register, encoded in the "Rd" field.
<T> Is an arrangement specifier, encoded in "size:Q":
```

```
<table>
<thead>
<tr>
<th>size</th>
<th>Q</th>
<th>&lt;T&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>0</td>
<td>8B</td>
</tr>
<tr>
<td>00</td>
<td>1</td>
<td>16B</td>
</tr>
<tr>
<td>01</td>
<td>0</td>
<td>4H</td>
</tr>
<tr>
<td>01</td>
<td>1</td>
<td>8H</td>
</tr>
<tr>
<td>10</td>
<td>0</td>
<td>2S</td>
</tr>
<tr>
<td>10</td>
<td>1</td>
<td>4S</td>
</tr>
<tr>
<td>11</td>
<td>x</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>
```

<Vn> Is the name of the SIMD&FP source register, encoded in the "Rn" field.

Operation

```
CheckFPAdvSIMDEnabled64();
bits(datasize) operand = V[n];
bits(datasize) result;

integer count;
for e = 0 to elements-1
  if countop == CountOp_CLS then
    count = CountLeadingSignBits(Elem[operand, e, esize]);
  else
    count = CountLeadingZeroBits(Elem[operand, e, esize]);
  Elem[result, e, esize] = count<esize-1:0>;
V[d] = result;
```

Operational information

If PSTATE.DIT is 1:
• The execution time of this instruction is independent of:
  ◦ The values of the data supplied in any of its registers.
  ◦ The values of the NZCV flags.
• The response of this instruction to asynchronous exceptions does not vary based on:
  ◦ The values of the data supplied in any of its registers.
  ◦ The values of the NZCV flags.
CLS

Count Leading Sign bits: \(Rd = \text{CLS}(Rn)\)

Count Leading Sign bits counts the number of leading bits of the source register that have the same value as the most significant bit of the register, and writes the result to the destination register. This count does not include the most significant bit of the source register.

| sf | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 |
| op | Rd |

32-bit (sf == 0)

CLS <Wd>, <Wn>

64-bit (sf == 1)

CLS <Xd>, <Xn>

integer d = \(\text{UInt}(Rd)\);
integer n = \(\text{UInt}(Rn)\);
integer datasize = if sf == '1' then 64 else 32;
\(\text{CountOp}\) opcode = if op == '0' then \(\text{CountOp CLZ}\) else \(\text{CountOp CLS}\);

Assembler Symbols

<Wd> Is the 32-bit name of the general-purpose destination register, encoded in the "Rd" field.
<Wn> Is the 32-bit name of the general-purpose source register, encoded in the "Rn" field.
<Xd> Is the 64-bit name of the general-purpose destination register, encoded in the "Rd" field.
<Xn> Is the 64-bit name of the general-purpose source register, encoded in the "Rn" field.

Operation

integer result;
bits(datasize) operand1 = \(X[n]\);
if opcode == \(\text{CountOp CLZ}\) then
    result = \(\text{CountLeadingZeroBits}(\text{operand1})\);
else
    result = \(\text{CountLeadingSignBits}(\text{operand1})\);
\(X[d]\) = result<datasize-1:0>;

Operational information

If PSTATE.DIT is 1:
- The execution time of this instruction is independent of:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
- The response of this instruction to asynchronous exceptions does not vary based on:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
**CLZ (vector)**

Count Leading Zero bits (vector). This instruction counts the number of consecutive zeros, starting from the most significant bit, in each vector element in the source SIMD&FP register, places the result into a vector, and writes the vector to the destination SIMD&FP register.

Depending on the settings in the `CPACR_EL1`, `CPTR_EL2`, and `CPTR_EL3` registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

### Vector

```
CLZ <Vd>,<T>, <Vn>,<T>
```

Integer d = UInt(Rd);
Integer n = UInt(Rn);

\[
\text{if size == '11' then UNDEFINED;}
\]
\[
\text{integer esize = 8 << \text{if size == '11' then ReservedValue();}}
\]
\[
\text{integer esize = 8 << UInt(size);}
\]
\[
\text{integer datasize = if Q == '1' then 128 else 64;}
\]
\[
\text{integer elements = datasize DIV esize;}
\]

CountOp countop = if U == '1' then CountOp_CLZ else CountOp_CLS;

### Assembler Symbols

- `<Vd>` is the name of the SIMD&FP destination register, encoded in the "Rd" field.
- `<T>` is an arrangement specifier, encoded in "size:Q":

<table>
<thead>
<tr>
<th>size</th>
<th>Q</th>
<th>&lt;T&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>0</td>
<td>8B</td>
</tr>
<tr>
<td>00</td>
<td>1</td>
<td>16B</td>
</tr>
<tr>
<td>01</td>
<td>0</td>
<td>4H</td>
</tr>
<tr>
<td>01</td>
<td>1</td>
<td>8H</td>
</tr>
<tr>
<td>10</td>
<td>0</td>
<td>2S</td>
</tr>
<tr>
<td>10</td>
<td>1</td>
<td>4S</td>
</tr>
<tr>
<td>11</td>
<td>x</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

- `<Vn>` is the name of the SIMD&FP source register, encoded in the "Rn" field.

### Operation

```
CheckFPAdvSIMDEnabled64();
bits(datasize) operand = \text{V}[n];
bits(datasize) result;

integer count;
for e = 0 to elements-1
    if countop == CountOp_CLS then
        count = CountLeadingSignBits(Elem[operand, e, esize]);
    else
        count = CountLeadingZeroBits(Elem[operand, e, esize]);
    Elem[result, e, esize] = count<esize-1:0>;
\text{V}[d] = result;
```

### Operational information

If PSTATE.DIT is 1:
- The execution time of this instruction is independent of:
• The values of the data supplied in any of its registers.
• The values of the NZCV flags.

• The response of this instruction to asynchronous exceptions does not vary based on:
  • The values of the data supplied in any of its registers.
  • The values of the NZCV flags.
CLZ

Count leading zeros: \( Rd = \text{CLZ}(Rn) \).

Count Leading Zeros counts the number of binary zero bits before the first binary one bit in the value of the source register, and writes the result to the destination register.

| sf | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| op | \( Rn \) | \( Rd \) |

32-bit (\( sf = 0 \))

CLZ \(<Wd>, <Wn>\)

64-bit (\( sf = 1 \))

CLZ \(<Xd>, <Xn>\)

integer \( d = \text{UInt}(Rd); \)
integer \( n = \text{UInt}(Rn); \)
integer \( \text{datasize} = \text{if } sf == '1' \text{ then } 64 \text{ else } 32; \)

\( \text{CountOp} \) opcode = \text{if } op == '0' \text{ then } \text{CountOp CLZ} \text{ else } \text{CountOp CLS};

Assembler Symbols

\(<Wd>\) Is the 32-bit name of the general-purpose destination register, encoded in the "Rd" field.

\(<Wn>\) Is the 32-bit name of the general-purpose source register, encoded in the "Rn" field.

\(<Xd>\) Is the 64-bit name of the general-purpose destination register, encoded in the "Rd" field.

\(<Xn>\) Is the 64-bit name of the general-purpose source register, encoded in the "Rn" field.

Operation

integer result;
bits(datasize) operand1 = \( X[n]; \)

if opcode == \text{CountOp CLZ} then
\( \text{result} = \text{CountLeadingZeroBits}(\text{operand1}); \)
else
\( \text{result} = \text{CountLeadingSignBits}(\text{operand1}); \)
\( \text{X}[d] = \text{result<datasize-1:0>;} \)

Operational information

If PSTATE.DIT is 1:

- The execution time of this instruction is independent of:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
- The response of this instruction to asynchronous exceptions does not vary based on:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
CMEQ (register)

Compare bitwise Equal (vector). This instruction compares each vector element from the first source SIMD&FP register with the corresponding vector element from the second source SIMD&FP register, and if the comparison is equal sets every bit of the corresponding vector element in the destination SIMD&FP register to one, otherwise sets every bit of the corresponding vector element in the destination SIMD&FP register to zero.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

It has encodings from 2 classes: Scalar and Vector

Scalar

| 31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0 |
| 0 1 1 1 1 1 1 0 | size | 1 | Rm | 1 0 0 0 1 1 | Rn | Rd |

Scalar

CMEQ \(<V><d>, <V><n>, <V><m>

```plaintext
text
integer d = UInt(Rd);
text
integer n = UInt(Rn);
text
integer m = UInt(Rm);
text
if size != '11' then UNDEFINED;
text
integer esize = 8 << if size != '11' then ReservedValue();
text
integer esize = 8 << UInt(size);
text
integer datasize = esize;
text
integer elements = 1;
text
boolean and_test = (U == '0');
```

Vector

| 31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0 |
| 0 Q 1 0 1 1 1 0 | size | 1 | Rm | 1 0 0 0 1 1 | Rn | Rd |

Vector

CMEQ \(<Vd>.<T>, <Vn>.<T>, <Vm>.<T>

```plaintext
text
integer d = UInt(Rd);
text
integer n = UInt(Rn);
text
integer m = UInt(Rm);
text
if size:Q == '110' then UNDEFINED;
text
integer esize = 8 << if size:Q == '110' then ReservedValue();
text
integer esize = 8 << UInt(size);
text
integer datasize = if Q == '1' then 128 else 64;
text
integer elements = datasize DIV esize;
text
boolean and_test = (U == '0');
```

Assembler Symbols

\(<V>\) Is a width specifier, encoded in “size”:

<table>
<thead>
<tr>
<th>size</th>
<th>(&lt;V&gt;)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0x</td>
<td>RESERVED</td>
</tr>
<tr>
<td>10</td>
<td>RESERVED</td>
</tr>
<tr>
<td>11</td>
<td>D</td>
</tr>
</tbody>
</table>

\(<d>\) Is the number of the SIMD&FP destination register, in the "Rd" field.
Is the number of the first SIMD&FP source register, encoded in the "Rn" field.

Is the number of the second SIMD&FP source register, encoded in the "Rm" field.

Is the name of the SIMD&FP destination register, encoded in the "Rd" field.

Is an arrangement specifier, encoded in “size:Q”:

\[
\begin{array}{c|c|c}
\text{size} & Q & <T> \\
00 & 0 & 8B \\
00 & 1 & 16B \\
01 & 0 & 4H \\
01 & 1 & 8H \\
10 & 0 & 2S \\
10 & 1 & 4S \\
11 & 0 & \text{RESERVED} \\
11 & 1 & 2D \\
\end{array}
\]

Is the name of the first SIMD&FP source register, encoded in the "Rn" field.

Is the name of the second SIMD&FP source register, encoded in the "Rm" field.

Operation

```plaintext
CheckFPAdvSIMDEnabled64();
bits(datasize) operand1 = V[n];
bits(datasize) operand2 = V[m];
bits(datasize) result;
bits(esize) element1;
bits(esize) element2;
boolean test_passed;
for e = 0 to elements-1
    element1 = Elem[operand1, e, esize];
    element2 = Elem[operand2, e, esize];
    if and_test then
        test_passed = !IsZero(element1 AND element2);
    else
        test_passed = (element1 == element2);
    Elem[result, e, esize] = if test_passed then Ones() else Zeros();
V[d] = result;
```

Operational information

If PSTATE.DIT is 1:

- The execution time of this instruction is independent of:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.

- The response of this instruction to asynchronous exceptions does not vary based on:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
CMEQ (zero)

Compare bitwise Equal to zero (vector). This instruction reads each vector element in the source SIMD&FP register and if the value is equal to zero sets every bit of the corresponding vector element in the destination SIMD&FP register to one, otherwise sets every bit of the corresponding vector element in the destination SIMD&FP register to zero.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

It has encodings from 2 classes: Scalar and Vector

Scalar

```
CMEQ <V><d>, <V><n>, #0
```

```plaintext
integer d = UInt(Rd);
integer n = UInt(Rn);

if size != '11' then UNDEFINED;
integer esize = 8 << if size != '11' then ReservedValue();
integer esize = 8 << UInt(size);
integer datasize = esize;
integer elements = 1;

CompareOp comparison;
```
```plaintext
case op:U of
  when '00' comparison = CompareOp_GT;
  when '01' comparison = CompareOp_GE;
  when '10' comparison = CompareOp_EQ;
  when '11' comparison = CompareOp_LE;
```
```
Vector

```
CMEQ <Vd>.<T>, <Vn>.<T>, #0
```

```plaintext
integer d = UInt(Rd);
integer n = UInt(Rn);

if size:Q == '110' then UNDEFINED;
integer esize = 8 << if size:Q == '110' then ReservedValue();
integer esize = 8 << UInt(size);
integer datasize = if Q == '1' then 128 else 64;
integer elements = datasize DIV esize;

CompareOp comparison;
```
```plaintext
case op:U of
  when '00' comparison = CompareOp_GT;
  when '01' comparison = CompareOp_GE;
  when '10' comparison = CompareOp_EQ;
  when '11' comparison = CompareOp_LE;
```
Assembler Symbols

<V> Is a width specifier, encoded in “size”:

<table>
<thead>
<tr>
<th>size</th>
<th>&lt;V&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0x</td>
<td>RESERVED</td>
</tr>
<tr>
<td>10</td>
<td>RESERVED</td>
</tr>
<tr>
<td>11</td>
<td>D</td>
</tr>
</tbody>
</table>

<d> Is the number of the SIMD&FP destination register, encoded in the "Rd" field.

<n> Is the number of the SIMD&FP source register, encoded in the "Rn" field.

<Vd> Is the name of the SIMD&FP destination register, encoded in the "Rd" field.

<T> Is an arrangement specifier, encoded in “size:Q”:

<table>
<thead>
<tr>
<th>size</th>
<th>Q</th>
<th>&lt;T&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>0</td>
<td>8B</td>
</tr>
<tr>
<td>00</td>
<td>1</td>
<td>16B</td>
</tr>
<tr>
<td>01</td>
<td>0</td>
<td>4H</td>
</tr>
<tr>
<td>01</td>
<td>1</td>
<td>8H</td>
</tr>
<tr>
<td>10</td>
<td>0</td>
<td>2S</td>
</tr>
<tr>
<td>10</td>
<td>1</td>
<td>4S</td>
</tr>
<tr>
<td>11</td>
<td>0</td>
<td>RESERVED</td>
</tr>
<tr>
<td>11</td>
<td>1</td>
<td>2D</td>
</tr>
</tbody>
</table>

<Vn> Is the name of the SIMD&FP source register, encoded in the "Rn" field.

Operation

```
CheckFPAdvSIMDEnabled64();
bits(datasize) operand = V[n];
bits(datasize) result;
integer element;
boolean test_passed;
for e = 0 to elements-1
    element = SInt(Elem[operand, e, esize]);
    case comparison of
    when CompareOp_GT test_passed = element > 0;
    when CompareOp_GE test_passed = element >= 0;
    when CompareOp_EQ test_passed = element == 0;
    when CompareOp_LE test_passed = element <= 0;
    when CompareOp_LT test_passed = element < 0;
    Elem[result, e, esize] = if test_passed then Ones() else Zeros();
V[d] = result;
```

Operational information

If PSTATE.DIT is 1:

- The execution time of this instruction is independent of:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
- The response of this instruction to asynchronous exceptions does not vary based on:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
CMGE (register)

Compare signed Greater than or Equal (vector). This instruction compares each vector element in the first source SIMD&FP register with the corresponding vector element in the second source SIMD&FP register and if the first signed integer value is greater than or equal to the second signed integer value sets every bit of the corresponding vector element in the destination SIMD&FP register to one, otherwise sets every bit of the corresponding vector element in the destination SIMD&FP register to zero.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

It has encodings from 2 classes: Scalar and Vector

**Scalar**

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9  | 8  | 7  | 6  | 5  | 4  | 3  | 2  | 1  | 0  |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0  | 1  | 0  | 1  | 1  | 1  | 1  | 0  | size| 1  | Rm | 0  | 0  | 1  | 1  | 1  | 1  | Rn |   | Rd |
| U  | eq |

**Vector**

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9  | 8  | 7  | 6  | 5  | 4  | 3  | 2  | 1  | 0  |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0  | Q  | 0  | 0  | 1  | 1  | 1  | 0  | size| 1  | Rm | 0  | 0  | 1  | 1  | 1  | 1  | Rn |   | Rd |
| U  | eq |

**Assembler Symbols**

<

Is a width specifier, encoded in "size":

```plaintext
integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rm);
if size != '11' then UNDEFINED;
integer esize = 8 << if size = '11' then ReservedValue() else UInt(size);
integer datasize = esize;
integer elements = 1;
boolean unsigned = (U == '1');
boolean cmp_eq = (eq == '1');
```

```plaintext
integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rm);
if size:Q == '110' then UNDEFINED;
integer esize = 8 << if size:Q = '110' then ReservedValue() else UInt(size);
integer datasize = if Q == '1' then 128 else 64;
integer elements = datasize DIV esize;
boolean unsigned = (U == '1');
boolean cmp_eq = (eq == '1');
```
Is the number of the SIMD&FP destination register, in the "Rd" field.

<n>
Is the number of the first SIMD&FP source register, encoded in the "Rn" field.

<m>
Is the number of the second SIMD&FP source register, encoded in the "Rm" field.

<Vd>
Is the name of the SIMD&FP destination register, encoded in the "Rd" field.

<T>
Is an arrangement specifier, encoded in “size:Q”:

<table>
<thead>
<tr>
<th>size</th>
<th>Q</th>
<th>&lt;T&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0x</td>
<td>0</td>
<td>8B</td>
</tr>
<tr>
<td>0x</td>
<td>1</td>
<td>16B</td>
</tr>
<tr>
<td>01</td>
<td>0</td>
<td>4H</td>
</tr>
<tr>
<td>01</td>
<td>1</td>
<td>8H</td>
</tr>
<tr>
<td>10</td>
<td>0</td>
<td>2S</td>
</tr>
<tr>
<td>10</td>
<td>1</td>
<td>4S</td>
</tr>
<tr>
<td>11</td>
<td>0</td>
<td>RESERVED</td>
</tr>
<tr>
<td>11</td>
<td>1</td>
<td>2D</td>
</tr>
</tbody>
</table>

<Vn>
Is the name of the first SIMD&FP source register, encoded in the "Rn" field.

<Vm>
Is the name of the second SIMD&FP source register, encoded in the "Rm" field.

Operation

```c
CheckFPAdvSIMDEnabled64();
bits(datasize) operand1 = V[n];
bits(datasize) operand2 = V[m];
bits(datasize) result;
integer element1;
integer element2;
boolean test_passed;
for e = 0 to elements-1
    element1 = Int(Elem[operand1, e, esize], unsigned);
    element2 = Int(Elem[operand2, e, esize], unsigned);
    test_passed = if cmp_eq then element1 >= element2 else element1 > element2;
    Elem[result, e, esize] = if test_passed then Ones() else Zeros();
V[d] = result;
```

Operational information

If PSTATE.DIT is 1:

- The execution time of this instruction is independent of:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
- The response of this instruction to asynchronous exceptions does not vary based on:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
CMGE (zero)

Compare signed Greater than or Equal to zero (vector). This instruction reads each vector element in the source SIMD&FP register and if the signed integer value is greater than or equal to zero sets every bit of the corresponding vector element in the destination SIMD&FP register to one, otherwise sets every bit of the corresponding vector element in the destination SIMD&FP register to zero.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

It has encodings from 2 classes: Scalar and Vector

Scalar

```plaintext
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 |  9 |  8 |  7 |  6 |  5 |  4 |  3 |  2 |  1 |  0 |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
|    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
|    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
|    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
```

CMGE <V>d, <V>n>, #0

```plaintext
integer d = UInt(Rd);
integer n = UInt(Rn);

if size != '11' then UNDEFINED;
integer esize = 8 << if size != '11' then ReservedValue();
integer esize = 8 << UInt(size);
integer datasize = esize;
integer elements = 1;

CompareOp comparison;
```

```plaintext
case op:U of
  when '00' comparison = CompareOp_GT;
  when '01' comparison = CompareOp_GE;
  when '10' comparison = CompareOp_EQ;
  when '11' comparison = CompareOp_LE;
```

Vector

```plaintext
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 |  9 |  8 |  7 |  6 |  5 |  4 |  3 |  2 |  1 |  0 |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
|    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| Q  | 1  | 0  | 1  | 1  | 1  | 0  |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
|    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
|    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
```

CMGE <Vd>,<T>, <Vn>,<T>, #0

```plaintext
integer d = UInt(Rd);
integer n = UInt(Rn);

if size:Q == '110' then UNDEFINED;
integer esize = 8 << if size:Q == '110' then ReservedValue();
integer esize = 8 << UInt(size);
integer datasize = if Q == '1' then 128 else 64;
integer elements = datasize DIV esize;

CompareOp comparison;
```

```plaintext
case op:U of
  when '00' comparison = CompareOp_GT;
  when '01' comparison = CompareOp_GE;
  when '10' comparison = CompareOp_EQ;
  when '11' comparison = CompareOp_LE;
```
Assembler Symbols

- **<V>** Is a width specifier, encoded in "size":
  
<table>
<thead>
<tr>
<th>size</th>
<th>&lt;V&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0x</td>
<td>RESERVED</td>
</tr>
<tr>
<td>10</td>
<td>RESERVED</td>
</tr>
<tr>
<td>11</td>
<td>D</td>
</tr>
</tbody>
</table>

- **<d>** Is the number of the SIMD&FP destination register, encoded in the "Rd" field.

- **<n>** Is the number of the SIMD&FP source register, encoded in the "Rn" field.

- **<Vd>** Is the name of the SIMD&FP destination register, encoded in the "Rd" field.

- **<T>** Is an arrangement specifier, encoded in “size:Q”:

<table>
<thead>
<tr>
<th>size</th>
<th>Q</th>
<th>&lt;T&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>0</td>
<td>8B</td>
</tr>
<tr>
<td>00</td>
<td>1</td>
<td>16B</td>
</tr>
<tr>
<td>01</td>
<td>0</td>
<td>4H</td>
</tr>
<tr>
<td>01</td>
<td>1</td>
<td>8H</td>
</tr>
<tr>
<td>10</td>
<td>0</td>
<td>2S</td>
</tr>
<tr>
<td>10</td>
<td>1</td>
<td>4S</td>
</tr>
<tr>
<td>11</td>
<td>0</td>
<td>RESERVED</td>
</tr>
<tr>
<td>11</td>
<td>1</td>
<td>2D</td>
</tr>
</tbody>
</table>

- **<Vn>** Is the name of the SIMD&FP source register, encoded in the "Rn" field.

Operation

```c
CheckFPAdvSIMDEnabled64();
bits(datasize) operand = V[n];
bits(datasize) result;
integer element;
boolean test_passed;
for e = 0 to elements-1
  element = SInt(Elem[operand, e, esize]);
  case comparison of
      when CompareOp_GT test_passed = element > 0;
      when CompareOp_GE test_passed = element >= 0;
      when CompareOp_EQ test_passed = element == 0;
      when CompareOp_LE test_passed = element <= 0;
      when CompareOp_LT test_passed = element < 0;
      Elem[result, e, esize] = if test_passed then Ones() else Zeros();
V[d] = result;
```

Operational information

- **If PSTATE.DIT is 1:**
  - The execution time of this instruction is independent of:
    - The values of the data supplied in any of its registers.
    - The values of the NZCV flags.
  - The response of this instruction to asynchronous exceptions does not vary based on:
    - The values of the data supplied in any of its registers.
    - The values of the NZCV flags.
CMGT (register)

Compare signed Greater than (vector). This instruction compares each vector element in the first source SIMD&FP register with the corresponding vector element in the second source SIMD&FP register and if the first signed integer value is greater than the second signed integer value sets every bit of the corresponding vector element in the destination SIMD&FP register to one, otherwise sets every bit of the corresponding vector element in the destination SIMD&FP register to zero.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

It has encodings from 2 classes: Scalar and Vector

Scalar

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9  | 8  | 7  | 6  | 5  | 4  | 3  | 2  | 1  | 0  |  
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0  | 1  | 0  | 1  | 1  | 1  | 0  | size| 1  | Rm | 0  | 0  | 1  | 1  | 0  | 1  | Rd |  
|    |    |    |    |    |    |    | U  |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
|    |    |    |    |    |    |    | eq |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |

Scalar

CMGT <V<d>, <V<n>, <V<m

```
integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rm);
if size != '11' then UNDEFINED;
integer esize = 8 << if size != '11' then ReservedValue() ;
integer datasize = esize;
integer elements = 1;
boolean unsigned = (U == '1');
boolean cmp_eq = (eq == '1');
```

Vector

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9  | 8  | 7  | 6  | 5  | 4  | 3  | 2  | 1  | 0  |  
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0  | Q | 0  | 0  | 1  | 1  | 1  | 0  | size| 1  | Rm | 0  | 0  | 1  | 1  | 0  | 1  | Rd |  
|    |    |    |    |    |    |    |    | U  |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
|    |    |    |    |    |    |    | eq |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |

Vector

CMGT <Vd>.<T>, <Vn>.<T>, <Vm>.<T

```
integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rm);
if size[Q == '110' then UNDEFINED;
integer esize = 8 << if size[Q == '110' then ReservedValue();
integer esize = 8 << if Q == '1' then 128 else 64;
integer elements = datasize DIV esize;
boolean unsigned = (U == '1');
boolean cmp_eq = (eq == '1');
```

Assembler Symbols

<V> Is a width specifier, encoded in "size":

<table>
<thead>
<tr>
<th>size</th>
<th>&lt;V&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0x</td>
<td>RESERVED</td>
</tr>
<tr>
<td>10</td>
<td>RESERVED</td>
</tr>
<tr>
<td>11</td>
<td>D</td>
</tr>
</tbody>
</table>

<d>
Is the number of the SIMD&FP destination register, in the "Rd" field.

<n>
Is the number of the first SIMD&FP source register, encoded in the "Rn" field.

<m>
Is the number of the second SIMD&FP source register, encoded in the "Rm" field.

<Vd>
Is the name of the SIMD&FP destination register, encoded in the "Rd" field.

<T>
Is an arrangement specifier, encoded in “size:Q”:

<table>
<thead>
<tr>
<th>size</th>
<th>Q</th>
<th>&lt;T&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>0</td>
<td>8B</td>
</tr>
<tr>
<td>00</td>
<td>1</td>
<td>16B</td>
</tr>
<tr>
<td>01</td>
<td>0</td>
<td>4H</td>
</tr>
<tr>
<td>01</td>
<td>1</td>
<td>8H</td>
</tr>
<tr>
<td>10</td>
<td>0</td>
<td>2S</td>
</tr>
<tr>
<td>10</td>
<td>1</td>
<td>4S</td>
</tr>
<tr>
<td>11</td>
<td>0</td>
<td>RESERVED</td>
</tr>
<tr>
<td>11</td>
<td>1</td>
<td>2D</td>
</tr>
</tbody>
</table>

<Vn>
Is the name of the first SIMD&FP source register, encoded in the "Rn" field.

<Vm>
Is the name of the second SIMD&FP source register, encoded in the "Rm" field.

**Operation**

```c
CheckFPAdvSIMDEnabled64();

bits(datasize) operand1 = V[n];
bits(datasize) operand2 = V[m];
bits(datasize) result;
integer element1;
integer element2;
boolean test_passed;

for e = 0 to elements-1
    element1 = Int(Elem[operand1, e, esize], unsigned);
    element2 = Int(Elem[operand2, e, esize], unsigned);
    test_passed = if cmp_eq then element1 >= element2 else element1 > element2;
    Elem[result, e, esize] = if test_passed then Ones() else Zeros();

V[d] = result;
```

**Operational information**

If PSTATE.DIT is 1:

- The execution time of this instruction is independent of:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
- The response of this instruction to asynchronous exceptions does not vary based on:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
CMGT (zero)

Compare signed Greater than zero (vector). This instruction reads each vector element in the source SIMD&FP register and if the signed integer value is greater than zero sets every bit of the corresponding vector element in the destination SIMD&FP register to one, otherwise sets every bit of the corresponding vector element in the destination SIMD&FP register to zero.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

It has encodings from 2 classes: Scalar and Vector

Scalar

CMGT \langle V \rangle ; <d>, \langle V \rangle ; <n>, \#0

integer d = \text{UInt}(Rd);
integer n = \text{UInt}(Rn);

if size != '11' then UNDEFINED;
integer esize = 8 << if size != '11' then ReservedValue();
integer esize = 8 << \text{UInt}(size);
integer datasize = esize;
integer elements = 1;

\text{CompareOp} comparison;
case op:U of
when '00' comparison = \text{CompareOp GT};
when '01' comparison = \text{CompareOp GE};
when '10' comparison = \text{CompareOp EQ};
when '11' comparison = \text{CompareOp LE};

Vector

CMGT \langle Vd\rangle .<T>, \langle Vn\rangle .<T>, \#0

integer d = \text{UInt}(Rd);
integer n = \text{UInt}(Rn);

if size:Q == '110' then UNDEFINED;
integer esize = 8 << if size:Q == '110' then ReservedValue();
integer esize = 8 << \text{UInt}(size);
integer datasize = if Q == '1' then 128 else 64;
integer elements = datasize DIV esize;

\text{CompareOp} comparison;
case op:U of
when '00' comparison = \text{CompareOp GT};
when '01' comparison = \text{CompareOp GE};
when '10' comparison = \text{CompareOp EQ};
when '11' comparison = \text{CompareOp LE};
Assembler Symbols

<V> Is a width specifier, encoded in "size":

<table>
<thead>
<tr>
<th>size</th>
<th>&lt;V&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0x</td>
<td>RESERVED</td>
</tr>
<tr>
<td>10</td>
<td>RESERVED</td>
</tr>
<tr>
<td>11</td>
<td>D</td>
</tr>
</tbody>
</table>

<d> Is the number of the SIMD&FP destination register, encoded in the "Rd" field.

<n> Is the number of the SIMD&FP source register, encoded in the "Rn" field.

<Vd> Is the name of the SIMD&FP destination register, encoded in the "Rd" field.

<T> Is an arrangement specifier, encoded in “size:Q”:

<table>
<thead>
<tr>
<th>size</th>
<th>Q</th>
<th>&lt;T&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>0</td>
<td>8B</td>
</tr>
<tr>
<td>00</td>
<td>1</td>
<td>16B</td>
</tr>
<tr>
<td>01</td>
<td>0</td>
<td>4H</td>
</tr>
<tr>
<td>01</td>
<td>1</td>
<td>8H</td>
</tr>
<tr>
<td>10</td>
<td>0</td>
<td>2S</td>
</tr>
<tr>
<td>10</td>
<td>1</td>
<td>4S</td>
</tr>
<tr>
<td>11</td>
<td>0</td>
<td>RESERVED</td>
</tr>
<tr>
<td>11</td>
<td>1</td>
<td>2D</td>
</tr>
</tbody>
</table>

<Vn> Is the name of the SIMD&FP source register, encoded in the "Rn" field.

Operation

```asm
CheckFPAdvSIMDEnabled64();
bits(datasize) operand = V[n];
bits(datasize) result;
exteger element;
boolean test_passed;
for e = 0 to elements-1
    element = SInt(Elem[operand, e, esize]);
    case comparison of
        when CompareOp_GT test_passed = element > 0;
        when CompareOp_GE test_passed = element >= 0;
        when CompareOp_EQ test_passed = element == 0;
        when CompareOp_LE test_passed = element <= 0;
        when CompareOp_LT test_passed = element < 0;
        Elem[result, e, esize] = if test_passed then Ones() else Zeros();
V[d] = result;
```

Operational information

If PSTATE.DIT is 1:

- The execution time of this instruction is independent of:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
- The response of this instruction to asynchronous exceptions does not vary based on:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
CMHI (register)

Compare unsigned Higher (vector). This instruction compares each vector element in the first source SIMD&FP register with the corresponding vector element in the second source SIMD&FP register and if the first unsigned integer value is greater than the second unsigned integer value sets every bit of the corresponding vector element in the destination SIMD&FP register to one, otherwise sets every bit of the corresponding vector element in the destination SIMD&FP register to zero.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

It has encodings from 2 classes: **Scalar** and **Vector**

### Scalar

<table>
<thead>
<tr>
<th>31</th>
<th>30</th>
<th>29</th>
<th>28</th>
<th>27</th>
<th>26</th>
<th>25</th>
<th>24</th>
<th>23</th>
<th>22</th>
<th>21</th>
<th>20</th>
<th>19</th>
<th>18</th>
<th>17</th>
<th>16</th>
<th>15</th>
<th>14</th>
<th>13</th>
<th>12</th>
<th>11</th>
<th>10</th>
<th>9</th>
<th>8</th>
<th>7</th>
<th>6</th>
<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
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<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>size</td>
<td>1</td>
<td>Rm</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>Rn</td>
<td>Rd</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>U</td>
<td>eq</td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Scalar**

CMHI <V><d>, <V><n>, <V><m>

```plaintext
integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rm);
if size != '11' then UNDEFINED;
integer esize = 8 << if size != '11' then ReservedValue();
integer esize = 8 << UInt(size);
integer datasize = esize;
integer elements = 1;
boolean unsigned = (U == '1');
boolean cmp_eq = (eq == '1');
```

### Vector

<table>
<thead>
<tr>
<th>31</th>
<th>30</th>
<th>29</th>
<th>28</th>
<th>27</th>
<th>26</th>
<th>25</th>
<th>24</th>
<th>23</th>
<th>22</th>
<th>21</th>
<th>20</th>
<th>19</th>
<th>18</th>
<th>17</th>
<th>16</th>
<th>15</th>
<th>14</th>
<th>13</th>
<th>12</th>
<th>11</th>
<th>10</th>
<th>9</th>
<th>8</th>
<th>7</th>
<th>6</th>
<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Q</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>size</td>
<td>1</td>
<td>Rm</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>Rn</td>
<td>Rd</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>U</td>
<td>eq</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Vector**

CMHI <Vd>.<T>, <Vn>.<T>, <Vm>.<T>

```plaintext
integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rm);
if size:Q == '11' then UNDEFINED;
integer esize = 8 << if size:Q == '11' then ReservedValue();
integer esize = 8 << UInt(size);
integer datasize = if Q == '1' then 128 else 64;
integer elements = datasize DIV esize;
boolean unsigned = (U == '1');
boolean cmp_eq = (eq == '1');
```

**Assembler Symbols**

`<V>` Is a width specifier, encoded in "size":

---

CMHI (register)
Is the number of the SIMD&FP destination register, in the "Rd" field.

<n>
Is the number of the first SIMD&FP source register, encoded in the "Rn" field.

<m>
Is the number of the second SIMD&FP source register, encoded in the "Rm" field.

<Vd>
Is the name of the SIMD&FP destination register, encoded in the "Rd" field.

<T>
Is an arrangement specifier, encoded in “size:Q”:

<table>
<thead>
<tr>
<th>size</th>
<th>&lt;V&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0x</td>
<td>RESERVED</td>
</tr>
<tr>
<td>10</td>
<td>RESERVED</td>
</tr>
<tr>
<td>11</td>
<td>D</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>size</th>
<th>Q</th>
<th>&lt;T&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>0</td>
<td>8B</td>
</tr>
<tr>
<td>00</td>
<td>1</td>
<td>16B</td>
</tr>
<tr>
<td>01</td>
<td>0</td>
<td>4H</td>
</tr>
<tr>
<td>01</td>
<td>1</td>
<td>8H</td>
</tr>
<tr>
<td>10</td>
<td>0</td>
<td>2S</td>
</tr>
<tr>
<td>10</td>
<td>1</td>
<td>4S</td>
</tr>
<tr>
<td>11</td>
<td>0</td>
<td>RESERVED</td>
</tr>
<tr>
<td>11</td>
<td>1</td>
<td>2D</td>
</tr>
</tbody>
</table>

<Vn>
Is the name of the first SIMD&FP source register, encoded in the "Rn" field.

<Vm>
Is the name of the second SIMD&FP source register, encoded in the "Rm" field.

Operation

```c
CheckFPAdvSIMDEnabled64();
bits(datasize) operand1 = V[n];
bzits(datasize) operand2 = V[m];
bzits(datasize) result;
integer element1;
integer element2;
boolean test_passed;
for e = 0 to elements-1
    element1 = Int(Elem[operand1, e, esize], unsigned);
    element2 = Int(Elem[operand2, e, esize], unsigned);
    test_passed = if cmp_eq then element1 >= element2 else element1 > element2;
    Elem[result, e, esize] = if test_passed then Ones() else Zeros();
V[d] = result;
```

Operational information

If PSTATE.DIT is 1:

- The execution time of this instruction is independent of:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.

- The response of this instruction to asynchronous exceptions does not vary based on:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
CMHS (register)

Compare unsigned Higher or Same (vector). This instruction compares each vector element in the first source SIMD&FP register with the corresponding vector element in the second source SIMD&FP register and if the first unsigned integer value is greater than or equal to the second unsigned integer value sets every bit of the corresponding vector element in the destination SIMD&FP register to one, otherwise sets every bit of the corresponding vector element in the destination SIMD&FP register to zero.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

It has encodings from 2 classes: **Scalar** and **Vector**

### Scalar

<table>
<thead>
<tr>
<th>31</th>
<th>30</th>
<th>29</th>
<th>28</th>
<th>27</th>
<th>26</th>
<th>25</th>
<th>24</th>
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<th>9</th>
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<th>7</th>
<th>6</th>
<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td>U</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>size</td>
<td>1</td>
<td>Rm</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>Rn</td>
<td>Rd</td>
<td>eq</td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**CMHS** `<V><d>`, `<V><n>`, `<V><m>`

```plaintext
integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rm);
if size != '11' then UNDEFINED;
integer esize = 8 << if size = '11' then ReservedValue() else UInt(size);
integer datasize = esize;
integer elements = 1;
boolean unsigned = (U == '1');
boolean cmp_eq = (eq == '1');
```

### Vector

<table>
<thead>
<tr>
<th>31</th>
<th>30</th>
<th>29</th>
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<th>27</th>
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<th>25</th>
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<th>7</th>
<th>6</th>
<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td>U</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>size</td>
<td>1</td>
<td>Rm</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>Rn</td>
<td>Rd</td>
<td>eq</td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**CMHS** `<Vd>.<T>`, `<Vn>.<T>`, `<Vm>.<T>`

```plaintext
integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rm);
if size:Q == '110' then UNDEFINED;
integer esize = 8 << if size:Q == '110' then ReservedValue() else UInt(size);
integer datasize = if Q == '1' then 128 else 64;
integer elements = datasize DIV esize;
boolean unsigned = (U == '1');
boolean cmp_eq = (eq == '1');
```

### Assembler Symbols

`<V>` Is a width specifier, encoded in "size":

<table>
<thead>
<tr>
<th>31</th>
<th>30</th>
<th>29</th>
<th>28</th>
<th>27</th>
<th>26</th>
<th>25</th>
<th>24</th>
<th>23</th>
<th>22</th>
<th>21</th>
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<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td>U</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>size</td>
<td>1</td>
<td>Rm</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>Rn</td>
<td>Rd</td>
<td>eq</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Is the number of the SIMD&FP destination register, in the "Rd" field.

<n>
Is the number of the first SIMD&FP source register, encoded in the "Rn" field.

<m>
Is the number of the second SIMD&FP source register, encoded in the "Rm" field.

<Vd>
Is the name of the SIMD&FP destination register, encoded in the "Rd" field.

<T>
Is an arrangement specifier, encoded in “size:Q”:

<table>
<thead>
<tr>
<th>size</th>
<th>Q</th>
<th>&lt;T&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>0</td>
<td>8B</td>
</tr>
<tr>
<td>00</td>
<td>1</td>
<td>16B</td>
</tr>
<tr>
<td>01</td>
<td>0</td>
<td>4H</td>
</tr>
<tr>
<td>01</td>
<td>1</td>
<td>8H</td>
</tr>
<tr>
<td>10</td>
<td>0</td>
<td>2S</td>
</tr>
<tr>
<td>10</td>
<td>1</td>
<td>4S</td>
</tr>
<tr>
<td>11</td>
<td>0</td>
<td>RESERVED</td>
</tr>
<tr>
<td>11</td>
<td>1</td>
<td>2D</td>
</tr>
</tbody>
</table>

<Vn>
Is the name of the first SIMD&FP source register, encoded in the "Rn" field.

<Vm>
Is the name of the second SIMD&FP source register, encoded in the "Rm" field.

Operation

```c
CheckFPAdvSIMDEnabled64();
bits(datasize) operand1 = V[n];
bias(datasize) operand2 = V[m];
bias(datasize) result;
integer element1;
integer element2;
boolean test_passed;
for e = 0 to elements-1
    element1 = Int(Elem[operand1, e, esize], unsigned);
    element2 = Int(Elem[operand2, e, esize], unsigned);
    test_passed = if cmp_eq then element1 >= element2 else element1 > element2;
    Elem[result, e, esize] = if test_passed then Ones() else Zeros();
V[d] = result;
```

Operational information

If PSTATE.DIT is 1:
- The execution time of this instruction is independent of:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
- The response of this instruction to asynchronous exceptions does not vary based on:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
CMLE (zero)

Compare signed Less than or Equal to zero (vector). This instruction reads each vector element in the source SIMD&FP register and if the signed integer value is less than or equal to zero sets every bit of the corresponding vector element in the destination SIMD&FP register to one, otherwise sets every bit of the corresponding vector element in the destination SIMD&FP register to zero.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

It has encodings from 2 classes: Scalar and Vector

Scalar

```
<table>
<thead>
<tr>
<th>31</th>
<th>30</th>
<th>29</th>
<th>28</th>
<th>27</th>
<th>26</th>
<th>25</th>
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<th>22</th>
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<th>8</th>
<th>7</th>
<th>6</th>
<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
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<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
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<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>Rn</td>
<td>Rd</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
```

```plaintext
U
op
```

Scalar

```plaintext
CMLE \langle V \rangle<d>, \langle V \rangle<n>, #0
```

```plaintext
integer d = UInt(Rd);
integer n = UInt(Rn);

if size != '11' then UNDEFINED;
integer esize = 8 << if size != '11' then ReservedValue();
integer esize = 8 << UInt(size);
integer datasize = esize;
integer elements = 1;

CompareOp comparison;
case op:U of
  when '00' comparison = CompareOp_GT;
  when '01' comparison = CompareOp_GE;
  when '10' comparison = CompareOp_EQ;
  when '11' comparison = CompareOp_LE;

Vector

```
<table>
<thead>
<tr>
<th>31</th>
<th>30</th>
<th>29</th>
<th>28</th>
<th>27</th>
<th>26</th>
<th>25</th>
<th>24</th>
<th>23</th>
<th>22</th>
<th>21</th>
<th>20</th>
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<th>9</th>
<th>8</th>
<th>7</th>
<th>6</th>
<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Q</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
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<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>Rn</td>
<td>Rd</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
```

```plaintext
U
op
```

Vector

```plaintext
CMLE \langle Vd\rangle.<T>, \langle Vn\rangle.<T>, #0
```

```plaintext
integer d = UInt(Rd);
integer n = UInt(Rn);

if size:Q == '110' then UNDEFINED;
integer esize = 8 << if size:Q == '110' then ReservedValue();
integer esize = 8 << UInt(size);
integer datasize = if Q == '1' then 128 else 64;
integer elements = datasize DIV esize;

CompareOp comparison;
case op:U of
  when '00' comparison = CompareOp_GT;
  when '01' comparison = CompareOp_GE;
  when '10' comparison = CompareOp_EQ;
  when '11' comparison = CompareOp_LE;
**Assembler Symbols**

- `<V>` is a width specifier, encoded in “size”:
  
<table>
<thead>
<tr>
<th>size</th>
<th><code>&lt;V&gt;</code></th>
</tr>
</thead>
<tbody>
<tr>
<td>0x</td>
<td>RESERVED</td>
</tr>
<tr>
<td>10</td>
<td>RESERVED</td>
</tr>
<tr>
<td>11</td>
<td>D</td>
</tr>
</tbody>
</table>

- `<d>` is the number of the SIMD&FP destination register, encoded in the "Rd" field.

- `<n>` is the number of the SIMD&FP source register, encoded in the "Rn" field.

- `<Vd>` is the name of the SIMD&FP destination register, encoded in the "Rd" field.

- `<T>` is an arrangement specifier, encoded in “size:Q”:

<table>
<thead>
<tr>
<th>size</th>
<th>Q</th>
<th><code>&lt;T&gt;</code></th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>0</td>
<td>8B</td>
</tr>
<tr>
<td>00</td>
<td>1</td>
<td>16B</td>
</tr>
<tr>
<td>01</td>
<td>0</td>
<td>4H</td>
</tr>
<tr>
<td>01</td>
<td>1</td>
<td>8H</td>
</tr>
<tr>
<td>10</td>
<td>0</td>
<td>2S</td>
</tr>
<tr>
<td>10</td>
<td>1</td>
<td>4S</td>
</tr>
<tr>
<td>11</td>
<td>0</td>
<td>RESERVED</td>
</tr>
<tr>
<td>11</td>
<td>1</td>
<td>2D</td>
</tr>
</tbody>
</table>

- `<Vn>` is the name of the SIMD&FP source register, encoded in the "Rn" field.

**Operation**

```c
CheckFPAdvSIMDEnabled64();
bits(datasize) operand = V[n];
bits(datasize) result;
integer element;
boolean test_passed;
for e = 0 to elements-1
  element = SInt(Elem[operand, e, esize]);
case comparison of
  when CompareOp_GT test_passed = element > 0;
  when CompareOp_GE test_passed = element >= 0;
  when CompareOp_EQ test_passed = element == 0;
  when CompareOp_LE test_passed = element <= 0;
  when CompareOp_LT test_passed = element < 0;
  Elem[result, e, esize] = if test_passed then Ones() else Zeros();
V[d] = result;
```

**Operational information**

If PSTATE.DIT is 1:

- The execution time of this instruction is independent of:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.

- The response of this instruction to asynchronous exceptions does not vary based on:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
CMLT (zero)

Compare signed Less than zero (vector). This instruction reads each vector element in the source SIMD&FP register and if the signed integer value is less than zero sets every bit of the corresponding vector element in the destination SIMD&FP register to one, otherwise sets every bit of the corresponding vector element in the destination SIMD&FP register to zero.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

It has encodings from 2 classes: Scalar and Vector

Scalar

```
31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10  9  8  7  6  5  4  3  2  1  0
 0 1 0 1 1 1 1 0 size 1 0 0 0 0 0 1 1 0 1 0 1 0 0 | Rn | Rd
```

```
Scalar

CMLT <V><d>, <V><n>, #0

integer d = UInt(Rd);
integer n = UInt(Rn);

if size != '11' then UNDEFINED;
integer esize = 8 << if size != '11' then ReservedValue() else UInt(size);
integer datasize = esize;
integer elements = 1;
CompareOp comparison = CompareOp_LT;
```

Vector

```
31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10  9  8  7  6  5  4  3  2  1  0
 0 Q 0 0 1 1 1 0 size 1 0 0 0 0 0 1 1 0 1 0 1 0 0 | Rn | Rd
```

```
Vector

CMLT <Vd>.<T>, <Vn>.<T>, #0

integer d = UInt(Rd);
integer n = UInt(Rn);

if size:Q == '110' then UNDEFINED;
integer esize = 8 << if size:Q == '110' then ReservedValue() else UInt(size);
integer datasize = if Q == '1' then 128 else 64;
integer elements = datasize DIV esize;
CompareOp comparison = CompareOp_LT;
```

Assembler Symbols

- `<V>` Is a width specifier, encoded in “size”:

```
<table>
<thead>
<tr>
<th>size</th>
<th>&lt;V&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0x</td>
<td>RESERVED</td>
</tr>
<tr>
<td>10</td>
<td>RESERVED</td>
</tr>
<tr>
<td>11</td>
<td>D</td>
</tr>
</tbody>
</table>
```

- `<d>` Is the number of the SIMD&FP destination register, encoded in the "Rd" field.
Is the number of the SIMD&FP source register, encoded in the "Rn" field.

Is the name of the SIMD&FP destination register, encoded in the "Rd" field.

Is an arrangement specifier, encoded in "size-Q":

<table>
<thead>
<tr>
<th>size</th>
<th>Q</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>0</td>
</tr>
<tr>
<td>00</td>
<td>1</td>
</tr>
<tr>
<td>01</td>
<td>0</td>
</tr>
<tr>
<td>01</td>
<td>1</td>
</tr>
<tr>
<td>10</td>
<td>0</td>
</tr>
<tr>
<td>10</td>
<td>1</td>
</tr>
<tr>
<td>11</td>
<td>0</td>
</tr>
<tr>
<td>11</td>
<td>1</td>
</tr>
</tbody>
</table>

Is the name of the SIMD&FP source register, encoded in the "Rn" field.

Operation

```c
CheckFPAdvSIMDEnabled64();
bits(datasize) operand = V[n];
bias(datasize) result;
integer element;
boolean test_passed;
for e = 0 to elements-1
    element = SInt(Elem[operand, e, esize]);
case comparison of
    when CompareOp_GT test_passed = element > 0;
    when CompareOp_GE test_passed = element >= 0;
    when CompareOp_EQ test_passed = element == 0;
    when CompareOp_LE test_passed = element <= 0;
    when CompareOp_LT test_passed = element < 0;
    Elem[result, e, esize] = if test_passed then Ones() else Zeros();
V[d] = result;
```

Operational information

If PSTATE.DIT is 1:

- The execution time of this instruction is independent of:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
- The response of this instruction to asynchronous exceptions does not vary based on:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
CMN (immediate)

Compare Negative (immediate) adds a register value and an optionally-shifted immediate value. It updates the condition flags based on the result, and discards the result.

This is an alias of ADDS (immediate). This means:

- The encodings in this description are named to match the encodings of ADDS (immediate).
- The description of ADDS (immediate) gives the operational pseudocode for this instruction.

| sf | 31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0 |
|----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| op | S   | 1   | 0   | 0   | 0   | 1   | 1   | shift | imm12 | Rn | 1 | 1 | 1 | 1 | 1 | Rd |
| 32-bit (sf == 0) |

CMN \(<Wn|WSP>, \#<imm>{, <shift>}\)

is equivalent to

ADDS WZR, \(<Wn|WSP>, \#<imm>{, <shift}>\)

and is always the preferred disassembly.

64-bit (sf == 1)

CMN \(<Xn|SP>, \#<imm>{, <shift>}\)

is equivalent to

ADDS XZR, \(<Xn|SP>, \#<imm>{, <shift}>\)

and is always the preferred disassembly.

Assembler Symbols

\(<Wn|WSP>\) Is the 32-bit name of the source general-purpose register or stack pointer, encoded in the "Rn" field.

\(<Xn|SP>\) Is the 64-bit name of the source general-purpose register or stack pointer, encoded in the "Rn" field.

\(<imm>\) Is an unsigned immediate, in the range 0 to 4095, encoded in the "imm12" field.

\(<shift>\) Is the optional left shift to apply to the immediate, defaulting to LSL #0 and encoded in “shift<0>”:

<table>
<thead>
<tr>
<th>shift&lt;0&gt;</th>
<th>&lt;shift&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>000</td>
<td>LSL #0</td>
</tr>
<tr>
<td>001</td>
<td>LSL #12</td>
</tr>
<tr>
<td>1xx</td>
<td>reserved</td>
</tr>
</tbody>
</table>

Operation

The description of ADDS (immediate) gives the operational pseudocode for this instruction.

Operational information

If PSTATE.DIT is 1:

- The execution time of this instruction is independent of:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
- The response of this instruction to asynchronous exceptions does not vary based on:
  - The values of the data supplied in any of its registers.
The values of the NZCV flags.

Internal version only: isa v30.25 v29.05 AdvSIMD v27.01 v26.01 pseudocode v85-xml-00bet8 rc3-0355 ; Build timestamp: 2018-09-13T13 2018-06-16T04 045

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CMP (immediate)

Compare (immediate) subtracts an optionally-shifted immediate value from a register value. It updates the condition flags based on the result, and discards the result.

This is an alias of SUBS (immediate). This means:

- The encodings in this description are named to match the encodings of SUBS (immediate).
- The description of SUBS (immediate) gives the operational pseudocode for this instruction.

<table>
<thead>
<tr>
<th>sf</th>
<th>1</th>
<th>1</th>
<th>0</th>
<th>0</th>
<th>0</th>
<th>1</th>
<th>imm12</th>
<th>Rn</th>
<th>Rd</th>
</tr>
</thead>
<tbody>
<tr>
<td>op</td>
<td>S</td>
<td>shift</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

32-bit (sf == 0)

CMP <Wn|WSP>, #<imm>{, <shift>}

is equivalent to

SUBS WZR, <Wn|WSP>, #<imm>{, <shift>}

and is always the preferred disassembly.

64-bit (sf == 1)

CMP <Xn|SP>, #<imm>{, <shift>}

is equivalent to

SUBS XZR, <Xn|SP>, #<imm>{, <shift>}

and is always the preferred disassembly.

Assembler Symbols

- <Wn|WSP> is the 32-bit name of the source general-purpose register or stack pointer, encoded in the "Rn" field.
- <Xn|SP> is the 64-bit name of the source general-purpose register or stack pointer, encoded in the "Rn" field.
- <imm> is an unsigned immediate, in the range 0 to 4095, encoded in the "imm12" field.
- <shift> is the optional left shift to apply to the immediate, defaulting to LSL #0 and encoded in “shift<0>”:

<table>
<thead>
<tr>
<th>shift&lt;0&gt;</th>
<th>&lt;shift&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>LSL #0</td>
</tr>
<tr>
<td>1</td>
<td>LSL #12</td>
</tr>
<tr>
<td>1x</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

Operation

The description of SUBS (immediate) gives the operational pseudocode for this instruction.

Operational information

If PSTATE.DIT is 1:

- The execution time of this instruction is independent of:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
- The response of this instruction to asynchronous exceptions does not vary based on:
  - The values of the data supplied in any of its registers.
- The values of the NZCV flags.
CMPP

Compare with Tag subtracts the 56-bit address held in the second source register from the 56-bit address held in the first source register, updates the condition flags based on the result of the subtraction, and discards the result.

This is an alias of SUBPS. This means:

- The encodings in this description are named to match the encodings of SUBPS.
- The description of SUBPS gives the operational pseudocode for this instruction.

Integer

(ARMv8.5)

```
<p>| | | | | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>31</td>
<td>30</td>
<td>29</td>
<td>28</td>
<td>27</td>
<td>26</td>
<td>25</td>
<td>24</td>
</tr>
<tr>
<td>31</td>
<td>30</td>
<td>29</td>
<td>28</td>
<td>27</td>
<td>26</td>
<td>25</td>
<td>24</td>
</tr>
<tr>
<td>23</td>
<td>22</td>
<td>21</td>
<td>20</td>
<td>19</td>
<td>18</td>
<td>17</td>
<td>16</td>
</tr>
<tr>
<td>15</td>
<td>14</td>
<td>13</td>
<td>12</td>
<td>11</td>
<td>10</td>
<td>9</td>
<td>8</td>
</tr>
<tr>
<td>7</td>
<td>6</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>0</td>
</tr>
</tbody>
</table>
```

```
Xm | Xn | Xd
0  | 0  | 1
0  | 0  | 1
```

Integer

CMPP <Xn|SP>, <Xm|SP>

is equivalent to

SUBPS XZR, <Xn|SP>, <Xm|SP>

and is always the preferred disassembly.

Assembler Symbols

<Xn|SP> Is the 64-bit name of the first source general-purpose register or stack pointer, encoded in the "Xn" field.

<Xm|SP> Is the 64-bit name of the second general-purpose source register or stack pointer, encoded in the "Xm" field.

Operation

The description of SUBPS gives the operational pseudocode for this instruction.
CMTST

Compare bitwise Test bits nonzero (vector). This instruction reads each vector element in the first source SIMD&FP register, performs an AND with the corresponding vector element in the second source SIMD&FP register, and if the result is not zero, sets every bit of the corresponding vector element in the destination SIMD&FP register to one, otherwise sets every bit of the corresponding vector element in the destination SIMD&FP register to zero.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

It has encodings from 2 classes: Scalar and Vector

Scalar

<table>
<thead>
<tr>
<th>31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0</th>
<th>size</th>
<th>Rm</th>
<th>U</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 1 0 1 1 1 1 0</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

Scalar

CMTST <V><d>, <V><n>, <V><m>

integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rm);
if size != '11' then UNDEFINED;
integer esize = 8 << if size == '0' then ReservedValue() else UInt(size);
integer datasize = esize;
integer elements = 1;
boolean and_test = (U == '0');

Vector

<table>
<thead>
<tr>
<th>31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0</th>
<th>size</th>
<th>Rm</th>
<th>U</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 1 0 1 1 1 1 0</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

Vector

CMTST <Vd>.<T>, <Vn>.<T>, <Vm>.<T>

integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rm);
if size:Q == '110' then UNDEFINED;
integer esize = 8 << if size:Q == '110' then ReservedValue() else UInt(size);
integer datasize = if Q == '1' then 128 else 64;
integer elements = datasize DIV esize;
boolean and_test = (U == '0');

Assembler Symbols

<V> Is a width specifier, encoded in “size”:

<table>
<thead>
<tr>
<th>size</th>
<th>&lt;V&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0x</td>
<td>RESERVED</td>
</tr>
<tr>
<td>10</td>
<td>RESERVED</td>
</tr>
<tr>
<td>11</td>
<td>D</td>
</tr>
</tbody>
</table>

<d> Is the number of the SIMD&FP destination register, in the "Rd" field.
Is the number of the first SIMD&FP source register, encoded in the "Rn" field.

Is the number of the second SIMD&FP source register, encoded in the "Rm" field.

Is the name of the SIMD&FP destination register, encoded in the "Rd" field.

Is an arrangement specifier, encoded in "size:Q":

<table>
<thead>
<tr>
<th>size</th>
<th>Q</th>
<th>&lt;T&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>0</td>
<td>8B</td>
</tr>
<tr>
<td>00</td>
<td>1</td>
<td>16B</td>
</tr>
<tr>
<td>01</td>
<td>0</td>
<td>4H</td>
</tr>
<tr>
<td>01</td>
<td>1</td>
<td>8H</td>
</tr>
<tr>
<td>10</td>
<td>0</td>
<td>2S</td>
</tr>
<tr>
<td>10</td>
<td>1</td>
<td>4S</td>
</tr>
<tr>
<td>11</td>
<td>0</td>
<td>RESERVED</td>
</tr>
<tr>
<td>11</td>
<td>1</td>
<td>2D</td>
</tr>
</tbody>
</table>

Is the name of the first SIMD&FP source register, encoded in the "Rn" field.

Is the name of the second SIMD&FP source register, encoded in the "Rm" field.

```c
CheckFPAdvSIMDEnabled64();
bounds(datasize) operand1 = V[n];
bounds(datasize) operand2 = V[m];
bounds(datasize) result;
bounds(esize) element1;
bounds(esize) element2;
boolean test_passed;
for e = 0 to elements-1
    element1 = Elem[operand1, e, esize];
    element2 = Elem[operand2, e, esize];
    if and_test then
        test_passed = !IsZero(element1 AND element2);
    else
        test_passed = (element1 == element2);
    Elem[result, e, esize] = if test_passed then Ones() else Zeros();
V[d] = result;
```

Operational information

If PSTATE.DIT is 1:

- The execution time of this instruction is independent of:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
- The response of this instruction to asynchronous exceptions does not vary based on:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
CNT

Population Count per byte. This instruction counts the number of bits that have a value of one in each vector element in the source SIMD&FP register, places the result into a vector, and writes the vector to the destination SIMD&FP register.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

Vector

\[
\begin{array}{cccccccccccccc}
\hline
0 & Q & 0 & 0 & 1 & 1 & 1 & 0 & size & 1 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 1 & 1 & 0 & Rn & Rd
\end{array}
\]

Assembler Symbols

<Vd> Is the name of the SIMD&FP destination register, encoded in the "Rd" field.
<T> Is an arrangement specifier, encoded in “size:Q”:

<table>
<thead>
<tr>
<th>size</th>
<th>Q</th>
<th>&lt;T&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>0</td>
<td>8B</td>
</tr>
<tr>
<td>00</td>
<td>1</td>
<td>16B</td>
</tr>
<tr>
<td>01</td>
<td>x</td>
<td>RESERVED</td>
</tr>
<tr>
<td>1x</td>
<td>x</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

<Vn> Is the name of the SIMD&FP source register, encoded in the "Rn" field.

Operation

\[
\begin{align*}
\text{CheckFPAdvSIMDEnabled64}() ; \\
\text{bits}(\text{datasize}) \ \text{operand} = V[n] ; \\
\text{bits}(\text{datasize}) \ \text{result} ; \\
\text{integer} \ \text{count} ; \\
\text{for} \ e = 0 \ \text{to elements-1} \\
\quad \text{count} = \text{BitCount} (\text{Elem}[\text{operand}, e, \text{esize}]) ; \\
\quad \text{Elem}[\text{result}, e, \text{esize}] = \text{count}<\text{esize}-1:0> ; \\
\quad V[d] = \text{result} ;
\end{align*}
\]

Operational information

If PSTATE.DIT is 1:

- The execution time of this instruction is independent of:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
- The response of this instruction to asynchronous exceptions does not vary based on:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
Cache Prefetch Prediction Restriction by Context prevents cache allocation predictions, based on information gathered from earlier execution within a particular execution context, from allowing later speculative execution within that context to be observable through side-channels. For more information, see CPP RCTX, Cache Prefetch Prediction Restriction by Context.

This is an alias of SYS. This means:

- The encodings in this description are named to match the encodings of SYS.
- The description of SYS gives the operational pseudocode for this instruction.

<table>
<thead>
<tr>
<th>31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 1 0 1 0 1 0 0 0 0 1 0 1 1 0 1 1 1 0 0 1 1 1 1 1 1 1</td>
</tr>
<tr>
<td>L _op1_ CRn CRm _op2_</td>
</tr>
</tbody>
</table>

System

CPP RCTX, \_<Xt>\> is equivalent to

SYS \#3, c8, c3, \#7, \_<Xt>\>

and is always the preferred disassembly.

Assembler Symbols

\<Xt>\> Is the 64-bit name of the general-purpose source register, encoded in the "Rt" field.

Operation

The description of SYS gives the operational pseudocode for this instruction.
CRC32B, CRC32H, CRC32W, CRC32X

CRC32 checksum performs a cyclic redundancy check (CRC) calculation on a value held in a general-purpose register. It takes an input CRC value in the first source operand, performs a CRC on the input value in the second source operand, and returns the output CRC value. The second source operand can be 8, 16, 32, or 64 bits. To align with common usage, the bit order of the values is reversed as part of the operation, and the polynomial 0x04C11DB7 is used for the CRC calculation.

In ARMv8-A, this is an **OPTIONAL** instruction, and in ARMv8.1 it is mandatory for all implementations to implement it.

**ID_AA64ISAR0_EL1** indicates whether this instruction is supported.

<table>
<thead>
<tr>
<th>sf</th>
<th>0</th>
<th>1</th>
<th>1</th>
<th>0</th>
<th>0</th>
<th>1</th>
<th>1</th>
<th>0</th>
<th>Rm</th>
<th>0</th>
<th>1</th>
<th>0</th>
<th>0</th>
<th>sz</th>
<th>Rn</th>
<th>Rd</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**CRC32B (sf == 0 & sz == 00)**

CRC32B `<Wd>`, `<Wn>`, `<Wm>`

**CRC32H (sf == 0 & sz == 01)**

CRC32H `<Wd>`, `<Wn>`, `<Wm>`

**CRC32W (sf == 0 & sz == 10)**

CRC32W `<Wd>`, `<Wn>`, `<Wm>`

**CRC32X (sf == 1 & sz == 11)**

CRC32X `<Wd>`, `<Wn>`, `<Xm>`

```java
if !HaveCRCExt() then UNDEFINED;
integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rm);
if sf == '1' && sz != '11' then UnallocatedEncoding();
if sf == '0' && sz == '11' then UnallocatedEncoding(Rm);
if sf == '1' && sz != '11' then UNDEFINED;
if sf == '0' && sz == '11' then UNDEFINED;
integer size = 8 << UInt(sz);  // 2-bit size field -> 8, 16, 32, 64
boolean crc32c = (C == '1');
```

**Assembler Symbols**

- `<Wd>` Is the 32-bit name of the general-purpose accumulator output register, encoded in the "Rd" field.
- `<Wn>` Is the 32-bit name of the general-purpose accumulator input register, encoded in the "Rn" field.
- `<Xm>` Is the 64-bit name of the general-purpose data source register, encoded in the "Rm" field.
- `<Wm>` Is the 32-bit name of the general-purpose data source register, encoded in the "Rm" field.
Operation

\[
\text{bits}(32) \quad \text{acc} = X[n]; \quad \text{// accumulator}
\]
\[
\text{bits}(\text{size}) \quad \text{val} = X[m]; \quad \text{// input value}
\]
\[
\text{bits}(32) \quad \text{poly} = \begin{cases} 0x1EDC6F41 & \text{if crc32c} \\ 0x04C11DB7 & \text{else} \end{cases} \langle 31:0 \rangle;
\]
\[
\text{bits}(32+\text{size}) \quad \text{tempacc} = \text{BitReverse}(\text{acc}) : \text{Zeros}(\text{size});
\]
\[
\text{bits}(\text{size}+32) \quad \text{tempval} = \text{BitReverse}(\text{val}) : \text{Zeros}(32);
\]

// Poly32Mod2 on a bitstring does a polynomial Modulus over \(\{0,1\}\) operation
\[
X[d] = \text{BitReverse}(\text{Poly32Mod2}(\text{tempacc EOR tempval}, \text{poly}));
\]

Operational information

If PSTATE.DIT is 1:

- The execution time of this instruction is independent of:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
- The response of this instruction to asynchronous exceptions does not vary based on:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
CRC32CB, CRC32CH, CRC32CW, CRC32CX

CRC32 checksum performs a cyclic redundancy check (CRC) calculation on a value held in a general-purpose register. It takes an input CRC value in the first source operand, performs a CRC on the input value in the second source operand, and returns the output CRC value. The second source operand can be 8, 16, 32, or 64 bits. To align with common usage, the bit order of the values is reversed as part of the operation, and the polynomial 0x1EDC6F41 is used for the CRC calculation.

In ARMv8-A, this is an OPTIONAL instruction, and in ARMv8.1 it is mandatory for all implementations to implement it.

ID_AA64ISAR0_EL1.CRC32 indicates whether this instruction is supported.

### Assembler Symbols

- `<Wd>`: Is the 32-bit name of the general-purpose accumulator output register, encoded in the "Rd" field.
- `<Wn>`: Is the 32-bit name of the general-purpose accumulator input register, encoded in the "Rn" field.
- `<Xm>`: Is the 64-bit name of the general-purpose data source register, encoded in the "Rm" field.
- `<Wm>`: Is the 32-bit name of the general-purpose data source register, encoded in the "Rm" field.

```markdown
<table>
<thead>
<tr>
<th>sf</th>
<th>0</th>
<th>1</th>
<th>1</th>
<th>0</th>
<th>1</th>
<th>1</th>
<th>1</th>
<th>Rm</th>
<th>0</th>
<th>1</th>
<th>0</th>
<th>1</th>
<th>sz</th>
<th>Rn</th>
<th>Rd</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

CRC32CB (sf == 0 & sz == 00)
CRC32CB `<Wd>`, `<Wn>`, `<Wm>`

CRC32CH (sf == 0 & sz == 01)
CRC32CH `<Wd>`, `<Wn>`, `<Wm>`

CRC32CW (sf == 0 & sz == 10)
CRC32CW `<Wd>`, `<Wn>`, `<Wm>`

CRC32CX (sf == 1 & sz == 11)
CRC32CX `<Wd>`, `<Wn>`, `<Xm>`

```python
if !HaveCRCExt() then UNDEFINED;
integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rm);
if sf == '1' && sz != '11' then UnallocatedEncoding();
if sf == '0' && sz == '11' then UnallocatedEncoding(Rm);
if sf == '0' && sz != '11' then UNDEFINED;
if sf == '1' && sz == '11' then UNDEFINED;
integer size = 8 << UInt(sz); // 2-bit size field -> 8, 16, 32, 64
boolean crc32c = (C == '1');
```
Operation

```
bits(32)  acc  = X[n];  // accumulator
bits(size) val  = X[m];  // input value
bits(32)  poly = {if crc32c then 0x1EDC6F41 else 0x04C11DB7}<31:0>;

bits(32+size) tempacc = BitReverse(acc) : Zeros(size);
bits(size+32)  tempval = BitReverse(val) : Zeros(32);

// Poly32Mod2 on a bitstring does a polynomial Modulus over (0,1) operation
X[d] = BitReverse(Poly32Mod2(tempacc EOR tempval, poly));
```

Operational information

If PSTATE.DIT is 1:
- The execution time of this instruction is independent of:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
- The response of this instruction to asynchronous exceptions does not vary based on:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
Consumption of Speculative Data Barrier is a memory barrier that controls speculative execution and data value prediction. No instruction other than branch instructions appearing in program order after the CSDB can be speculatively executed using the results of any:

- Data value predictions of any instructions.
- PSTATE.\{N,Z,C,V\} predictions of any instructions other than conditional branch instructions appearing in program order before the CSDB that have not been architecturally resolved.
- Predictions of SVE prediction state for any SVE instructions.

For purposes of the definition of CSDB, PSTATE.\{N,Z,C,V\} is not considered a data value. This definition permits:

- Control flow speculation before and after the CSDB.
- Speculative execution of conditional data processing instructions after the CSDB, unless they use the results of data value or PSTATE.\{N,Z,C,V\} predictions of instructions appearing in program order before the CSDB that have not been architecturally resolved.

```plaintext
31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
1 1 0 1 0 1 0 0 0 1 1 0 0 1 0 0 0 1 0 1 0 0 0 1 1 1 1

CRm   op2
```

System

```plaintext
SystemHintOp op;

case CRm:op2 of
  when '0000 000' op = SystemHintOp_NOP;
  when '0000 001' op = SystemHintOp_YIELD;
  when '0000 010' op = SystemHintOp_WFE;
  when '0000 011' op = SystemHintOp_WFI;
  when '0000 100' op = SystemHintOp_SEV;
  when '0000 101' op = SystemHintOp_SEVL;
  when '0000 111' 
      SEE "XPACLRI";
  when '0001 xxx'
      SEE "PACIA1716, PACIB1716, AUTIA1716, AUTIB1716";
  when '0010 000'
      if !HaveRASExt() then EndOfInstruction(); // Instruction executes as NOP
      op = SystemHintOp_ESB;
  when '0010 001'
      if !HaveStatisticalProfiling() then EndOfInstruction(); // Instruction executes as NOP
      op = SystemHintOp_PSE;
  when '0010 010'
      if !HaveSelfHostedTrace() then EndOfInstruction(); // Instruction executes as NOP
      op = SystemHintOp_TSE;
  when '0010 100'
      op = SystemHintOp_CSDB;
  when '0011 xxx'
      SEE "PACIAZ, PACIASP, PACIBZ, PACIBSP, AUTIAZ, AUTIASP, AUTIBZ, AUTIBSP";
  when '0100 xxx'
      op = SystemHintOp_BTI;
  otherwise BTypeCompatible = BTypeCompatible_BTI(op2<2:1>);
  otherwise EndOfInstruction(); // Instruction executes as NOP
```
case op of
  when SystemHintOp_YIELDHint_Yield();

  when SystemHintOp_WFE
    if IsEventRegisterSet() then
      ClearEventRegister();
    else
      if PSTATE.EL == EL0 then
        // Check for traps described by the OS which may be EL1 or EL2.
        AArch64.CheckForWFxTrap(EL1, TRUE);
      if EL2Enabled() && PSTATE.EL IN {EL0, EL1} && !IsInHost() then
        // Check for traps described by the Hypervisor.
        AArch64.CheckForWFxTrap(EL2, TRUE);
      if HaveEL(EL3) && PSTATE.EL != EL3 then
        // Check for traps described by the Secure Monitor.
        AArch64.CheckForWFxTrap(EL3, TRUE);
      WaitForEvent();

  when SystemHintOp_WFI
    if !InterruptPending() then
      if PSTATE.EL == EL0 then
        // Check for traps described by the OS which may be EL1 or EL2.
        AArch64.CheckForWFxTrap(EL1, FALSE);
      if EL2Enabled() && PSTATE.EL IN {EL0, EL1} && !IsInHost() then
        // Check for traps described by the Hypervisor.
        AArch64.CheckForWFxTrap(EL2, FALSE);
      if HaveEL(EL3) && PSTATE.EL != EL3 then
        // Check for traps described by the Secure Monitor.
        AArch64.CheckForWFxTrap(EL3, FALSE);
      WaitForInterrupt();

  when SystemHintOp_SEVS_SendEvent();

  when SystemHintOp_SEVLS_SendEventLocal();

  when SystemHintOp_ESBS_SynchronizeErrors();
    AArch64.ESSOperation();
    if EL2Enabled() && PSTATE.EL IN {EL0, EL1} then
      TakeUnmaskedErrorInterrupts();

  when SystemHintOp_PSB_ProfilingSynchronizationBarrier();

  when SystemHintOp_TSB
    TraceSynchronizationBarrier();

  when SystemHintOp_CSDB_ConsumptionOfSpeculativeDataBarrier();

  when SystemHintOp_BTI
    BTypeNext = '00';

  otherwise // do nothing

Internal version only: isa v30.25, v29.05, AdvSIMD v27.01, pseudocode v85-xml-00bet8_rc325 ; Build timestamp: 2018-09-13T12:2018-06-16T09:04:45

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DC

Data Cache operation. For more information, see .

This is an alias of SYS. This means:

- The encodings in this description are named to match the encodings of SYS.
- The description of SYS gives the operational pseudocode for this instruction.

31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0

L CRn

System

DC `<dc_op>, <Xt>`

is equivalent to

SYS #<op1>, C7, <Cm>, #<op2>, <Xt>

and is the preferred disassembly when SysOp(op1,'0111',CRm,op2) == Sys_DC.

Assembler Symbols

<dc_op> Is a DC instruction name, as listed for the DC system instruction group, encoded in “op1:CRm:op2”:

<table>
<thead>
<tr>
<th>op1</th>
<th>CRm</th>
<th>op2</th>
<th><code>&lt;dc_op&gt;</code></th>
<th>Architectural Feature</th>
</tr>
</thead>
<tbody>
<tr>
<td>000</td>
<td>0110</td>
<td>001</td>
<td>IVAC</td>
<td>-</td>
</tr>
<tr>
<td>000</td>
<td>0110</td>
<td>010</td>
<td>ISW</td>
<td>-</td>
</tr>
<tr>
<td>001</td>
<td>0110</td>
<td>11101</td>
<td>IGVAC</td>
<td>ARMv8.5-MemTag</td>
</tr>
<tr>
<td>000</td>
<td>0110</td>
<td>10011</td>
<td>IGSW</td>
<td>ARMv8.5-MemTag</td>
</tr>
<tr>
<td>001</td>
<td>0110</td>
<td>10011</td>
<td>IGDVAC</td>
<td>ARMv8.5-MemTag</td>
</tr>
<tr>
<td>001</td>
<td>1010</td>
<td>0010</td>
<td>CSVAC</td>
<td>-</td>
</tr>
<tr>
<td>001</td>
<td>1010</td>
<td>10010</td>
<td>CGSVAC</td>
<td>ARMv8.5-MemTag ARMv8.2-DCPoP</td>
</tr>
<tr>
<td>001</td>
<td>1010</td>
<td>11010</td>
<td>CGDSVAC</td>
<td>ARMv8.5-MemTag ARMv8.5-MemTag</td>
</tr>
<tr>
<td>000</td>
<td>1110</td>
<td>010</td>
<td>CISW</td>
<td>-</td>
</tr>
<tr>
<td>000</td>
<td>1110</td>
<td>100</td>
<td>CIGSW</td>
<td>ARMv8.5-MemTag</td>
</tr>
<tr>
<td>000</td>
<td>1110</td>
<td>110</td>
<td>CIGDSW</td>
<td>ARMv8.5-MemTag</td>
</tr>
<tr>
<td>011</td>
<td>0100</td>
<td>001</td>
<td>ZVA</td>
<td>-</td>
</tr>
<tr>
<td>011</td>
<td>0100</td>
<td>011</td>
<td>GVA</td>
<td>ARMv8.5-MemTag</td>
</tr>
<tr>
<td>011</td>
<td>0100</td>
<td>100</td>
<td>GZVA</td>
<td>ARMv8.5-MemTag</td>
</tr>
<tr>
<td>011</td>
<td>1010</td>
<td>001</td>
<td>CVAC</td>
<td>-</td>
</tr>
<tr>
<td>011</td>
<td>1010</td>
<td>011</td>
<td>CGVAC</td>
<td>ARMv8.5-MemTag</td>
</tr>
<tr>
<td>011</td>
<td>1010</td>
<td>101</td>
<td>CGDVAC</td>
<td>ARMv8.5-MemTag</td>
</tr>
<tr>
<td>011</td>
<td>1011</td>
<td>001</td>
<td>CVAU</td>
<td>-</td>
</tr>
<tr>
<td>011</td>
<td>1100</td>
<td>001</td>
<td>CVAP</td>
<td>ARMv8.2-DCPoP</td>
</tr>
<tr>
<td>011</td>
<td>1100</td>
<td>011</td>
<td>CGVAP</td>
<td>ARMv8.5-MemTag</td>
</tr>
<tr>
<td>011</td>
<td>1100</td>
<td>101</td>
<td>CGDVAP</td>
<td>ARMv8.5-MemTag</td>
</tr>
<tr>
<td>011</td>
<td>1101</td>
<td>001</td>
<td>CVADP</td>
<td>ARMv8.2-DCCVADP</td>
</tr>
<tr>
<td>011</td>
<td>1101</td>
<td>011</td>
<td>CGVADP</td>
<td>ARMv8.5-MemTag</td>
</tr>
<tr>
<td>011</td>
<td>1101</td>
<td>101</td>
<td>CGDVADP</td>
<td>ARMv8.5-MemTag</td>
</tr>
<tr>
<td>011</td>
<td>1110</td>
<td>001</td>
<td>CIVAC</td>
<td>-</td>
</tr>
<tr>
<td>011</td>
<td>1110</td>
<td>011</td>
<td>CIGVAC</td>
<td>ARMv8.5-MemTag</td>
</tr>
<tr>
<td>011</td>
<td>1110</td>
<td>101</td>
<td>CGIDVAC</td>
<td>ARMv8.5-MemTag</td>
</tr>
</tbody>
</table>

<op1> Is a 3-bit unsigned immediate, in the range 0 to 7, encoded in the "op1" field.

<Cm> Is a name 'Cm', with 'm' in the range 0 to 15, encoded in the "CRm" field.

<op2> Is a 3-bit unsigned immediate, in the range 0 to 7, encoded in the "op2" field.
Is the 64-bit name of the general-purpose source register, encoded in the "Rt" field.

Operation

The description of SYS gives the operational pseudocode for this instruction.
DCPS1

Debug Change PE State to EL1, when executed in Debug state:

- If executed at EL0 changes the current Exception level and SP to EL1 using SP_EL1.
- Otherwise, if executed at ELx, selects SP_ELx.

The target exception level of a DCPS1 instruction is:

- EL1 if the instruction is executed at EL0.
- Otherwise, the Exception level at which the instruction is executed.

When the target Exception level of a DCPS1 instruction is ELx, on executing this instruction:

- ELR_ELx becomes UNKNOWN.
- SPSR_ELx becomes UNKNOWN.
- ESR_ELx becomes UNKNOWN.
- DLR_EL0 and DPSR_EL0 become UNKNOWN.
- The endianness is set according to SCTLR_ELx.EE.

This instruction is UNDEFINED at EL0 in Non-secure state if EL2 is implemented and HCR_EL2.TGE == 1.
This instruction is always UNDEFINED in Non-debug state.

For more information on the operation of the DCPSn instructions, see DCPS.

System

```
DCPS1 {#<imm>}

bits(2) target_level = LL;
if LL == '00' then UNDEFINED;
if !Halted() then AArch64.UndefiedFault();
```

Assembler Symbols

```
<imm> Is an optional 16-bit unsigned immediate, in the range 0 to 65535, defaulting to 0 and encoded in the "imm16" field.
```

Operation

```
DCPSInstruction(target_level);
```

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DCPS2

Debug Change PE State to EL2, when executed in Debug state:

- If executed at EL0 or EL1 changes the current Exception level and SP to EL2 using SP_EL2.
- Otherwise, if executed at ELx, selects SP_ELx.

The target exception level of a DCPS2 instruction is:

- EL2 if the instruction is executed at an exception level that is not EL3.
- EL3 if the instruction is executed at EL3.

When the target Exception level of a DCPS2 instruction is ELx, on executing this instruction:

- \( ELR_{ELx} \) becomes UNKNOWN.
- \( SPSR_{ELx} \) becomes UNKNOWN.
- \( ESR_{ELx} \) becomes UNKNOWN.
- \( DLR_{EL0} \) and \( DSPSR_{EL0} \) become UNKNOWN.
- The endianness is set according to \( SCTLR_{ELx}.EE \).

This instruction is UNDEFINED at the following exception levels:

- All exception levels if EL2 is not implemented.
- At EL0 and EL1 in Secure state if EL2 is disabled in the current Security state.

This instruction is always UNDEFINED in Non-debug state.

For more information on the operation of the DCPSn instructions, see DCPS.

### System

```
DCPS2 {#<imm>}

bits(2) target_level = LL;
if LL == '00' then UNDEFINED;
if !Halted() then AArch64.UndefinedFault();
```

### Assembler Symbols

<imm> Is an optional 16-bit unsigned immediate, in the range 0 to 65535, defaulting to 0 and encoded in the "imm16" field.

### Operation

```
DCPSInstruction(target_level);
```

Internal version only: isa v30.25, AdvSIMD v27.01, pseudocode v85-xml-008838_rc3352 ; Build timestamp: 2018-09-13 13:45:16

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DCPS3

Debug Change PE State to EL3, when executed in Debug state:
- If executed at EL3 selects SP_EL3.
- Otherwise, changes the current Exception level and SP to EL3 using SP_EL3.

The target exception level of a DCPS3 instruction is EL3.

On executing a DCPS3 instruction:
- ELR_EL3 becomes UNKNOWN.
- SPSR_EL3 becomes UNKNOWN.
- ESR_EL3 becomes UNKNOWN.
- DLR_EL0 and DSPSR_EL0 become UNKNOWN.
- The endianness is set according to SCTLR_EL3.EE.

This instruction is UNDEFINED at all exception levels if either:
- EDSCHR SDD == 1.
- EL3 is not implemented.

This instruction is always UNDEFINED in Non-debug state.

For more information on the operation of the DCPSn instructions, see DCPS.

31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
1 1 0 1 0 1 0 0 1 0 1 imm16
0 0 0 1 1 LL

System

DCPS3 {#<imm>}

DCPSInstruction(target_level);

Assembler Symbols

<imm> Is an optional 16-bit unsigned immediate, in the range 0 to 65535, defaulting to 0 and encoded in the "imm16" field.

Operation

Internal version only: isa v30.25 p29.25, AdvSIMD v27.01 p26.01, pseudocode v85-xml-006e8_f8_c362384a; Build timestamp: 2018-09-13T13:04:45-04:00

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DMB

Data Memory Barrier is a memory barrier that ensures the ordering of observations of memory accesses, see Data Memory Barrier.

System

```assembly
DMB <option> |{-#<imm>

MemBarrierOp op;
MBReqDomain domain;
MBReqTypes types;

case opc of
    when '00' op = MemBarrierOp_DSB;
    when '01' op = MemBarrierOp_DMB;
    when '10' op = MemBarrierOp_ISB;
    otherwise
        if otherwise HaveSBExtUnallocatedEncoding() && CRm<3:0> == '0000' then
            op =();

case CRm<3:2> of
    when '00' domain = MemBarrierOp_SB;
    else
        UNDEFINED;

case CRm<3:2> of
    when '00' domain = MBReqDomain_OuterShareable;
    when '01' domain = MBReqDomain_Nonshareable;
    when '10' domain = MBReqDomain_InnerShareable;
    when '11' domain = MBReqDomain_FullSystem;

case CRm<1:0> of
    when '01' types = MBReqTypes_Reads;
    when '10' types = MBReqTypes_Writes;
    when '11' types = MBReqTypes_All;
    otherwise
        if CRm<3:2> == '01' then
            if CRm<3:2> == '00' then
                op = MemBarrierOp_PSSBB;
            elsif CRm<3:2> == '00' && opc == '00' then
                op = MemBarrierOp_SSBB;
            elsif CRm<3:2> == '01' then
                op = HaveSBExtMemBarrierOp_PSSBB() && CRm<3:2> == '00' && opc == '11' then
                    op = MemBarrierOp_SSBB;
            else
                types = MBReqTypes_All;
                domain = MBReqDomain_FullSystem;

Assembler Symbols

<option> Specifies the limitation on the barrier operation. Values are:

SY Full system is the required shareability domain, reads and writes are the required access types, both before and after the barrier instruction. This option is referred to as the full system barrier. Encoded as CRm = 0b1111.

ST Full system is the required shareability domain, writes are the required access type, both before and after the barrier instruction. Encoded as CRm = 0b1110.
```
Full system is the required shareability domain, reads are the required access type before the barrier instruction, and reads and writes are the required access types after the barrier instruction. Encoded as CRm = 0b1101.

Inner Shareable is the required shareability domain, reads and writes are the required access types, both before and after the barrier instruction. Encoded as CRm = 0b1011.

Inner Shareable is the required shareability domain, writes are the required access type, both before and after the barrier instruction. Encoded as CRm = 0b1010.

Inner Shareable is the required shareability domain, reads are the required access type before the barrier instruction, and reads and writes are the required access types after the barrier instruction. Encoded as CRm = 0b1001.

Non-shareable is the required shareability domain, reads and writes are the required access, both before and after the barrier instruction. Encoded as CRm = 0b0111.

Non-shareable is the required shareability domain, writes are the required access type, both before and after the barrier instruction. Encoded as CRm = 0b0110.

Non-shareable is the required shareability domain, reads are the required access type before the barrier instruction, and reads and writes are the required access types after the barrier instruction. Encoded as CRm = 0b0101.

Outer Shareable is the required shareability domain, reads and writes are the required access types, both before and after the barrier instruction. Encoded as CRm = 0b0011.

Outer Shareable is the required shareability domain, writes are the required access type, both before and after the barrier instruction. Encoded as CRm = 0b0010.

Outer Shareable is the required shareability domain, reads are the required access type before the barrier instruction, and reads and writes are the required access types after the barrier instruction. Encoded as CRm = 0b0001.

All other encodings of CRm that are not listed above are reserved, and can be encoded using the #<imm> syntax. It is IMPLEMENTATION DEFINED whether options other than SY are implemented. All unsupported and reserved options must execute as a full system barrier operation, but software must not rely on this behavior. For more information on whether an access is before or after a barrier instruction, see Data Memory Barrier (DMB) or see Data Synchronization Barrier (DSB).

<imm>
Is a 4-bit unsigned immediate, in the range 0 to 15, encoded in the "CRm" field.

### Operation

```c
case op of
  when MemBarrierOp_DSBDataSynchronizationBarrier (domain, types);
  when MemBarrierOp_DMBDataMemoryBarrier (domain, types);
  when MemBarrierOp_ISBInstructionSynchronizationBarrier ();
  when MemBarrierOp_SSSBSSpeculativeSynchronizationBarrierToVA ();
  when MemBarrierOp_PSSBSSpeculativeSynchronizationBarrierToPA ();
  when MemBarrierOp_SBSpeculationBarrier ();
```

Internal version only: isa v30.25, AdvSIMD v27.01, pseudocode v85-xml-00bet8_rc3.115; Build timestamp: 2018-09-13T13:04:45

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DRPS

Debug restore process state.

```
DRPS

if !Halted() || PSTATE.EL == EL0 then UNDEFINED; then UnallocatedEncoding();
```

Operation

```
DRPSInstruction();
```

System

Internal version only: isa v30.25, AdvSIMD v27.0, pseudocode v85-xml-008eb8_rc3.0.5

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Data Synchronization Barrier is a memory barrier that ensures the completion of memory accesses, see Data Synchronization Barrier.

System

\[
\begin{array}{cccccccccccc}
1 & 1 & 0 & 0 & 1 & 0 & 1 & 1 & 0 & 0 & 1 & 1 \end{array}
\]

\[CRm\] \[opc\]

Assembler Symbols

\(<option>\)\|\<imm>

Specifies the limitation on the barrier operation. Values are:

**SY**

Full system is the required shareability domain, reads and writes are the required access types, both before and after the barrier instruction. This option is referred to as the full system barrier. Encoded as CRm = 0b1111.

**ST**

Full system is the required shareability domain, writes are the required access type, both before and after the barrier instruction. Encoded as CRm = 0b1110.
**LD**
Full system is the required shareability domain, reads are the required access type before the barrier instruction, and reads and writes are the required access types after the barrier instruction. Encoded as CRm = 0b1101.

**ISH**
Inner Shareable is the required shareability domain, reads and writes are the required access types, both before and after the barrier instruction. Encoded as CRm = 0b1011.

**ISHST**
Inner Shareable is the required shareability domain, writes are the required access type, both before and after the barrier instruction. Encoded as CRm = 0b1010.

**ISHLD**
Inner Shareable is the required shareability domain, reads are the required access type before the barrier instruction, and reads and writes are the required access types after the barrier instruction. Encoded as CRm = 0b1001.

**NSH**
Non-shareable is the required shareability domain, reads and writes are the required access, both before and after the barrier instruction. Encoded as CRm = 0b0111.

**NSHST**
Non-shareable is the required shareability domain, writes are the required access type, both before and after the barrier instruction. Encoded as CRm = 0b0110.

**NSHLD**
Non-shareable is the required shareability domain, reads are the required access type before the barrier instruction, and reads and writes are the required access types after the barrier instruction. Encoded as CRm = 0b0101.

**OSH**
Outer Shareable is the required shareability domain, reads and writes are the required access types, both before and after the barrier instruction. Encoded as CRm = 0b0011.

**OSHST**
Outer Shareable is the required shareability domain, writes are the required access type, both before and after the barrier instruction. Encoded as CRm = 0b0010.

**OSHLD**
Outer Shareable is the required shareability domain, reads are the required access type before the barrier instruction, and reads and writes are the required access types after the barrier instruction. Encoded as CRm = 0b0001.

All other encodings of CRm that are not listed above are reserved, and can be encoded using the #<imm> syntax. It is IMPLEMENTATION DEFINED whether options other than SY are implemented. All unsupported and reserved options must execute as a full system barrier operation, but software must not rely on this behavior. For more information on whether an access is before or after a barrier instruction, see Data Memory Barrier (DMB) or see Data Synchronization Barrier (DSB).

<imm>
Is a 4-bit unsigned immediate, in the range 0 to 15, encoded in the "CRm" field.

### Operation

```c
case op of
  when MemBarrierOp_DSBDataSynchronizationBarrier (domain, types);
  when MemBarrierOp_DMBDataMemoryBarrier (domain, types);
  when MemBarrierOp_ISBInstructionSynchronizationBarrier ();
  when MemBarrierOp_SSBBSpeculativeSynchronizationBarrierToVA ();
  when MemBarrierOp_PSSBBSSpeculativeSynchronizationBarrierToPA ();
  when MemorialOp_SSBBSpeculationBarrier ();
```

Internal version only: isa v30.25, AdvSIMD v27.01, pseudocode v85-xml-00bet8_rc3, v35.3
Build timestamp: 2018-09-13T13:20:45
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DUP (element)

Duplicate vector element to vector or scalar. This instruction duplicates the vector element at the specified element index in the source SIMD&FP register into a scalar or each element in a vector, and writes the result to the destination SIMD&FP register.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

This instruction is used by the alias MOV (scalar).

It has encodings from 2 classes: Scalar and Vector

Scalar

\[
\begin{array}{|c|c|c|}
\hline
\text{Rn} & \text{Rd} \\
\hline
\end{array}
\]

Scalar

\[
\text{DUP } <V><d>, <Vn>.<T>[<index>]\\n\]

\[
\begin{array}{l}
\text{integer } d = \text{UInt}(\text{Rd}); \\
\text{integer } n = \text{UInt}(\text{Rn}); \\
\text{integer size} = \text{LowestSetBit}(\text{imm5}); \\
\text{if } size > 3 \text{ then UNDEFINED}; \\
\text{integer index} = \text{if } size > 3 \text{ then UnallocatedEncoding}; \\
\text{integer index} = \text{UInt}(\text{imm5}<4:\text{size}+1>); \\
\text{integer idxdsize} = \text{if } \text{imm5}<4> == '1' \text{ then 128 else 64}; \\
\text{integer esize} = 8 \text{ << size}; \\
\text{integer datasize} = \text{esize}; \\
\text{integer elements} = 1; \\
\end{array}
\]

Vector

\[
\begin{array}{|c|c|c|}
\hline
\text{Rn} & \text{Rd} \\
\hline
\end{array}
\]

\[
\begin{array}{l}
\text{integer } d = \text{UInt}(\text{Rd}); \\
\text{integer } n = \text{UInt}(\text{Rn}); \\
\text{integer size} = \text{LowestSetBit}(\text{imm5}); \\
\text{if } size > 3 \text{ then UNDEFINED}; \\
\text{integer index} = \text{if } size > 3 \text{ then UnallocatedEncoding}; \\
\text{integer index} = \text{UInt}(\text{imm5}<4:\text{size}+1>); \\
\text{integer idxdsize} = \text{if } \text{imm5}<4> == '1' \text{ then 128 else 64}; \\
\text{integer esize} = 8 \text{ << size}; \\
\text{integer datasize} = \text{esize}; \\
\text{integer elements} = 1; \\
\end{array}
\]

DUP (element)
Vector

DUP \langle Vd \rangle \langle T \rangle, \langle Vn \rangle \langle Ts \rangle[\langle index \rangle]

integer d = UInt(Rd);
integer n = UInt(Rn);

integer size = LowestSetBit(imm5);
if size > 3 then UNDEFINED;

integer index = if size > 3 then UnallocatedEncoding();
integer index = UInt(imm5<4:size+1>);
integer idxsize = if imm5<4> == '1' then 128 else 64;
if size == 3 && Q == '0' then ReservedValue(imm5<4:size+1>);
integer idxsize = if imm5<4> == '1' then 128 else 64;
if size == 3 && Q == '0' then UNDEFINED;

integer esize = 8 << size;
integer datasize = if Q == '1' then 128 else 64;
integer elements = datasize DIV esize;

Assembler Symbols

\langle T \rangle

For the scalar variant: is the element width specifier, encoded in “imm5”:

<table>
<thead>
<tr>
<th>imm5</th>
<th>\langle T \rangle</th>
</tr>
</thead>
<tbody>
<tr>
<td>x0000</td>
<td>RESERVED</td>
</tr>
<tr>
<td>xxxx1</td>
<td>B</td>
</tr>
<tr>
<td>xxxx10</td>
<td>H</td>
</tr>
<tr>
<td>xx100</td>
<td>S</td>
</tr>
<tr>
<td>x1000</td>
<td>D</td>
</tr>
</tbody>
</table>

For the vector variant: is an arrangement specifier, encoded in “imm5:Q”:

<table>
<thead>
<tr>
<th>imm5</th>
<th>Q</th>
<th>\langle T \rangle</th>
</tr>
</thead>
<tbody>
<tr>
<td>x0000</td>
<td>x</td>
<td>RESERVED</td>
</tr>
<tr>
<td>xxxx1</td>
<td>0</td>
<td>8B</td>
</tr>
<tr>
<td>xxxx1</td>
<td>1</td>
<td>16B</td>
</tr>
<tr>
<td>xxxx10</td>
<td>0</td>
<td>4H</td>
</tr>
<tr>
<td>xxxx10</td>
<td>1</td>
<td>8H</td>
</tr>
<tr>
<td>xx100</td>
<td>0</td>
<td>2S</td>
</tr>
<tr>
<td>xx100</td>
<td>1</td>
<td>4S</td>
</tr>
<tr>
<td>x1000</td>
<td>0</td>
<td>RESERVED</td>
</tr>
<tr>
<td>x1000</td>
<td>1</td>
<td>2D</td>
</tr>
</tbody>
</table>

\langle Ts \rangle

Is an element size specifier, encoded in “imm5”:

<table>
<thead>
<tr>
<th>imm5</th>
<th>\langle Ts \rangle</th>
</tr>
</thead>
<tbody>
<tr>
<td>x0000</td>
<td>RESERVED</td>
</tr>
<tr>
<td>xxxx1</td>
<td>B</td>
</tr>
<tr>
<td>xxxx10</td>
<td>H</td>
</tr>
<tr>
<td>xx100</td>
<td>S</td>
</tr>
<tr>
<td>x1000</td>
<td>D</td>
</tr>
</tbody>
</table>

\langle V \rangle

Is the destination width specifier, encoded in “imm5”:

<table>
<thead>
<tr>
<th>imm5</th>
<th>\langle V \rangle</th>
</tr>
</thead>
<tbody>
<tr>
<td>x0000</td>
<td>RESERVED</td>
</tr>
<tr>
<td>xxxx1</td>
<td>B</td>
</tr>
<tr>
<td>xxxx10</td>
<td>H</td>
</tr>
<tr>
<td>xx100</td>
<td>S</td>
</tr>
<tr>
<td>x1000</td>
<td>D</td>
</tr>
</tbody>
</table>

\langle Vn \rangle

Is the name of the SIMD&FP source register, encoded in the "Rn" field.

\langle index \rangle

Is the element index encoded in “imm5”:
<table>
<thead>
<tr>
<th>imm5</th>
<th>&lt;index&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>x0000</td>
<td>RESERVED</td>
</tr>
<tr>
<td>xxxx1</td>
<td>imm5&lt;4:1&gt;</td>
</tr>
<tr>
<td>xxx10</td>
<td>imm5&lt;4:2&gt;</td>
</tr>
<tr>
<td>xx100</td>
<td>imm5&lt;4:3&gt;</td>
</tr>
<tr>
<td>x1000</td>
<td>imm5&lt;4&gt;</td>
</tr>
</tbody>
</table>

<d> Is the number of the SIMD&FP destination register, encoded in the "Rd" field.

<Vd> Is the name of the SIMD&FP destination register, encoded in the "Rd" field.

**Operation**

```c
CheckFPAdvSIMDEnabled64();
bits(idxdsize) operand = V[n];
bits(datasize) result;
bits(esize) element;

element = Elem[operand, index, esize];
for e = 0 to elements-1
   Elem[result, e, esize] = element;
V[d] = result;
```

**Operational information**

If PSTATE.DIT is 1:

- The execution time of this instruction is independent of:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
- The response of this instruction to asynchronous exceptions does not vary based on:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
DUP (general)

Duplicate general-purpose register to vector. This instruction duplicates the contents of the source general-purpose register into a scalar or each element in a vector, and writes the result to the SIMD&FP destination register.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

### Advanced SIMD

**DUP <Vd>.<T>, <R><n>**

integer d = UInt(Rd);
integer n = UInt(Rn);

integer size = LowestSetBit(imm5);
if size > 3 then UNDEFINED;

// imm5<4:size+1> is IGNORED

if size == 3 && Q == '0' then UNDEFINED;
integer esize = 8 << size;
integer datasize = if Q == '1' then 128 else 64;
integer elements = datasize DIV esize;
if size > 3 then UnallocatedEncoding();

// imm5[size+1] is IGNORED

if size == 3 && Q == '0' then ReservedValue();
integer esize = 8 << size;
integer datasize = if Q == '1' then 128 else 64;
integer elements = datasize DIV esize;

**Assembler Symbols**

- **<Vd>**
  - Is the name of the SIMD&FP destination register, encoded in the "Rd" field.

- **<T>**
  - Is an arrangement specifier, encoded in “imm5:Q”:

<table>
<thead>
<tr>
<th>imm5</th>
<th>Q</th>
<th>&lt;T&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0000</td>
<td>x</td>
<td>RESERVED</td>
</tr>
<tr>
<td>xxxx1</td>
<td>0</td>
<td>8B</td>
</tr>
<tr>
<td>xxxx1</td>
<td>1</td>
<td>16B</td>
</tr>
<tr>
<td>xxxx1</td>
<td>1</td>
<td>8H</td>
</tr>
<tr>
<td>xxxx1</td>
<td>0</td>
<td>4H</td>
</tr>
<tr>
<td>xxxx1</td>
<td>1</td>
<td>2S</td>
</tr>
<tr>
<td>xxxx1</td>
<td>0</td>
<td>4S</td>
</tr>
<tr>
<td>xxxx1</td>
<td>0</td>
<td>2D</td>
</tr>
<tr>
<td>xxxx1</td>
<td>1</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

- **<R>**
  - Is the width specifier for the general-purpose source register, encoded in “imm5”:

<table>
<thead>
<tr>
<th>imm5</th>
<th>&lt;R&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0000</td>
<td>RESERVED</td>
</tr>
<tr>
<td>xxxx1</td>
<td>W</td>
</tr>
<tr>
<td>xxxx1</td>
<td>W</td>
</tr>
<tr>
<td>xxxx1</td>
<td>W</td>
</tr>
<tr>
<td>xxxx1</td>
<td>W</td>
</tr>
</tbody>
</table>

Unspecified bits in “imm5” are ignored but should be set to zero by an assembler.

- **<n>**
  - Is the number [0-30] of the general-purpose source register or ZR (31), encoded in the "Rn" field.
Operation

```c
CheckFPAdvSIMDEnabled64();
bits(esize) element = X[n];
bits(datasize) result;

for e = 0 to elements-1
  Elem[result, e, esize] = element;
V[d] = result;
```

Operational information

If PSTATE.DIT is 1:
- The execution time of this instruction is independent of:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
- The response of this instruction to asynchronous exceptions does not vary based on:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
DVP

Data Value Prediction Restriction by Context prevents data value predictions, based on information gathered from earlier execution within an particular execution context, from allowing later speculative execution within that context to be observable through side-channels.

For more information, see DVP RCTX, Data Value Prediction Restriction by Context.

This is an alias of SYS. This means:

- The encodings in this description are named to match the encodings of SYS.
- The description of SYS gives the operational pseudocode for this instruction.

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 1  | 1  | 0  | 1  | 0  | 1  | 0  | 0  | 0  | 0  | 1  | 0  | 1  | 1  | 1  | 0  | 1  | 1  | 1  | 0  | 0  | 1  | 1  | 1  | 0  | 1 |

L       op1       CRn       CRm       op2

Rt

System

DVP RCTX, <Xt>

is equivalent to

SYS #3, C8, C3, #5, <Xt>

and is always the preferred disassembly.

Assembler Symbols

<Xt>  Is the 64-bit name of the general-purpose source register, encoded in the "Rt" field.

Operation

The description of SYS gives the operational pseudocode for this instruction.
EON (shifted register)

Bitwise Exclusive OR NOT (shifted register) performs a bitwise Exclusive OR NOT of a register value and an optionally-shifted register value, and writes the result to the destination register.

### 32-bit (sf == 0)

EON \(<Wd>, <Wn>, <Wm>\{|, <shift> \#<amount>\}\)

### 64-bit (sf == 1)

EON \(<Xd>, <Xn>, < Xm>\{|, <shift> \#<amount>\}\)

```plaintext
integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rm);
integer datasize = if sf == '1' then 64 else 32;
boolean setflags;
LogicalOp op;
case opc of
  when '00' op = LogicalOp_AND; setflags = FALSE;
  when '01' op = LogicalOp_ORR; setflags = FALSE;
  when '10' op = LogicalOp_EOR; setflags = FALSE;
  when '11' op = LogicalOp_AND; setflags = TRUE;
if sf == '0' && imm6<5> == '1' then UNDEFINED;
ReservedValue();
ShiftType shift_type = DecodeShift(shift);
integer shift_amount = UInt(imm6);
boolean invert = (N == '1');
```

### Assembler Symbols

- **<Wd>** Is the 32-bit name of the general-purpose destination register, encoded in the "Rd" field.
- **<Wn>** Is the 32-bit name of the first general-purpose source register, encoded in the "Rn" field.
- **<Wm>** Is the 32-bit name of the second general-purpose source register, encoded in the "Rm" field.
- **<Xd>** Is the 64-bit name of the general-purpose destination register, encoded in the "Rd" field.
- **<Xn>** Is the 64-bit name of the first general-purpose source register, encoded in the "Rn" field.
- **<Xm>** Is the 64-bit name of the second general-purpose source register, encoded in the "Rm" field.
- **<shift>** Is the optional shift to be applied to the final source, defaulting to LSL and encoded in “shift”:

<table>
<thead>
<tr>
<th>shift</th>
<th>&lt;shift&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>LSL</td>
</tr>
<tr>
<td>01</td>
<td>LSR</td>
</tr>
<tr>
<td>10</td>
<td>ASR</td>
</tr>
<tr>
<td>11</td>
<td>ROR</td>
</tr>
</tbody>
</table>

- **<amount>** For the 32-bit variant: is the shift amount, in the range 0 to 31, defaulting to 0 and encoded in the "imm6" field.
  For the 64-bit variant: is the shift amount, in the range 0 to 63, defaulting to 0 and encoded in the "imm6" field,
Operation

```
bits(datasize) operand1 = X[n];
bits(datasize) operand2 = ShiftReg(m, shift_type, shift_amount);

if invert then operand2 = NOT(operand2);

case op of
    when LogicalOp_AND result = operand1 AND operand2;
    when LogicalOp_ORR result = operand1 OR operand2;
    when LogicalOp_EOR result = operand1 EOR operand2;

if setflags then
    PSTATE.<N,Z,C,V> = result<datasize-1>:IsZeroBit(result) :'00';

X[d] = result;
```

Operational information

If PSTATE.DIT is 1:

- The execution time of this instruction is independent of:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
- The response of this instruction to asynchronous exceptions does not vary based on:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.

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EOR3

Three-way Exclusive OR performs a three-way exclusive OR of the values in the three source SIMD&FP registers, and writes the result to the destination SIMD&FP register.

This instruction is implemented only when ARMv8.2-SHA is implemented.

Advanced SIMD
(ARMv8.2)

Advanced SIMD

EOR3 <Vd>.16B, <Vn>.16B, <Vm>.16B, <Va>.16B

if !HaveSHA3Ext() then UNDEFINED;
integer d = d() then UnallocatedEncoding();
integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rm);
integer a = UInt(Ra);

Assembler Symbols

<Vd> Is the name of the SIMD&FP destination register, encoded in the "Rd" field.
<Vn> Is the name of the first SIMD&FP source register, encoded in the "Rn" field.
<Vm> Is the name of the second SIMD&FP source register, encoded in the "Rm" field.
<Va> Is the name of the third SIMD&FP source register, encoded in the "Ra" field.

Operation

AArch64.CheckFPAdvSIMDEnabled();

bits(128) Vm = V[m];
bits(128) Vn = V[n];
bits(128) Va = V[a];
V[d] = Vn EOR Vm EOR Va;

Operational information

If PSTATE.DIT is 1:

- The execution time of this instruction is independent of:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
- The response of this instruction to asynchronous exceptions does not vary based on:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
EOR (immediate)

Bitwise Exclusive OR (immediate) performs a bitwise Exclusive OR of a register value and an immediate value, and writes the result to the destination register.

<table>
<thead>
<tr>
<th>sf</th>
<th>1</th>
<th>0</th>
<th>0</th>
<th>0</th>
<th>1</th>
<th>0</th>
<th>0</th>
<th>N</th>
<th>immr</th>
<th>immr</th>
<th>immr</th>
<th>Rn</th>
<th>Rd</th>
</tr>
</thead>
</table>

32-bit (sf == 0 && N == 0)

EOR <Wd|WSP>, <Wn>, #<imm>

64-bit (sf == 1)

EOR <Xd|SP>, <Xn>, #<imm>

```plaintext
integer d = UInt(Rd);
integer n = UInt(Rn);
integer datasize = if sf == '1' then 64 else 32;
boolean setflags;
LogicalOp op;

case opc of
  when '00' op = LogicalOp_AND; setflags = FALSE;
  when '01' op = LogicalOp_ORR; setflags = FALSE;
  when '10' op = LogicalOp_EOR; setflags = FALSE;
  when '11' op = LogicalOp_AND; setflags = TRUE;

bits(datasize) imm;
if sf == '0' && N != '0' then UNDEFINED;
(imm, -) = if sf == '0' && N != '0' then ReservedValue();
(imm, -) = DecodeBitMasks(N, imms, immr, TRUE);
```

Assembler Symbols

<Wd|WSP>  Is the 32-bit name of the destination general-purpose register or stack pointer, encoded in the "Rd" field.

<Wn>    Is the 32-bit name of the general-purpose source register, encoded in the "Rn" field.

<Xd|SP>  Is the 64-bit name of the destination general-purpose register or stack pointer, encoded in the "Rd" field.

<Xn>    Is the 64-bit name of the general-purpose source register, encoded in the "Rn" field.

<imm> For the 32-bit variant: is the bitmask immediate, encoded in "imms:immr".

For the 64-bit variant: is the bitmask immediate, encoded in "N:imms:immr".
Operation

```
bits(datasize) result;
bits(datasize) operand1 = X[n];
bits(datasize) operand2 = imm;

case op of
    when LogicalOp_AND result = operand1 AND operand2;
    when LogicalOp_ORR result = operand1 OR operand2;
    when LogicalOp_EOR result = operand1 EOR operand2;

    if setflags then
        PSTATE.<N,Z,C,V> = result<datasize-1>:IsZeroBit(result):'00';

    if d == 31 && !setflags then
        SP[] = result;
    else
        X[d] = result;
```

Operational information

If PSTATE.DIT is 1:

- The execution time of this instruction is independent of:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
- The response of this instruction to asynchronous exceptions does not vary based on:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
EOR (shifted register)

Bitwise Exclusive OR (shifted register) performs a bitwise Exclusive OR of a register value and an optionally-shifted register value, and writes the result to the destination register.

```plaintext
<table>
<thead>
<tr>
<th>sf</th>
<th>1</th>
<th>0</th>
<th>0</th>
<th>0</th>
<th>1</th>
<th>0</th>
<th>shift</th>
<th>0</th>
<th>Rm</th>
<th>imm6</th>
<th>Rn</th>
<th>Rd</th>
</tr>
</thead>
<tbody>
<tr>
<td>opc</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

32-bit (sf == 0)

EOR <Wd>, <Wn>, <Wm>{, <shift> #<amount>}

64-bit (sf == 1)

EOR <Xd>, <Xn>, <Xm>{, <shift> #<amount>}

```plaintext
integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rm);
integer datasize = if sf == '1' then 64 else 32;
boolean setflags;
LogicalOp op;
case opc of
    when '00' op = LogicalOp_AND; setflags = FALSE;
    when '01' op = LogicalOp_ORR; setflags = FALSE;
    when '10' op = LogicalOp_EOR; setflags = FALSE;
    when '11' op = LogicalOp_AND; setflags = TRUE;

if sf == '0' && imm6<5> == '1' then UNDEFINED;
ReservedValue();
ShiftType shift_type = DecodeShift(shift);
integer shift_amount = UInt(imm6);
boolean invert = (N == '1');
```

Assembler Symbols

- `<Wd>` Is the 32-bit name of the general-purpose destination register, encoded in the "Rd" field.
- `<Wn>` Is the 32-bit name of the first general-purpose source register, encoded in the "Rn" field.
- `<Wm>` Is the 32-bit name of the second general-purpose source register, encoded in the "Rm" field.
- `<Xd>` Is the 64-bit name of the general-purpose destination register, encoded in the "Rd" field.
- `<Xn>` Is the 64-bit name of the first general-purpose source register, encoded in the "Rn" field.
- `<Xm>` Is the 64-bit name of the second general-purpose source register, encoded in the "Rm" field.
- `<shift>` Is the optional shift to be applied to the final source, defaulting to LSL and encoded in “shift”:

<table>
<thead>
<tr>
<th>shift</th>
<th>&lt;shift&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>LSL</td>
</tr>
<tr>
<td>01</td>
<td>LSR</td>
</tr>
<tr>
<td>10</td>
<td>ASR</td>
</tr>
<tr>
<td>11</td>
<td>ROR</td>
</tr>
</tbody>
</table>

- `<amount>` For the 32-bit variant: is the shift amount, in the range 0 to 31, defaulting to 0 and encoded in the "imm6" field.
- For the 64-bit variant: is the shift amount, in the range 0 to 63, defaulting to 0 and encoded in the "imm6" field,
Operation

\[
\begin{align*}
\text{bits}(\text{datasize}) \text{ operand1} &= X[n]; \\
\text{bits}(\text{datasize}) \text{ operand2} &= \text{ShiftReg}(m, \text{shift_type}, \text{shift_amount}); \\
\text{if invert then operand2} &= \text{NOT}(\text{operand2}); \\
\end{align*}
\]

\[
\text{case op of}
\begin{align*}
\text{when LogicalOp AND} & \quad \text{result} = \text{operand1 AND operand2}; \\
\text{when LogicalOp ORR} & \quad \text{result} = \text{operand1 OR operand2}; \\
\text{when LogicalOp EOR} & \quad \text{result} = \text{operand1 EOR operand2}; \\
\end{align*}
\]

\[
\text{if setflags then}
\begin{align*}
P\text{STATE.<N,Z,C,V>} &= \text{result<datasize-1>:IsZeroBit(result):'00'}; \\
X[d] &= \text{result};
\end{align*}
\]

Operational information

If PSTATE.DIT is 1:
- The execution time of this instruction is independent of:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
- The response of this instruction to asynchronous exceptions does not vary based on:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
ERET

Exception Return using the ELR and SPSR for the current Exception level. When executed, the PE restores `PSTATE` from the SPSR, and branches to the address held in the ELR.

The PE checks the SPSR for the current Exception level for an illegal return event. See *Illegal return events from AArch64 state*. ERET is UNDEFINED at EL0.

31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0

<table>
<thead>
<tr>
<th>A</th>
<th>M</th>
<th>Rn</th>
<th>op4</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

System

ERET

```plaintext
if PSTATE.EL == EL0 then UNDEFINED;

boolean pac = (A == '1');
boolean use_key_a = (M == '0');

if !pac && op4 != '00000' then
    UNDEFINED;
elsif pac && (!
then
    UnallocatedEncoding();

boolean pac = (A == '1');
boolean use_key_a = (M == '0');

if !pac && op4 != '00000' then
    UNDEFINED;
elsif pac && (!
    UnallocatedEncoding();

if Rn != '11111' then
    UNDEFINED;

if Rn != '11111' then
    UnallocatedEncoding();

if Rn != '11111' then
    UNDEFINED;

if Rn != '11111' then
    UNDEFINED;

if use_key_a then
    target = AuthIA(ELR[], SP[]);
else
    target = AuthIB(ELR[], SP[]);

AArch64.ExceptionReturn(target, SPSR[]);
```

Operation

```plaintext
AArch64.CheckForERetTrap(pac, use_key_a);

bits(64) target = ELR[];

if pac then
    if use_key_a then
        target = AuthIA(ELR[], SP[]);
    else
        target = AuthIB(ELR[], SP[]);

AArch64.ExceptionReturn(target, SPSR[]);
```
ERETAA, ERETAB

Exception Return, with pointer authentication. This instruction authenticates the address in ELR, using SP as the modifier and the specified key, the PE restores PSTATE from the SPSR for the current Exception level, and branches to the authenticated address.

Key A is used for ERETAA, and key B is used for ERETAB.

If the authentication passes, the PE continues execution at the target of the branch. If the authentication fails, a Translation fault is generated. The authenticated address is not written back to ELR.

The PE checks the SPSR for the current Exception level for an illegal return event. See Illegal return events from AArch64 state.

ERETAA and ERETAB are UNDEFINED at EL0.

Integer
(ARMv8.3)

```
|    | 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9  | 8  | 7  | 6  | 5  | 4  | 3  | 2  | 1  | 0  |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| A  | 1  | 1  | 0  | 1  | 0  | 1  | 0  | 1  | 1  | 1  | 1  | 0  | 0  | 0  | 0  | 1  | M  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  |
| Rn |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| op4|    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
```

ERETAA (M == 0)

```
ERETAA
```

ERETAB (M == 1)

```
ERETAB
```

Operation

```
AArch64.CheckForERetTrap(pac, use_key_a);
```

```
bits(64) target = ELR[];
```

```
if pac then
    if use_key_a then
        target = AuthIA(ELR[]), SP[]);
    else
        target = AuthIB(ELR[]), SP[]);
AArch64.ExceptionReturn(target, SPSR[]);
```
ESB

Error Synchronization Barrier is an error synchronization event that might also update DISR_EL1 and VDISR_EL2.

This instruction can be used at all Exception levels and in Debug state.

In Debug state, this instruction behaves as if SError interrupts are masked at all Exception levels. See Error Synchronization Barrier in the ARM(R) Reliability, Availability, and Serviceability (RAS) Specification, ARMv8, for ARMv8-A architecture profile.

If the RAS Extension is not implemented, this instruction executes as a NOP.

### System
(ARMv8.2)

```
<table>
<thead>
<tr>
<th>31</th>
<th>30</th>
<th>29</th>
<th>28</th>
<th>27</th>
<th>26</th>
<th>25</th>
<th>24</th>
<th>23</th>
<th>22</th>
<th>21</th>
<th>20</th>
<th>19</th>
<th>18</th>
<th>17</th>
<th>16</th>
<th>15</th>
<th>14</th>
<th>13</th>
<th>12</th>
<th>11</th>
<th>10</th>
<th>9</th>
<th>8</th>
<th>7</th>
<th>6</th>
<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
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<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
</tbody>
</table>

**ESB**

```SystemHintOp op;

case CRm:op2 of
  
  when '0000 000' op = SystemHintOp_NOP;
  when '0000 001' op = SystemHintOp_YIELD;
  when '0000 010' op = SystemHintOp_WFE;
  when '0000 011' op = SystemHintOp_WFI;
  when '0000 100' op = SystemHintOp_SEV;
  when '0000 101' op = SystemHintOp_SEVL;
  when '0000 111'  
    SEE "XPACLRI";
  when '0001 xxx'  
    SEE "PACIA1716, PACIB1716, AUTIA1716, AUTIB1716";
  when '0010 000'  
    if !HaveRASExt() then EndOfInstruction(); // Instruction executes as NOP
    op = SystemHintOp_ESB;
  when '0010 001'  
    if !HaveStatisticalProfiling() then EndOfInstruction(); // Instruction executes as NOP
    op = SystemHintOp_PSB;
  when '0010 010'  
    if !HaveSelfHostedTrace() then EndOfInstruction(); // Instruction executes as NOP
    op = SystemHintOp_TSB;
  when '0010 100'  
    op = SystemHintOp_CSDB;
  when '0011 xxx'  
    SEE "PACIAZ, PACTASP, PACIBZ, PACIBSP, AUTIAZ, AUTIASP, AUTIBZ, AUTIBSP";
  when '0100 xx0'  
    op = otherwise SystemHintOp_BTI;
    BTypeCompatible = BTypeCompatible_BTI(op2<2:1>);
  otherwise EndOfInstruction(); // Instruction executes as NOP
```
case op of
  when SystemHintOp_YIELDHint_Yield();
  when SystemHintOp_WFE
    if IsEventRegisterSet() then
      ClearEventRegister();
    else
      if PSTATE.EL == EL0 then
        // Check for traps described by the OS which may be EL1 or EL2.
        AArch64.CheckForWFxTrap(EL1, TRUE);
      if EL2Enabled() && PSTATE.EL IN {EL0, EL1} && !IsInHost() then
        // Check for traps described by the Hypervisor.
        AArch64.CheckForWFxTrap(EL2, TRUE);
      if HaveEL(EL3) && PSTATE.EL != EL3 then
        // Check for traps described by the Secure Monitor.
        AArch64.CheckForWFxTrap(EL3, TRUE);
      WaitForEvent();
    when SystemHintOp_WFI
      if ! InterruptPending() then
        if PSTATE.EL == EL0 then
          // Check for traps described by the OS which may be EL1 or EL2.
          AArch64.CheckForWFxTrap(EL1, FALSE);
        if EL2Enabled() && PSTATE.EL IN {EL0, EL1} && !IsInHost() then
          // Check for traps described by the Hypervisor.
          AArch64.CheckForWFxTrap(EL2, FALSE);
        if HaveEL(EL3) && PSTATE.EL != EL3 then
          // Check for traps described by the Secure Monitor.
          AArch64.CheckForWFxTrap(EL3, FALSE);
        WaitForInterrupt();
      when SystemHintOp_SEVSSendEvent();
      when SystemHintOp_SEVLSendEventLocal();
  when SystemHintOp_ESBSynchronizeErrors();
    AArch64.ESBOperation();
    if EL2Enabled() && PSTATE.EL IN {EL0, EL1} then AArch64.vESBOperation();
    TakeUnmaskedSErrorInterrupts();
  when SystemHintOp_PSBProfilingSynchronizationBarrier();
  when SystemHintOp_TSB
    TraceSynchronizationBarrier();
  when SystemHintOp_CSDBCConsumptionOfSpeculativeDataBarrier();
  when otherwise // do nothing SystemHintOp_BTI
    BTypeNext = '00';
  otherwise // do nothing

EXT

Extract vector from pair of vectors. This instruction extracts the lowest vector elements from the second source SIMD&FP register and the highest vector elements from the first source SIMD&FP register, concatenates the results into a vector, and writes the vector to the destination SIMD&FP register vector. The index value specifies the lowest vector element to extract from the first source register, and consecutive elements are extracted from the first, then second, source registers until the destination vector is filled.

The following figure shows an example of the operation of EXT doubleword operation for Q = 0 and imm4<2:0> = 3.

![Example Figure]

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

Advanced SIMD

```assembly
EXT <Vd>.<T>, <Vn>.<T>, <Vm>.<T>, #<index>
```

integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rm);

if Q == '0' && imm4<3> == '1' then UNDEFINED;

integer datasize = if Q == '1' then 128 else 64;
integer position = if Q == '0' && imm4<3> == '1' then UnallocatedEncoding();
integer datasize = if Q == '1' then 128 else 64;
integer position = UInt(imm4) << 3;
```

Assembler Symbols

- `<Vd>` Is the name of the SIMD&FP destination register, encoded in the "Rd" field.
- `<T>` Is an arrangement specifier, encoded in “Q”:

<table>
<thead>
<tr>
<th>Q</th>
<th>&lt;T&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>8B</td>
</tr>
<tr>
<td>1</td>
<td>16B</td>
</tr>
</tbody>
</table>

- `<Vn>` Is the name of the first SIMD&FP source register, encoded in the "Rn" field.
- `<Vm>` Is the name of the second SIMD&FP source register, encoded in the "Rm" field.
- `<index>` Is the lowest numbered byte element to be extracted, encoded in “Q:imm4”:

<table>
<thead>
<tr>
<th>Q</th>
<th>imm4&lt;3&gt;</th>
<th>&lt;index&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>imm4&lt;2:0&gt;</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>RESERVED</td>
</tr>
<tr>
<td>1</td>
<td>x</td>
<td>imm4</td>
</tr>
</tbody>
</table>
Operation

```c
CheckFPAdvSIMDEnabled64();
bits(datasize) hi = V[m];
bits(datasize) lo = V[n];
bits(datasize*2) concat = hi : lo;
V[d] = concat<position+datasize-1:position>;
```

Operational information

If PSTATE.DIT is 1:

- The execution time of this instruction is independent of:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.

- The response of this instruction to asynchronous exceptions does not vary based on:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
EXTR

Extract register extracts a register from a pair of registers.

This instruction is used by the alias ROR (immediate).

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| sf | 0  | 0  | 1  | 0  | 0  | 1  | 1  | N  | 0  | 0  | 0  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | N  | 0  | 0  | 0  | 1  | 1  | 1  | 1  | 0  |
|    | Rm | imms | Rn | Rd |

32-bit (sf == 0 && N == 0 && imms == 0xxxxx)

EXTR <Wd>, <Wn>, <Wm>, #<lab>

64-bit (sf == 1 && N == 1)

EXTR <Xd>, <Xn>, <Xm>, #<lab>

```plaintext
integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rm);
integer datasize = if sf == '1' then 64 else 32;
integer lsb;

if N != sf then UNDEFINED;
if sf == '0' && imms<5> == '1' then UNDEFINED;
lsb = if N != sf then UnallocatedEncoding();
    if sf == '0' && imms<5> == '1' then ReservedValue();
    lsb = UInt(imms);
```

Assembler Symbols

- `<Wd>` Is the 32-bit name of the general-purpose destination register, encoded in the "Rd" field.
- `<Wn>` Is the 32-bit name of the first general-purpose source register, encoded in the "Rn" field.
- `<Wm>` Is the 32-bit name of the second general-purpose source register, encoded in the "Rm" field.
- `<Xd>` Is the 64-bit name of the general-purpose destination register, encoded in the "Rd" field.
- `<Xn>` Is the 64-bit name of the first general-purpose source register, encoded in the "Rn" field.
- `<Xm>` Is the 64-bit name of the second general-purpose source register, encoded in the "Rm" field.
- `<lab>` For the 32-bit variant: is the least significant bit position from which to extract, in the range 0 to 31, encoded in the "imms" field.
  For the 64-bit variant: is the least significant bit position from which to extract, in the range 0 to 63, encoded in the "imms" field.

Alias Conditions

<table>
<thead>
<tr>
<th>Alias</th>
<th>Is preferred when</th>
</tr>
</thead>
<tbody>
<tr>
<td>ROR (immediate)</td>
<td>Rn == Rn</td>
</tr>
</tbody>
</table>
operation

```
bts(datasize) result;
bts(datasize) operand1 = X[n];
bts(datasize) operand2 = X[m];
bts(2*datasize) concat = operand1:operand2;
result = concat<lsb+datasize-1:lsb>;
X[d] = result;
```

Operational information

If PSTATE.DIT is 1:

- The execution time of this instruction is independent of:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
- The response of this instruction to asynchronous exceptions does not vary based on:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.

Internal version only: isa v30.25p28.05, AdvSIMD v27.0p26.05, pseudocode v85-xml-00bet8 pc32523 ; Build timestamp: 2018-09-13 13:20:15.891440 04:04

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Floating-point Absolute Difference (vector). This instruction subtracts the floating-point values in the elements of the second source SIMD&FP register, from the corresponding floating-point values in the elements of the first source SIMD&FP register, places the absolute value of each result in a vector, and writes the vector to the destination SIMD&FP register.

This instruction can generate a floating-point exception. Depending on the settings in FPCR, the exception results in either a flag being set in FPSR, or a synchronous exception being generated. For more information, see Floating-point exception traps.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

It has encodings from 4 classes: Scalar half precision, Scalar single-precision and double-precision, Vector half precision and Vector single-precision and double-precision.

### Scalar half precision
(ARMv8.2)

FABD <Hd>, <Hn>, <Hm>

```haskell
if !HaveFP16Ext() then UNDEFINED;
integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rm);
integer esize = 16;
integer datasize = esize;
integer elements = 1;
boolean abs = TRUE;
```

### Scalar single-precision and double-precision

31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
\[
\begin{array}{cccccccccccccccccccc}
0 & 1 & 1 & 1 & 1 & 1 & 0 & 1 & 1 & 0 & 0 & 0 & 1 & 0 & 1 & 1 & Rn & Rm & Rd
\end{array}
\]

### Scalar single-precision and double-precision

FABD <V>d>, <V>n>, <V>m

```haskell
integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rm);
integer esize = 32 << UInt(sz);
integer datasize = esize;
integer elements = 1;
boolean abs = TRUE;
```

### Vector half precision
(ARMv8.2)

FABD <V>Q>
Vector half precision

FABD <Vd>, <T>, <Vn>, <T>, <Vm>, <T>

if !HaveFP16Ext() then UNDEFINED;
integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rm);
integer esize = 16;
datatype datasize = if Q == '1' then 128 else 64;
datatype elements = datasize DIV esize;
boolean abs = (U == '1');

Vector single-precision and double-precision

FABD <Vd>, <T>, <Vn>, <T>, <Vm>, <T>

integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rm);
if sz:Q == '10' then UNDEFINED;
integer esize = 32 << if sz:Q == '10' then ReservedValue();
integer esize = 32 << UInt(sz);
integer datasize = if Q == '1' then 128 else 64;
datatype elements = datasize DIV esize;
boolean abs = (U == '1');

Assembler Symbols

<Hd> Is the 16-bit name of the SIMD&FP destination register, encoded in the "Rd" field.
<Hn> Is the 16-bit name of the first SIMD&FP source register, encoded in the "Rn" field.
<Hm> Is the 16-bit name of the second SIMD&FP source register, encoded in the "Rm" field.
<V> Is a width specifier, encoded in "sz":

<table>
<thead>
<tr>
<th>sz</th>
<th>&lt;V&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>S</td>
</tr>
<tr>
<td>1</td>
<td>D</td>
</tr>
</tbody>
</table>

<d> Is the number of the SIMD&FP destination register, in the "Rd" field.
<n> Is the number of the first SIMD&FP source register, encoded in the "Rn" field.
<m> Is the number of the second SIMD&FP source register, encoded in the "Rm" field.
<Vd> Is the name of the SIMD&FP destination register, encoded in the "Rd" field.
<T> For the vector half precision variant: is an arrangement specifier, encoded in “Q”:

<table>
<thead>
<tr>
<th>Q</th>
<th>&lt;T&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>4H</td>
</tr>
<tr>
<td>1</td>
<td>8H</td>
</tr>
</tbody>
</table>

For the vector single-precision and double-precision variant: is an arrangement specifier, encoded in “sz:Q”:

<table>
<thead>
<tr>
<th>sz</th>
<th>Q</th>
<th>&lt;T&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>2S</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>4S</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>RESERVED</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>2D</td>
</tr>
</tbody>
</table>
<Vn> Is the name of the first SIMD&FP source register, encoded in the "Rn" field.
<Vm> Is the name of the second SIMD&FP source register, encoded in the "Rm" field.

**Operation**

```c
void CheckFPAdvSIMDEnabled64()
{
    bits(datasize) operand1 = V[n];
    bits(datasize) operand2 = V[m];
    bits(datasize) result;
    bits(esize) element1;
    bits(esize) element2;
    bits(esize) diff;
    for e = 0 to elements-1
        element1 = Elem[operand1, e, esize];
        element2 = Elem[operand2, e, esize];
        diff = FPSub(element1, element2, FPCR);
        Elem[result, e, esize] = if abs then FPAbs(diff) else diff;
    V[d] = result;
}
```

Internal version only: isa v30.25 v29.05, AdvSIMD v27.01 v26.0, pseudocode v85-xml-00bet8_rc3v3; Build timestamp: 2018-09-13T13:2018-06-16T09:45:045

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FABS (vector)

Floating-point Absolute value (vector). This instruction calculates the absolute value of each vector element in the source SIMD&FP register, writes the result to a vector, and writes the vector to the destination SIMD&FP register.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

It has encodings from 2 classes: Half-precision and Single-precision and double-precision

**Half-precision**

(ARMv8.2)

```
| 31  | 30  | 29  | 28  | 27  | 26  | 25  | 24  | 23  | 22  | 21  | 20  | 19  | 18  | 17  | 16  | 15  | 14  | 13  | 12  | 11  | 10  |  9  |  8  |  7  |  6  |  5  |  4  |  3  |  2  |  1  |  0  |
|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| 0   | Q   | 0   | 0   | 1   | 1   | 1   | 0   | 1   | 1   | 1   | 1   | 1   | 0   | 0   | 0   | 1   | 1   | 1   | 1   | 1   | 1   | 0   |     |     |     |     |     |     |
| U   | Rd  |
```

Half-precision

```
FABS <Vd>.<T>, <Vn>.<T>

if !HaveFP16Ext() then UNDEFINED;

integer d = UInt(Rd);
integer n = UInt(Rn);

integer esize = 16;
integer datasize = if Q == '1' then 128 else 64;
integer elements = datasize DIV esize;
neg = (U == '1');
```

**Single-precision and double-precision**

```
| 31  | 30  | 29  | 28  | 27  | 26  | 25  | 24  | 23  | 22  | 21  | 20  | 19  | 18  | 17  | 16  | 15  | 14  | 13  | 12  | 11  | 10  |  9  |  8  |  7  |  6  |  5  |  4  |  3  |  2  |  1  |  0  |
|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| 0   | Q   | 0   | 0   | 1   | 1   | 1   | 0   | 1   | 0   | 0   | 0   | 0   | 0   | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 0   |     |     |     |     |     |     |
| U   | Rd  |
```

Single-precision and double-precision

```
FABS <Vd>.<T>, <Vn>.<T>

integer d = UInt(Rd);
neg = (U == '1');
```

Assembler Symbols

- `<Vd>` Is the name of the SIMD&FP destination register, encoded in the "Rd" field.
- `<T>` For the half-precision variant: is an arrangement specifier, encoded in “Q”:

```
Q <T>
  0  AH
  1  BH
```

FABS (vector)
For the single-precision and double-precision variant: is an arrangement specifier, encoded in “sz:Q”:

<table>
<thead>
<tr>
<th>sz</th>
<th>Q</th>
<th>&lt;T&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>2S</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>4S</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>RESERVED</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>2D</td>
</tr>
</tbody>
</table>

Vin is the name of the SIMD&FP source register, encoded in the "Rn" field.

**Operation**

```c
CheckFPAdvSIMDEnabled64();
bits(datasize) operand = V[n];
bits(datasize) result;
bits(esize) element;

for e = 0 to elements-1
    element = Elem[operand, e, esize];
    if neg then
        element = FPNeg(element);
    else
        element = FPAbs(element);
    Elem[result, e, esize] = element;
V[d] = result;
```

(Internal version only: isa v30.25, AdvSIMD v27.0, pseudocode v85-xml-00bet8_rc3-v35.3; Build timestamp: 2018-09-13T13:2018-06-16T08:04:45)

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FABS (scalar)

Floating-point Absolute value (scalar). This instruction calculates the absolute value in the SIMD&FP source register and writes the result to the SIMD&FP destination register.

Depending on the settings in the \texttt{CPACR\_EL1}, \texttt{CPTR\_EL2}, and \texttt{CPTR\_EL3} registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

| 31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0 |
|-----------------------------------------------|-----------------|-----------------|
| 0 0 0 1 1 1 0 | type | 1 0 0 0 0 | 0 1 1 0 0 0 |
| opc |

Half-precision (type == 11) 
(ARMv8.2)

\[ \text{FABS} \ <\Hd>, \ <\Hn> \]

Single-precision (type == 00)

\[ \text{FABS} \ <\Sd>, \ <\Sn> \]

Double-precision (type == 01)

\[ \text{FABS} \ <\Dd>, \ <\Dn> \]

```plaintext
integer d = \textbf{UInt}(Rd);
integer n = \textbf{UInt}(Rn);

integer datasize;
case type of
  when '00' datasize = 32;
  when '01' datasize = 64;
  when '10' \textbf{UNDEFINED};
  when '11' \textbf{if}
    when '10' UnallocatedEncoding();
    when '11' if HaveFP16Ext() then
      datasize = 16;
    else
      UnallocatedEncoding() then
        datasize = 16;
    else
      \textbf{UNDEFINED}();

FPUnaryOp fpop;
case opc of
  when '00' fpop = FPUnaryOp\_MOV;
  when '01' fpop = FPUnaryOp\_ABS;
  when '10' fpop = FPUnaryOp\_NEG;
  when '11' fpop = FPUnaryOp\_SQRT;
```

Assembler Symbols

- \texttt{<Dd>} Is the 64-bit name of the SIMD&FP destination register, encoded in the "Rd" field.
- \texttt{<Dn>} Is the 64-bit name of the SIMD&FP source register, encoded in the "Rn" field.
- \texttt{<Hd>} Is the 16-bit name of the SIMD&FP destination register, encoded in the "Rd" field.
- \texttt{<Hn>} Is the 16-bit name of the SIMD&FP source register, encoded in the "Rn" field.
- \texttt{<Sd>} Is the 32-bit name of the SIMD&FP destination register, encoded in the "Rd" field.
- \texttt{<Sn>} Is the 32-bit name of the SIMD&FP source register, encoded in the "Rn" field.
Operation

```c
CheckFPAdvSIMEnabled64();

bits(datasize) result;
bits(datasize) operand = V[n];

case fpop of
    when FPUnaryOp_MOV result = operand;
    when FPUnaryOp_ABS result = FPAbs(operand);
    when FPUnaryOp_NEG result = FPNeg(operand);
    when FPUnaryOp_SQRT result = FPSqrt(operand, FPCR);

V[d] = result;
```

Internal version only: isa v30.25, AdvSIMD v27.01, pseudocode v85-xml-00bet8_rc3b5; Build timestamp: 2018-09-13T13:2018-06-16T09:04:45

Copyright © 2010-2018 ARM Limited or its affiliates. All rights reserved. This document is Non-Confidential.
Floating-point Absolute Compare Greater than or Equal (vector). This instruction compares the absolute value of each floating-point value in the first source SIMD&FP register with the absolute value of the corresponding floating-point value in the second source SIMD&FP register and if the first value is greater than or equal to the second value sets every bit of the corresponding vector element in the destination SIMD&FP register to one, otherwise sets every bit of the corresponding vector element in the destination SIMD&FP register to zero.

This instruction can generate a floating-point exception. Depending on the settings in FPCR, the exception results in either a flag being set in FPSR, or a synchronous exception being generated. For more information, see Floating-point exception traps.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

It has encodings from 4 classes: Scalar half precision, Scalar single-precision and double-precision, Vector half precision and Vector single-precision and double-precision

Scalar half precision

(ARMv8.2)

31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
0 1 1 1 1 1 1 0 | 0 1 0 | Rm | 0 0 1 0 | 1 1 | Rn | Rd | ac
U E ac

Scalar single-precision and double-precision

31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
0 1 1 1 1 1 1 0 | 0 sz 1 | Rm | 1 1 1 0 | 1 1 | Rn | Rd | ac
U E ac
Scalar single-precision and double-precision

FACGE <V><d>, <V><n>, <V><m>

integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rm);
integer esize = 32 << UInt(sz);
integer datasize = esize;
integer elements = 1;
CompareOp cmp;
boolean abs;

case E:U:ac of
  when '000' cmp = CompareOp_EQ; abs = FALSE;
  when '010' cmp = CompareOp_GE; abs = FALSE;
  when '011' cmp = CompareOp_GE; abs = TRUE;
  when '110' cmp = CompareOp_GT; abs = FALSE;
  when '111' cmp = CompareOp_GT; abs = TRUE;
  otherwise UNDEFINED;

Vector half precision

(ARMv8.2)

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9  | 8  | 7  | 6  | 5  | 4  | 3  | 2  | 1  | 0  |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| U  | E  | Q | 1 | 0 | 1 | 1 | 1 | 0 | 0 | 1 | 0 |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| Rd | Rn |

Vector half precision

FACGE <Vd><T>, <Vn><T>, <Vm><T>

if !HaveFP16Ext() then UNDEFINED;

integer d = Uni(Rd);
integer n = Uni(Rn);
integer m = Uni(Rm);
integer esize = 16;
integer datasize = if Q == '1' then 128 else 64;
integer elements = datasize DIV esize;
CompareOp cmp;
boolean abs;

case E:U:ac of
  when '000' cmp = CompareOp_EQ; abs = FALSE;
  when '010' cmp = CompareOp_GE; abs = FALSE;
  when '011' cmp = CompareOp_GE; abs = TRUE;
  when '110' cmp = CompareOp_GT; abs = FALSE;
  when '111' cmp = CompareOp_GT; abs = TRUE;
  otherwise UNDEFINED;

Vector single-precision and double-precision

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9  | 8  | 7  | 6  | 5  | 4  | 3  | 2  | 1  | 0  |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| U  | E  | Q | 1 | 0 | 1 | 1 | 1 | 0 | 0 | sz | 1 |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| Rd | Rn |

FACGE
Vector single-precision and double-precision

FACGE <Vd>.<T>, <Vn>.<T>, <Vm>.<T>

integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rm);
if sz:Q == '10' then UNDEFINED;
integer esize = 32 << UInt(sz);
integer datasize = if Q == '1' then 128 else 64;
integer elements = datasize DIV esize;
CompareOp cmp;
boolean abs;

case E:U:ac of
  when '000' cmp = CompareOp_EQ; abs = FALSE;
  when '010' cmp = CompareOp_GE; abs = FALSE;
  when '011' cmp = CompareOp_GE; abs = TRUE;
  when '110' cmp = CompareOp_GT; abs = FALSE;
  when '111' cmp = CompareOp_GT; abs = TRUE;
  otherwise UnallocatedEncoding; abs = TRUE;
  otherwise UNDEFINED;

Assembler Symbols

<Hd> Is the 16-bit name of the SIMD&FP destination register, encoded in the "Rd" field.
<Hn> Is the 16-bit name of the first SIMD&FP source register, encoded in the "Rn" field.
<Hm> Is the 16-bit name of the second SIMD&FP source register, encoded in the "Rm" field.
<V> Is a width specifier, encoded in "sz":

<table>
<thead>
<tr>
<th>sz</th>
<th>&lt;V&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>S</td>
</tr>
<tr>
<td>1</td>
<td>D</td>
</tr>
</tbody>
</table>

<d> Is the number of the SIMD&FP destination register, in the "Rd" field.
<n> Is the number of the first SIMD&FP source register, encoded in the "Rn" field.
<m> Is the number of the second SIMD&FP source register, encoded in the "Rm" field.
<Vd> Is the name of the SIMD&FP destination register, encoded in the "Rd" field.
<T> For the vector half precision variant: is an arrangement specifier, encoded in "Q":

<table>
<thead>
<tr>
<th>Q</th>
<th>&lt;T&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>4H</td>
</tr>
<tr>
<td>1</td>
<td>8H</td>
</tr>
</tbody>
</table>

For the vector single-precision and double-precision variant: is an arrangement specifier, encoded in "sz:Q":

<table>
<thead>
<tr>
<th>sz</th>
<th>Q</th>
<th>&lt;T&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>2S</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>4S</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>RESERVED</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>2D</td>
</tr>
</tbody>
</table>

<Vn> Is the name of the first SIMD&FP source register, encoded in the "Rn" field.
<Vm> Is the name of the second SIMD&FP source register, encoded in the "Rm" field.
Operation

```c
CheckFPAdvSIMDEnabled64();
bits(datasize) operand1 = V[n];
bits(datasize) operand2 = V[m];
bits(datasize) result;
bits(esize) element1;
bits(esize) element2;
boolean test_passed;

for e = 0 to elements-1
    element1 = Elem[operand1, e, esize];
    element2 = Elem[operand2, e, esize];
    if abs then
        element1 = FPAbs(element1);
        element2 = FPAbs(element2);
    case cmp of
        when CompareOp_EQ test_passed = FPCompareEQ(element1, element2, FPCR);
        when CompareOp_GE test_passed = FPCompareGE(element1, element2, FPCR);
        when CompareOp_GT test_passed = FPCompareGT(element1, element2, FPCR);
    Elem[result, e, esize] = if test_passed then Ones() else Zeros();

V[d] = result;
```


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FACGT

Floating-point Absolute Compare Greater than (vector). This instruction compares the absolute value of each vector element in the first source SIMD&FP register with the absolute value of the corresponding vector element in the second source SIMD&FP register and if the first value is greater than the second value sets every bit of the corresponding vector element in the destination SIMD&FP register to one, otherwise sets every bit of the corresponding vector element in the destination SIMD&FP register to zero.

This instruction can generate a floating-point exception. Depending on the settings in \textit{FPCR}, the exception results in either a flag being set in \textit{FPSR}, or a synchronous exception being generated. For more information, see Floating-point exception traps.

Depending on the settings in the \textit{CPACR_EL1}, \textit{CPTR_EL2}, and \textit{CPTR_EL3} registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

It has encodings from 4 classes: Scalar half precision, Scalar single-precision and double-precision, Vector half precision and Vector single-precision and double-precision

Scalar half precision

\textbf{(ARMv8.2)}

\begin{center}
\begin{tabular}{cccccccccccccccccccc}
\hline
0 & 1 & 1 & 1 & 1 & 1 & 0 & 1 & 1 & 0 & Rm & 0 & 0 & 1 & 0 & 1 & 1 & Rn & Rd & \qquad & U & E & ac
\end{tabular}
\end{center}

Scalar single-precision and double-precision

\begin{center}
\begin{tabular}{cccccccccccccccccccc}
\hline
0 & 1 & 1 & 1 & 1 & 1 & 0 & 1 & sz & 1 & Rm & 1 & 1 & 1 & 0 & 1 & 1 & Rn & Rd & \qquad & U & E & ac
\end{tabular}
\end{center}
Scalar single-precision and double-precision

```c
FACGT <V><d>, <V><n>, <V><m>

integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rm);
integer esize = 32 << UInt(sz);
integer datasize = esize;
integer elements = 1;
CompareOp cmp;
boolean abs;

case E:U:ac of
  when '000' cmp = CompareOp_EQ; abs = FALSE;
  when '010' cmp = CompareOp_GE; abs = FALSE;
  when '011' cmp = CompareOp_GE; abs = TRUE;
  when '110' cmp = CompareOp_GT; abs = FALSE;
  when '111' cmp = CompareOp_GT; abs = TRUE;
  otherwise UNDEFINED;

Vector half precision
(ARMv8.2)

<table>
<thead>
<tr>
<th>31</th>
<th>30</th>
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<th>28</th>
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<th>9</th>
<th>8</th>
<th>7</th>
<th>6</th>
<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Q</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1</td>
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<td>1</td>
<td>Rm</td>
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<td>Rn</td>
<td>Rd</td>
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<td>ac</td>
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</tr>
</tbody>
</table>

Vector half precision

FACGT <Vd>.<T>, <Vn>.<T>, <Vm>.<T>

if !HaveFP16Ext() then UNDEFINED;

integer d = -1 then UnallocatedEncoding();

integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rm);
integer esize = 16;
integer datasize = if Q == '1' then 128 else 64;
integer elements = datasize DIV esize;
CompareOp cmp;
boolean abs;

case E:U:ac of
  when '000' cmp = CompareOp_EQ; abs = FALSE;
  when '010' cmp = CompareOp_GE; abs = FALSE;
  when '011' cmp = CompareOp_GE; abs = TRUE;
  when '110' cmp = CompareOp_GT; abs = FALSE;
  when '111' cmp = CompareOp_GT; abs = TRUE;
  otherwise UnallocatedEncoding(); abs = TRUE;
  otherwise UNDEFINED;

Vector single-precision and double-precision

<table>
<thead>
<tr>
<th>31</th>
<th>30</th>
<th>29</th>
<th>28</th>
<th>27</th>
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<th>8</th>
<th>7</th>
<th>6</th>
<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Q</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>1</td>
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<td>1</td>
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<td>1</td>
<td>Rm</td>
<td>sz</td>
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<td>1</td>
<td>Rn</td>
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<td>U</td>
<td>E</td>
<td>ac</td>
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</tr>
</tbody>
</table>
```

FACGT
Vector single-precision and double-precision

FACGT <Vd>.<T>, <Vn>.<T>, <Vm>.<T>

integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rm);
if sz:Q == '10' then UNDEFINED;
integer esize = 32 <if sz:Q == '10' then ReservedValue();
integer datasize = if Q == '1' then 128 else 64;
integer elements = datasize DIV esize;
CompareOp cmp;
boolean abs;

case E:U:ac of
  when '000' cmp = CompareOp_EQ; abs = FALSE;
  when '010' cmp = CompareOp_GE; abs = FALSE;
  when '011' cmp = CompareOp_GE; abs = TRUE;
  when '110' cmp = CompareOp_GT; abs = FALSE;
  when '111' cmp = CompareOp_GT; abs = TRUE;
otherwise  UnallocatedEncoding; abs = TRUE;
otherwise  UNDEFINED;

Assembler Symbols

<Hd>   Is the 16-bit name of the SIMD&FP destination register, encoded in the "Rd" field.
<Hn>   Is the 16-bit name of the first SIMD&FP source register, encoded in the "Rn" field.
<Hm>   Is the 16-bit name of the second SIMD&FP source register, encoded in the "Rm" field.
<V> Is a width specifier, encoded in "sz":

<table>
<thead>
<tr>
<th>sz</th>
<th>&lt;V&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>S</td>
</tr>
<tr>
<td>1</td>
<td>D</td>
</tr>
</tbody>
</table>

<d>   Is the number of the SIMD&FP destination register, in the "Rd" field.
<n>   Is the number of the first SIMD&FP source register, encoded in the "Rn" field.
<m>   Is the number of the second SIMD&FP source register, encoded in the "Rm" field.
<Vd>  Is the name of the SIMD&FP destination register, encoded in the "Rd" field.
<T>  For the vector half precision variant: is an arrangement specifier, encoded in “Q”:

<table>
<thead>
<tr>
<th>Q</th>
<th>&lt;T&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>4H</td>
</tr>
<tr>
<td>1</td>
<td>8H</td>
</tr>
</tbody>
</table>

For the vector single-precision and double-precision variant: is an arrangement specifier, encoded in "sz:Q”:

<table>
<thead>
<tr>
<th>sz</th>
<th>Q</th>
<th>&lt;T&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>2S</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>4S</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>RESERVED</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>2D</td>
</tr>
</tbody>
</table>

<Vn>   Is the name of the first SIMD&FP source register, encoded in the "Rn" field.
<Vm>   Is the name of the second SIMD&FP source register, encoded in the "Rm" field.
Operation

```c
CheckFPAdvSIMDEnabled64();

bits(datasize) operand1 = \texttt{V}[n];
bits(datasize) operand2 = \texttt{V}[m];
bits(datasize) result;
bits(esize) element1;
bits(esize) element2;
boolean test_passed;

for e = 0 to elements-1
  element1 = \texttt{Elem}[operand1, e, esize];
  element2 = \texttt{Elem}[operand2, e, esize];
  if abs then
    element1 = \texttt{FPAbs}(element1);
    element2 = \texttt{FPAbs}(element2);
  case cmp of
    when \texttt{CompareOp_EQ} test_passed = \texttt{FPCompareEQ}(element1, element2, FPCR);
    when \texttt{CompareOp_GE} test_passed = \texttt{FPCompareGE}(element1, element2, FPCR);
    when \texttt{CompareOp_GT} test_passed = \texttt{FPCompareGT}(element1, element2, FPCR);
  \texttt{Elem}[result, e, esize] = if test_passed then \texttt{Ones()} else \texttt{Zeros}();

\texttt{V}[d] = result;
```


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FADD (vector)

Floating-point Add (vector). This instruction adds corresponding vector elements in the two source SIMD&FP registers, writes the result into a vector, and writes the vector to the destination SIMD&FP register. All the values in this instruction are floating-point values.

This instruction can generate a floating-point exception. Depending on the settings in $FPSCR$, the exception results in either a flag being set in $FPSCR$ or a synchronous exception being generated. For more information, see Floating-point exception traps.

Depending on the settings in the $CPACR_EL1$, $CPTR_EL2$, and $CPTR_EL3$ registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

It has encodings from 2 classes: Half-precision and Single-precision and double-precision

**Half-precision**

(ARMv8.2)

**Single-precision and double-precision**

**Assembler Symbols**

$<Vd>$ Is the name of the SIMD&FP destination register, encoded in the "Rd" field.

$<T>$ For the half-precision variant: is an arrangement specifier, encoded in “Q”:
For the single-precision and double-precision variant: is an arrangement specifier, encoded in “sz:Q”:

<table>
<thead>
<tr>
<th>sz</th>
<th>0</th>
<th>1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q</td>
<td>4H</td>
<td>8H</td>
</tr>
</tbody>
</table>

operate on

<table>
<thead>
<tr>
<th>sz</th>
<th>0</th>
<th>1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q</td>
<td>2S</td>
<td>4S</td>
</tr>
</tbody>
</table>

reserved

<table>
<thead>
<tr>
<th>sz</th>
<th>1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>sz</th>
<th>1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q</td>
<td>2D</td>
</tr>
</tbody>
</table>

<\text{n}> Is the name of the first SIMD&FP source register, encoded in the “Rn” field.

<\text{m}> Is the name of the second SIMD&FP source register, encoded in the “Rm” field.

**Operation**

```c
CheckFPAdvSIMDEnabled64();

bits(datasize) operand1 = V[n];
bits(datasize) operand2 = V[m];
bits(datasize) result;
bits(2*datasize) concat = operand2:operand1;
bits(esize) element1;
bits(esize) element2;
for e = 0 to elements-1
  if pair then
    element1 = Elem[concat, 2*e, esize];
    element2 = Elem[concat, (2*e)+1, esize];
  else
    element1 = Elem[operand1, e, esize];
    element2 = Elem[operand2, e, esize];
  Elem[result, e, esize] = FPAdd(element1, element2, FPCR);
V[d] = result;
```

Internal version only: isa 
AdvSIMD 
build timestamp: 2018-09-13T13:45
Build timestamp: 2018-06-16T09:45
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FADD (scalar)

Floating-point Add (scalar). This instruction adds the floating-point values of the two source SIMD&FP registers, and writes the result to the destination SIMD&FP register.

This instruction can generate a floating-point exception. Depending on the settings in FPCR, the exception results in either a flag being set in FPSR, or a synchronous exception being generated. For more information, see Floating-point exception traps.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

Half-precision (type == 11)
(ARMv8.2)

FADD <Hd>, <Hn>, <Hm>

Single-precision (type == 00)

FADD <Sd>, <Sn>, <Sm>

Double-precision (type == 01)

FADD <Dd>, <Dn>, <Dm>

```java
int d = Uint(Rd);
int n = Uint(Rn);
int m = Uint(Rm);

int datasize;
switch (type) {
    case '00': datasize = 32;
    case '01': datasize = 64;
    case '10': UNDEFINED;
    case '11':
        if (type == '11') UnallocatedEncoding();
        if HaveFP16Ext() then
            datasize = 16;
        else
            datasize = 16;
        else
            UNDEFINED;
    default:
        UNDEFINED;
}
boolean sub_op = (op == '1');
```

Assembler Symbols

- `<Dd>` Is the 64-bit name of the SIMD&FP destination register, encoded in the "Rd" field.
- `<Dn>` Is the 64-bit name of the first SIMD&FP source register, encoded in the "Rn" field.
- `<Dm>` Is the 64-bit name of the second SIMD&FP source register, encoded in the "Rm" field.
- `<Hd>` Is the 16-bit name of the SIMD&FP destination register, encoded in the "Rd" field.
- `<Hn>` Is the 16-bit name of the first SIMD&FP source register, encoded in the "Rn" field.
- `<Hm>` Is the 16-bit name of the second SIMD&FP source register, encoded in the "Rm" field.
<Sd> Is the 32-bit name of the SIMD&FP destination register, encoded in the “Rd” field.
<Sn> Is the 32-bit name of the first SIMD&FP source register, encoded in the “Rn” field.
<Sm> Is the 32-bit name of the second SIMD&FP source register, encoded in the “Rm” field.

**Operation**

```c
CheckFPAdvSIMDEnabled64();
bits(datasize) result;
bits(datasize) operand1 = V[n];
bits(datasize) operand2 = V[m];

if sub_op then
    result = FPSub(operand1, operand2, FPCR);
else
    result = FPAdd(operand1, operand2, FPCR);
V[d] = result;
```

Internal version only: isa v30.25 <br>v29.05 <br>v27.01 <br>v26.0 <br>pseudocode v85-xml-00bet8_rc3b5a <br>Build timestamp: 2018-09-13T11:2018-06-16T04:04:45

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FADDP (scalar)

Floating-point Add Pair of elements (scalar). This instruction adds two floating-point vector elements in the source SIMD&FP register and writes the scalar result into the destination SIMD&FP register.

This instruction can generate a floating-point exception. Depending on the settings in FPCR, the exception results in either a flag being set in FPSR or a synchronous exception being generated. For more information, see Floating-point exception traps.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

It has encodings from 2 classes: Half-precision and Single-precision and double-precision

### Half-precision

(ARMv8.2)

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9  | 8  | 7  | 6  | 5  | 4  | 3  | 2  | 1  | 0  |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
|    |    |    |    |    |    |    |    |    |    |    | 1  | 1  | 1  | 1  | 0  |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
|    | Rn |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |

<table>
<thead>
<tr>
<th>sz</th>
</tr>
</thead>
</table>

**Half-precision**

FADDP <V><d>, <Vn>.<T>

```plaintext
if !HaveFP16Ext() then UNDEFINED;
integer d = 0 then UnallocatedEncoding();
integer d = UInt(Rd);
integer n = UInt(Rn);
integer esize = 16;
if sz == '1' then ReservedValue(Rn);
integer esize = 16;
if sz == '1' then UNDEFINED;
integer datasize = esize * 2;
integer elements = 2;
ReduceOp op = ReduceOp_FADD;
```

### Single-precision and double-precision

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9  | 8  | 7  | 6  | 5  | 4  | 3  | 2  | 1  | 0  |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
|    |    |    |    |    |    |    |    |    |    | 1  | 1  | 1  | 1  | 0  |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
|    | Rn |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |

<table>
<thead>
<tr>
<th>sz</th>
</tr>
</thead>
</table>

**Single-precision and double-precision**

FADDP <V><d>, <Vn>.<T>

```plaintext
integer d = UInt(Rd);
integer n = UInt(Rn);

integer esize = 32 << UInt(sz);
integer datasize = esize * 2;
integer elements = 2;
ReduceOp op = ReduceOp_FADD;
```

### Assembler Symbols

For the half-precision variant: is the destination width specifier, encoded in “sz”:
For the single-precision and double-precision variant: is the destination width specifier, encoded in “sz”:

| sz | V < 0 | H | 1 | RESERVED |

Is the number of the SIMD&FP destination register, encoded in the "Rd" field.

| d | S | 1 | D |

Is the name of the SIMD&FP source register, encoded in the "Rn" field.

| T | 0 | 2H | 1 | RESERVED |

For the half-precision variant: is the source arrangement specifier, encoded in “sz”:

| sz | T < 0 | 2S | 1 | 2D |

For the single-precision and double-precision variant: is the source arrangement specifier, encoded in “sz”:

| sz | T < 0 | 2S | 1 | 2D |

**Operation**

```c
CheckFPAdvSIMDEnabled64();
bits(datasize) operand = V[n];
V[d] = Reduce(op, operand, esize);
```

Internal version only: isa v30.25, v29.05, v35.3; Build timestamp: 2018-09-13T13:45:45

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FADDP (vector)

Floating-point Add Pairwise (vector). This instruction creates a vector by concatenating the vector elements of the first source SIMD&FP register after the vector elements of the second source SIMD&FP register, reads each pair of adjacent vector elements from the concatenated vector, adds each pair of values together, places the result into a vector, and writes the vector to the destination SIMD&FP register. All the values in this instruction are floating-point values.

This instruction can generate a floating-point exception. Depending on the settings in FPCR, the exception results in either a flag being set in FPSR or a synchronous exception being generated. For more information, see Floating-point exception traps.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

It has encodings from 2 classes: Half-precision and Single-precision and double-precision

Half-precision

(ARMv8.2)

| 0 | Q | 1 | 0 | 1 | 1 | 0 | 0 | 1 | 0 | Rm | 0 | 0 | 1 | 1 | 0 | 1 | Rn | Rd |
|---|---|---|---|---|---|---|---|---|---|----|---|---|---|---|---|---|---|---|---|
|   |   |   |   |   |   |   |   |   |   |    |   |   |   |   |   |   |   |   |   |
| U |

Half-precision

FADDP <Vd>.<T>, <Vn>.<T>, <Vm>.<T>

if !HaveFP16Ext() then UNDEFINED;
integer d = 1; then UnallocatedEncoding(1);
integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rm);
integer esize = 16;
integer datasize = if Q == '1' then 128 else 64;
integer elements = datasize DIV esize;
boolean pair = (U == '1');

Single-precision and double-precision

| 0 | Q | 1 | 0 | 1 | 1 | 0 | 0 | sz | 1 | Rm | 1 | 1 | 0 | 1 | 0 | 1 | Rn | Rd |
|---|---|---|---|---|---|---|---|---|---|----|---|---|---|---|---|---|---|---|---|
|   |   |   |   |   |   |   |   |   |   |    |   |   |   |   |   |   |   |   |   |
| U |

Single-precision and double-precision

FADDP <Vd>.<T>, <Vn>.<T>, <Vm>.<T>

integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rm);
if sz:Q == '10' then UNDEFINED;
integer esize = 32 << if sz:Q == '10' then ReservedValue(1); = 32 << UInt(sz);
integer datasize = if Q == '1' then 128 else 64;
integer elements = datasize DIV esize;
boolean pair = (U == '1');
**Assembler Symbols**

<\texttt{Vd}> Is the name of the SIMD&FP destination register, encoded in the "Rd" field.

<\texttt{T}> For the half-precision variant: is an arrangement specifier, encoded in "Q":

<table>
<thead>
<tr>
<th>\texttt{Q}</th>
<th>&lt;\texttt{T}&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>4H</td>
</tr>
<tr>
<td>1</td>
<td>8H</td>
</tr>
</tbody>
</table>

For the single-precision and double-precision variant: is an arrangement specifier, encoded in “sz:Q”:

<table>
<thead>
<tr>
<th>sz</th>
<th>Q</th>
<th>&lt;\texttt{T}&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>2S</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>4S</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>RESERVED</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>2D</td>
</tr>
</tbody>
</table>

<\texttt{Vn}> Is the name of the first SIMD&FP source register, encoded in the "Rn" field.

<\texttt{Vm}> Is the name of the second SIMD&FP source register, encoded in the "Rm" field.

**Operation**

```c
CheckFPAdvSIMDEnabled64();
bits(datasize) operand1 = \texttt{V}[n];
bits(datasize) operand2 = \texttt{V}[m];
bits(datasize) result;
bits(2*datasize) concat = operand2:operand1;
bv(size) element1;
bv(size) element2;
for e = 0 to elements-1
    if pair then
        element1 = \texttt{Elem}[concat, 2*e, esize];
        element2 = \texttt{Elem}[concat, (2*e)+1, esize];
    else
        element1 = \texttt{Elem}[operand1, e, esize];
        element2 = \texttt{Elem}[operand2, e, esize];
    \texttt{Elem}[result, e, esize] = FPAdd(element1, element2, FPCR);
\texttt{V}[d] = result;
```

Internal version only: isa \texttt{v30.25}, \texttt{v29.05}, \texttt{AdvSIMD v27.01}, \texttt{pseudocode v85-xml-00bet8_rc3e53a}; Build timestamp: 2018-09-13T13:21:54.044Z

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FCADD

Floating-point Complex Add.

This instruction operates on complex numbers that are represented in SIMD&FP registers as pairs of elements, with the more significant element holding the imaginary part of the number and the less significant element holding the real part of the number. Each element holds a floating-point value. It performs the following computation on the corresponding complex number element pairs from the two source registers:

- Considering the complex number from the second source register on an Argand diagram, the number is rotated counterclockwise by 90 or 270 degrees.
- The rotated complex number is added to the complex number from the first source register.

This instruction can generate a floating-point exception. Depending on the settings in FPCR, the exception results in either a flag being set in FPSR or a synchronous exception being generated. For more information, see Floating-point exception traps.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

Three registers of the same type
(ARMv8.3)

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0  | Q  | 1  | 0  | 1  | 1  | 0  | size | 0  | Rm | 1  | 1  | 1  | rot | 0  | 1  | 1  | 0  | 1  | 1  | 0  | Rn | Rd |

Three registers of the same type

FCADD <Vd>.<T>, <Vn>.<T>, <Vm>.<T>, #<rotate>

if !HaveFCADDExt() then UNDEFINED;
integer d = if d != 4 then UnallocatedEncoding();
integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rm);
if Q == '00' then UNDEFINED;
if Q == '0' && size == '11' then UNDEFINED;
integer esize = 8 << if size == '00' then ReservedValue();
if Q == '0' && size == '11' then ReservedValue();
integer esize = 8 << UInt(size);
if !HaveFP16Ext() && esize == 16 then ReservedValue() && esize == 16 then UNDEFINED;
integer datasize = if Q == '1' then 128 else 64;
integer elements = datasize DIV esize;

Assembler Symbols

<Vd>    Is the name of the SIMD&FP destination register, encoded in the "Rd" field.
<T>    Is an arrangement specifier, encoded in "size:Q":

<table>
<thead>
<tr>
<th>size</th>
<th>Q</th>
<th>&lt;T&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>x</td>
<td>RESERVED</td>
</tr>
<tr>
<td>01</td>
<td>0</td>
<td>4H</td>
</tr>
<tr>
<td>01</td>
<td>1</td>
<td>8H</td>
</tr>
<tr>
<td>10</td>
<td>0</td>
<td>2S</td>
</tr>
<tr>
<td>10</td>
<td>1</td>
<td>4S</td>
</tr>
<tr>
<td>11</td>
<td>0</td>
<td>RESERVED</td>
</tr>
<tr>
<td>11</td>
<td>1</td>
<td>2D</td>
</tr>
</tbody>
</table>

<Vn>    Is the name of the first SIMD&FP source register, encoded in the "Rn" field.
<Vm>    Is the name of the second SIMD&FP source register, encoded in the "Rm" field.
<rotate>    Is the rotation, encoded in "rot":

<table>
<thead>
<tr>
<th>rot</th>
<th>&lt;rotate&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>90</td>
</tr>
<tr>
<td>1</td>
<td>270</td>
</tr>
</tbody>
</table>

FCADD
Operation

```c
CheckFPAdvSIMDEnabled64();
bits(datasize) operand1 = V[n];
bits(datasize) operand2 = V[m];
bits(datasize) operand3 = V[d];
bits(datasize) result;
bits(eseize) element1;
bits(eseize) element3;

for e = 0 to (elements DIV 2) -1
    case rot of
        when '0'
            element1 = FPNeg(Elem[operand2, e*2+1, esize]);
            element3 = Elem[operand2, e*2, esize];
        when '1'
            element1 = Elem[operand2, e*2+1, esize];
            element3 = FPNeg(Elem[operand2, e*2, esize]);
    Elem[result, e*2, esize] = FPAdd(Elem[operand1, e*2, esize], element1, FPCR);
    Elem[result, e*2+1, esize] = FPAdd(Elem[operand1, e*2+1, esize], element3, FPCR);

V[d] = result;
```

Internal version only: isa v36.25 v27.0 v26.0, AdvSIMD v35.3 v27.01 v26.0, pseudocode v85-xml-00bet8_rc3-v35.3; Build timestamp: 2018-09-13T13:2018-06-16T09:45

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FCCMP

Floating-point Conditional quiet Compare (scalar). This instruction compares the two SIMD&FP source register values and writes the result to the PSTATE. {N, Z, C, V} flags. If the condition does not pass then the PSTATE. {N, Z, C, V} flags are set to the flag bit specifier.

It raises an Invalid Operation exception only if either operand is a signaling NaN.

A floating-point exception can be generated by this instruction. Depending on the settings in FPCR, the exception results in either a flag being set in FPSR, or a synchronous exception being generated. For more information, see Floating-point exception traps.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

Half-precision (type == 11)
(ARMv8.2)

FCCMP <Hn>, <Hm>, #<nzcv>, <cond>

Single-precision (type == 00)

FCCMP <Sn>, <Sm>, #<nzcv>, <cond>

Double-precision (type == 01)

FCCMP <Dn>, <Dm>, #<nzcv>, <cond>

```plaintext
integer n = UInt(Rn);
integer m = UInt(Rm);

integer datasize;

switch (type) {
  case '00': datasize = 32;
  case '01': datasize = 64;
  case '10': UNDEFINED;
  case '11':
    if (signal_all_nans) UnallocatedEncoding();
    else if (HaveFP16Ext()) then datasize = 16;
    else UnallocatedEncoding() then datasize = 16;
    else UNDEFINED;
}

boolean signal_all_nans = (op == '1');
bits(4) condition = cond;
bits(4) flags = nzcv;
```

Assembler Symbols

<Dn> Is the 64-bit name of the first SIMD&FP source register, encoded in the "Rn" field.
<Dm> Is the 64-bit name of the second SIMD&FP source register, encoded in the "Rm" field.
<Hn> Is the 16-bit name of the first SIMD&FP source register, encoded in the "Rn" field.
<Hm> Is the 16-bit name of the second SIMD&FP source register, encoded in the "Rm" field.
<Sn> Is the 32-bit name of the first SIMD&FP source register, encoded in the "Rn" field.
<Sm> Is the 32-bit name of the second SIMD&FP source register, encoded in the "Rm" field.

<nzcv> Is the flag bit specifier, an immediate in the range 0 to 15, giving the alternative state for the 4-bit NZCV condition flags, encoded in the "nzcv" field.

<cond> Is one of the standard conditions, encoded in the "cond" field in the standard way.

NaNs
The IEEE 754 standard specifies that the result of a comparison is precisely one of <, ==, > or unordered. If either or both of the operands are NaNs, they are unordered, and all three of (Operand1 < Operand2), (Operand1 == Operand2) and (Operand1 > Operand2) are false. This case results in the FPSCR flags being set to N=0, Z=0, C=1, and V=1.

Operation

```c
CheckFPAdvSIMDEnabled64();

bits(datasize) operand1 = V[n];
bits(datasize) operand2 = V[m];
if ConditionHolds(condition) then
  flags = FPCompare(operand1, operand2, signal_all_nans, FPCR);
PSTATE.<N,Z,C,V> = flags;
```

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FCCMPE

Floating-point Conditional signaling Compare (scalar). This instruction compares the two SIMD&FP source register values and writes the result to the $PSTATE\{N, Z, C, V\}$ flags. If the condition does not pass then the $PSTATE\{N, Z, C, V\}$ flags are set to the flag bit specifier.

If either operand is any type of NaN, or if either operand is a signaling NaN, the instruction raises an Invalid Operation exception.

A floating-point exception can be generated by this instruction. Depending on the settings in $FPCR$, the exception results in either a flag being set in $FPSR$, or a synchronous exception being generated. For more information, see Floating-point exception traps.

Depending on the settings in the $CPACR_EL1$, $CPTER_EL2$, and $CPTER_EL3$ registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

### Half-precision (type == 11)

(ARMv8.2)

FCCMPE $<Hn>, <Hm>, #<nzcv>, <cond>

### Single-precision (type == 00)

FCCMPE $<Sn>, <Sm>, #<nzcv>, <cond>

### Double-precision (type == 01)

FCCMPE $<Dn>, <Dm>, #<nzcv>, <cond>

```python
integer n = UInt(Rn);
integer m = UInt(Rm);

integer datasize;
  case type of
    when '00' datasize = 32;
    when '01' datasize = 64;
    when '10' UNDEFINED;
    when '11'
      if when '10' UnallocatedEncoding();
      when '11'
        if HaveFP16Ext() then
          datasize = 16;
        else
          UnallocatedEncoding() then
            datasize = 16;
          else
            UNDEFINED;
      end when;
  end case;

boolean signal_all_nans = (op == '1');
bits(4) condition = cond;
bits(4) flags = nzcv;
```

### Assembler Symbols

- $<Dn>$: Is the 64-bit name of the first SIMD&FP source register, encoded in the "Rn" field.
- $<Dm>$: Is the 64-bit name of the second SIMD&FP source register, encoded in the "Rm" field.
- $<Hn>$: Is the 16-bit name of the first SIMD&FP source register, encoded in the "Rn" field.
- $<Hm>$: Is the 16-bit name of the second SIMD&FP source register, encoded in the "Rm" field.
- $<Sn>$: Is the 32-bit name of the first SIMD&FP source register, encoded in the "Rn" field.
Is the 32-bit name of the second SIMD&FP source register, encoded in the "Rm" field.

Is the flag bit specifier, an immediate in the range 0 to 15, giving the alternative state for the 4-bit NZCV condition flags, encoded in the "nzcv" field.

Is one of the standard conditions, encoded in the "cond" field in the standard way.

NaNs

The IEEE 754 standard specifies that the result of a comparison is precisely one of <, ==, > or unordered. If either or both of the operands are NaNs, they are unordered, and all three of (Operand1 < Operand2), (Operand1 == Operand2) and (Operand1 > Operand2) are false. This case results in the FPSCR flags being set to N=0, Z=0, C=1, and V=1.

FCCMPE raises an Invalid Operation exception if either operand is any type of NaN, and is suitable for testing for <, <=, >, >=, and other predicates that raise an exception when the operands are unordered.

Operation

```c
CheckFPAdvSIMDEnabled64();

bits(datasize) operand1 = V[n];
bits(datasize) operand2;
operand2 = V[m];
if ConditionHolds(condition) then
    flags = FPCompare(operand1, operand2, signal_all_nans, FPCR);
PSTATE.<N,Z,C,V> = flags;
```

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FCMEQ (register)

Floating-point Compare Equal (vector). This instruction compares each floating-point value from the first source SIMD&FP register, with the corresponding floating-point value from the second source SIMD&FP register, and if the comparison is equal sets every bit of the corresponding vector element in the destination SIMD&FP register to one, otherwise sets every bit of the corresponding vector element in the destination SIMD&FP register to zero.

This instruction can generate a floating-point exception. Depending on the settings in FPCR, the exception results in either a flag being set in FPSR, or a synchronous exception being generated. For more information, see Floating-point exception traps.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

It has encodings from 4 classes: Scalar half precision, Scalar single-precision and double-precision, Vector half precision and Vector single-precision and double-precision

Scalar half precision

(ARMv8.2)

```
31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
<table>
<thead>
<tr>
<th>0</th>
<th>1</th>
<th>1</th>
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<th>1</th>
<th>0</th>
<th>0</th>
<th>1</th>
<th>0</th>
<th>1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rm</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>Rn</td>
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</tr>
</tbody>
</table>
```

Scalar single-precision and double-precision

```
31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
<table>
<thead>
<tr>
<th>0</th>
<th>1</th>
<th>1</th>
<th>1</th>
<th>1</th>
<th>0</th>
<th>0</th>
<th>sz</th>
<th>1</th>
<th>1</th>
<th>1</th>
<th>0</th>
<th>0</th>
<th>1</th>
<th>Rn</th>
<th>Rd</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rm</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>Rn</td>
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</tr>
</tbody>
</table>
Scalar single-precision and double-precision

FCMEQ <V><d>, <V><n>, <V><m>

integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rm);
integer esize = 32 << UInt(sz);
integer datasize = esize;
integer elements = 1;
CompareOp cmp;
boolean abs;

case E:U:ac of
  when '000' cmp = CompareOp_EQ; abs = FALSE;
  when '010' cmp = CompareOp_GE; abs = FALSE;
  when '011' cmp = CompareOp_GE; abs = TRUE;
  when '110' cmp = CompareOp_GT; abs = FALSE;
  when '111' cmp = CompareOp_GT; abs = TRUE;
  otherwise UNDEFINED;
otherwise UnallocatedEncoding();

Vector half precision

(ARMv8.2)

<table>
<thead>
<tr>
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<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Q</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>Rm</td>
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</tr>
</tbody>
</table>

Vector half precision

FCMEQ <Vd>.<T>, <Vn>.<T>, <Vm>.<T>

if !HaveFP16Ext() then UNDEFINED;

integer d =-1 then UnallocatedEncoding();

integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rm);
integer esize = 16;
integer datasize = if Q == '1' then 128 else 64;
integer elements = datasize DIV esize;
CompareOp cmp;
boolean abs;

case E:U:ac of
  when '000' cmp = CompareOp_EQ; abs = FALSE;
  when '010' cmp = CompareOp_GE; abs = FALSE;
  when '011' cmp = CompareOp_GE; abs = TRUE;
  when '110' cmp = CompareOp_GT; abs = FALSE;
  when '111' cmp = CompareOp_GT; abs = TRUE;
  otherwise UnallocatedEncoding(); abs = TRUE;
  otherwise UNDEFINED; }

Vector single-precision and double-precision

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<th>27</th>
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<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Q</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>sz</td>
<td>1</td>
<td>Rm</td>
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<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>Rn</td>
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<td>Rd</td>
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</tr>
</tbody>
</table>
Vector single-precision and double-precision

FCMEQ <Vd>.<T>, <Vn>.<T>, <Vm>.<T>

integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rm);
if sz:Q == '10' then UNDEFINED;
integer esize = 32 << UInt(sz);
integer datasize = if Q == '1' then 128 else 64;
integer elements = datasize DIV esize;
CompareOp cmp;
boolean abs;
case E:U:ac of
  when '000' cmp = CompareOp_EQ; abs = FALSE;
  when '010' cmp = CompareOp_GE; abs = FALSE;
  when '011' cmp = CompareOp_EQ; abs = TRUE;
  when '110' cmp = CompareOp_GT; abs = FALSE;
  when '111' cmp = CompareOp_GT; abs = TRUE;
  otherwise UnallocatedEncoding; abs = TRUE;
otherwise UNDEFINED;

Assembler Symbols

<Hd> Is the 16-bit name of the SIMD&FP destination register, encoded in the "Rd" field.
<Hn> Is the 16-bit name of the first SIMD&FP source register, encoded in the "Rn" field.
<Hm> Is the 16-bit name of the second SIMD&FP source register, encoded in the "Rm" field.
<V> Is a width specifier, encoded in "sz":

<table>
<thead>
<tr>
<th>sz</th>
<th>&lt;V&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>S</td>
</tr>
<tr>
<td>1</td>
<td>D</td>
</tr>
</tbody>
</table>

<d> Is the number of the SIMD&FP destination register, in the "Rd" field.
<n> Is the number of the first SIMD&FP source register, encoded in the "Rn" field.
<m> Is the number of the second SIMD&FP source register, encoded in the "Rm" field.
<Vd> Is the name of the SIMD&FP destination register, encoded in the "Rd" field.
<T> For the vector half precision variant: is an arrangement specifier, encoded in "Q":

<table>
<thead>
<tr>
<th>Q</th>
<th>&lt;T&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>4H</td>
</tr>
<tr>
<td>1</td>
<td>8H</td>
</tr>
</tbody>
</table>

For the vector single-precision and double-precision variant: is an arrangement specifier, encoded in "sz:Q":

<table>
<thead>
<tr>
<th>sz</th>
<th>Q</th>
<th>&lt;T&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>2S</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>4S</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>RESERVED</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>2D</td>
</tr>
</tbody>
</table>

<Vn> Is the name of the first SIMD&FP source register, encoded in the "Rn" field.
<Vm> Is the name of the second SIMD&FP source register, encoded in the "Rm" field.
Operation

```c
CheckFPAdvSIMDEnabled64();
bits(datasize) operand1 = V[n];
bits(datasize) operand2 = V[m];
bits(datasize) result;
bits(esize) element1;
bits(esize) element2;
boolean test_passed;
for e = 0 to elements-1
    element1 = Elem[operand1, e, esize];
    element2 = Elem[operand2, e, esize];
    if abs then
        element1 = FPAbs(element1);
        element2 = FPAbs(element2);
    case cmp of
        when CompareOp_EQ test_passed = FPCompareEQ(element1, element2, FPCR);
        when CompareOp_GE test_passed = FPCompareGE(element1, element2, FPCR);
        when CompareOp_GT test_passed = FPCompareGT(element1, element2, FPCR);
        Elem[result, e, esize] = if test_passed then Ones() else Zeros();
    V[d] = result;
```

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FCMEQ (zero)

Floating-point Compare Equal to zero (vector). This instruction reads each floating-point value in the source SIMD&FP register and if the value is equal to zero sets every bit of the corresponding vector element in the destination SIMD&FP register to one, otherwise sets every bit of the corresponding vector element in the destination SIMD&FP register to zero.

This instruction can generate a floating-point exception. Depending on the settings in FPCR, the exception results in either a flag being set in FPSR, or a synchronous exception being generated. For more information, see Floating-point exception traps.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

It has encodings from 4 classes: Scalar half precision, Scalar single-precision and double-precision, Vector half precision, and Vector single-precision and double-precision.

Scalar half precision

(ARMv8.2)

<table>
<thead>
<tr>
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</tr>
</thead>
<tbody>
<tr>
<td>0</td>
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<td>1</td>
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</tr>
</tbody>
</table>

Scalar half precision

FCMEQ <Hd>, <Hn>, #0.0

if !HaveFP16Ext() then UNDEFINED;

integer d = 1 then UnallocatedEncoding();
integer d = UInt(Rd);
integer n = UInt(Rn);

integer esize = 16;
integer datasize = esize;
integer elements = 1;

CompareOp comparison;
case op:U of
  when '00' comparison = CompareOp_GT;
  when '01' comparison = CompareOp_GE;
  when '10' comparison = CompareOp_EQ;
  when '11' comparison = CompareOp_LE;

Scalar single-precision and double-precision

<table>
<thead>
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<tbody>
<tr>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>sz</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>Rn</td>
<td>Rd</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

FCMEQ (zero)
Scalar single-precision and double-precision

FCMEQ \texttt{<V><d>, <V><n>, #0.0}

\begin{verbatim}
integer d = \texttt{UInt}(Rd);
integer n = \texttt{UInt}(Rn);

integer esize = 32 \ll \texttt{UInt}(sz);
integer datasize = esize;
integer elements = 1;

\texttt{CompareOp} comparison;
case op:U of
  when '00' comparison = \texttt{CompareOp_GT};
  when '01' comparison = \texttt{CompareOp_GE};
  when '10' comparison = \texttt{CompareOp_EQ};
  when '11' comparison = \texttt{CompareOp_LE};
\end{verbatim}

Vector half precision

(ARMv8.2)

\begin{verbatim}
31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
\hline 0 & Q & 0 & 0 & 1 & 1 & 1 & 0 & 1 & 1 & 1 & 1 & 0 & 0 & 0 & 1 & 1 & 0 & 1 & 1 & 0 & \ 
\hline
U & op & Rd & Rn
\end{verbatim}

Vector half precision

FCMEQ \texttt{<Vd>.<T>, <Vn>.<T>, #0.0}

if !\texttt{HaveFP16Ext}() then UNDEFINED;

\begin{verbatim}
integer d = () then \texttt{UnallocatedEncoding}();
integer d = \texttt{UInt}(Rd);
integer n = \texttt{UInt}(Rn);

integer esize = 16;
integer datasize = if Q == '1' then 128 else 64;
integer elements = datasize DIV esize;

\texttt{CompareOp} comparison;
case op:U of
  when '00' comparison = \texttt{CompareOp_GT};
  when '01' comparison = \texttt{CompareOp_GE};
  when '10' comparison = \texttt{CompareOp_EQ};
  when '11' comparison = \texttt{CompareOp_LE};
\end{verbatim}

Vector single-precision and double-precision

\begin{verbatim}
31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
\hline 0 & Q & 0 & 0 & 1 & 1 & 1 & 0 & 1 & sz & 1 & 0 & 0 & 0 & 0 & 0 & 1 & 1 & 0 & 1 & 1 & 0 & \ 
\hline
U & op & Rd & Rn
\end{verbatim}

FCMEQ (zero)
Vector single-precision and double-precision

FCMEQ \(<V_d>\cdot <T>\), \(<V_n>. <T>\), \#0.0

integer \(d = \text{UInt}(Rd)\);
integer \(n = \text{UInt}(Rn)\);

if \(sz:Q == '10'\) then UNDEFINED;
integer \(esize = 32 \times \text{Int}(sz)\);
integer \(datasize = \text{if } Q == '1' \text{ then } 128 \text{ else } 64\);
integer \(elements = \text{datasize} \div \text{esize}\);

Case \(\text{op}:U\) of
  when '00' \(\text{comparison} = \text{CompareOp_GT}\);
  when '01' \(\text{comparison} = \text{CompareOp_GE}\);
  when '10' \(\text{comparison} = \text{CompareOp_EQ}\);
  when '11' \(\text{comparison} = \text{CompareOp_LE}\);

Assembler Symbols

\(<H_d>\) Is the 16-bit name of the SIMD&FP destination register, encoded in the "Rd" field.
\(<H_n>\) Is the 16-bit name of the SIMD&FP source register, encoded in the "Rn" field.
\(<V>\) Is a width specifier, encoded in "sz":

<table>
<thead>
<tr>
<th>(sz)</th>
<th>(&lt;V&gt;)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>S</td>
</tr>
<tr>
<td>1</td>
<td>D</td>
</tr>
</tbody>
</table>

\(<d>\) Is the number of the SIMD&FP destination register, encoded in the "Rd" field.
\(<n>\) Is the number of the SIMD&FP source register, encoded in the "Rn" field.
\(<V_d>\) Is the name of the SIMD&FP destination register, encoded in the "Rd" field.
\(<T>\) For the vector half precision variant: is an arrangement specifier, encoded in “Q”:

<table>
<thead>
<tr>
<th>(Q)</th>
<th>(&lt;T&gt;)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>NH</td>
</tr>
<tr>
<td>1</td>
<td>8H</td>
</tr>
</tbody>
</table>

For the vector single-precision and double-precision variant: is an arrangement specifier, encoded in “sz:Q”:

<table>
<thead>
<tr>
<th>(sz)</th>
<th>(Q)</th>
<th>(&lt;T&gt;)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>2S</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>4S</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>RESERVED</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>2D</td>
</tr>
</tbody>
</table>

\(<V_n>\) Is the name of the SIMD&FP source register, encoded in the "Rn" field.
Operation

```c
CheckFPAdvSIMDEnabled64();
bits(datasize) operand = V[n];
bits(datasize) result;
bits(esize) zero = FPZero('0');
bits(esize) element;
boolean test_passed;
for e = 0 to elements-1
    element = Elem[operand, e, esize];
    case comparison of
        when CompareOp_GT test_passed = FPCompareGT(element, zero, FPCR);
        when CompareOp_GE test_passed = FPCompareGE(element, zero, FPCR);
        when CompareOp_EQ test_passed = FPCompareEQ(element, zero, FPCR);
        when CompareOp_LE test_passed = FPCompareGE(zero, element, FPCR);
        when CompareOp_LT test_passed = FPCompareGT(zero, element, FPCR);
    Elem[result, e, esize] = if test_passed then Ones() else Zeros();
V[d] = result;
```

Internal version only: isa v30.25, AdvSIMD v27.01, pseudocode v85-xml-008e8_0c335b ; Build timestamp: 2018-09-13T13:45 2018-06-16T09:45

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FCMGE (register)

Floating-point Compare Greater than or Equal (vector). This instruction reads each floating-point value in the first source SIMD&FP register and if the value is greater than or equal to the corresponding floating-point value in the second source SIMD&FP register sets every bit of the corresponding vector element in the destination SIMD&FP register to one, otherwise sets every bit of the corresponding vector element in the destination SIMD&FP register to zero.

This instruction can generate a floating-point exception. Depending on the settings in FPCR, the exception results in either a flag being set in FPSR, or a synchronous exception being generated. For more information, see Floating-point exception traps.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

It has encodings from 4 classes: Scalar half precision, Scalar single-precision and double-precision, Vector half precision and Vector single-precision and double-precision

Scalar half precision

(ARMv8.2)

<table>
<thead>
<tr>
<th>31</th>
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<th>4</th>
<th>3</th>
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<tbody>
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<td>1</td>
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<td>Rm</td>
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Scalar single-precision and double-precision

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<th>3</th>
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</tr>
</tbody>
</table>

Scalar half precision

FCMGE <Hd>, <Hn>, <Hm>

if !HaveFP16Ext() then UNDEFINED;

integer d = |Hd| then UnallocatedEncoding();
integer d = |Hn| then UnallocatedEncoding();
integer d = |Hm| then UnallocatedEncoding();
integer n = UInt(Rn);
integer m = UInt(Rm);
integer esize = 16;
integer datasize = esize;
integer elements = 1;
CompareOp cmp;
boolean abs;

case E:U:ac of
when '000' cmp = CompareOp_EQ; abs = FALSE;
when '010' cmp = CompareOp_GE; abs = FALSE;
when '011' cmp = CompareOp_GE; abs = TRUE;
when '110' cmp = CompareOp_GT; abs = FALSE;
when '111' cmp = CompareOp_GT; abs = TRUE;
otherwise UnallocatedEncoding(); abs = TRUE;
otherwise UNDEFINED();

Scalar single-precision and double-precision

FCMGE (register)
Scalar single-precision and double-precision

FCMGE \langle V \rangle <d>, <V><n>, <V><m>

integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rm);
integer esize = 32 << UInt(sz);
integer datasize = esize;
integer elements = 1;
CompareOp cmp;
boolean abs;

case E:U:ac of
  when '000' cmp = CompareOp_EQ; abs = FALSE;
  when '010' cmp = CompareOp_GE; abs = FALSE;
  when '011' cmp = CompareOp_GE; abs = TRUE;
  when '110' cmp = CompareOp_GT; abs = FALSE;
  when '111' cmp = CompareOp_GT; abs = TRUE;
  otherwise UNDEFINED; otherwise UnallocatedEncoding();

Vector half precision

(ARMv8.2)

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9  | 8  | 7  | 6  | 5  | 4  | 3  | 2  | 1  | 0  |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0  | Q  | 1  | 0  | 1  | 1  | 1  | 0  | 0  | 1  | 0  | Rm | 0  | 0  | 1  | 0  | 0  | 1  | Rd |
|    | U  | E  |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |

Vector single-precision and double-precision

integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rm);
integer esize = 16;
integer datasize = if Q == '1' then 128 else 64;
integer elements = datasize DIV esize;
CompareOp cmp;
boolean abs;

case E:U:ac of
  when '000' cmp = CompareOp_EQ; abs = FALSE;
  when '010' cmp = CompareOp_GE; abs = FALSE;
  when '011' cmp = CompareOp_GE; abs = TRUE;
  when '110' cmp = CompareOp_GT; abs = FALSE;
  when '111' cmp = CompareOp_GT; abs = TRUE;
  otherwise UnallocatedEncoding(); abs = TRUE;
  otherwise UNDEFINED();

Vector single-precision and double-precision

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9  | 8  | 7  | 6  | 5  | 4  | 3  | 2  | 1  | 0  |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0  | Q  | 1  | 0  | 1  | 1  | 1  | 0  | 0  | sz | 1  | Rm | 1  | 1  | 1  | 0  | 0  | 1  | Rd |
|    | U  | E  |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
Vector single-precision and double-precision

FCMGE \(<V_d>, <T>, <V_n>, <T>, <V_m>, <T>\)

integer \(d = \text{UInt}(R_d);\)
integer \(n = \text{UInt}(R_n);\)
integer \(m = \text{UInt}(R_m);\)
if \(sz:Q = '10'\) then UNDEFINED;
integer esize = 32 << \(\text{UInt}(sz);\)
integer dataszize = if \(Q = '1'\) then 128 else 64;
integer elements = dataszize DIV esize;
CompareOp \(\text{cmp};\)
boolean \(\text{abs};\)
case E:U:ac of
  when '000' \(\text{cmp} = \text{CompareOp}_E Q; \text{abs} = \text{FALSE};\)
  when '010' \(\text{cmp} = \text{CompareOp}_E G E; \text{abs} = \text{FALSE};\)
  when '011' \(\text{cmp} = \text{CompareOp}_E G E; \text{abs} = \text{TRUE};\)
  when '110' \(\text{cmp} = \text{CompareOp}_G T; \text{abs} = \text{FALSE};\)
  when '111' \(\text{cmp} = \text{CompareOp}_G T; \text{abs} = \text{TRUE};\)
  otherwise \(\text{UnallocatedEncoding}; \text{abs} = \text{TRUE};\)
otherwise UNDEFINED;

Assembler Symbols

\(<H_d>\) Is the 16-bit name of the SIMD&FP destination register, encoded in the "Rd" field.
\(<H_n>\) Is the 16-bit name of the first SIMD&FP source register, encoded in the "Rn" field.
\(<H_m>\) Is the 16-bit name of the second SIMD&FP source register, encoded in the "Rm" field.
\(<V>\) Is a width specifier, encoded in "sz":

<table>
<thead>
<tr>
<th>(sz)</th>
<th>(&lt;V&gt;)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>S</td>
</tr>
<tr>
<td>1</td>
<td>D</td>
</tr>
</tbody>
</table>

\(<d>\) Is the number of the SIMD&FP destination register, in the "Rd" field.
\(<n>\) Is the number of the first SIMD&FP source register, encoded in the "Rn" field.
\(<m>\) Is the number of the second SIMD&FP source register, encoded in the "Rm" field.
\(<V_d>\) Is the name of the SIMD&FP destination register, encoded in the "Rd" field.
\(<T>\) For the vector half precision variant: is an arrangement specifier, encoded in "Q":

<table>
<thead>
<tr>
<th>(Q)</th>
<th>(&lt;T&gt;)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>4H</td>
</tr>
<tr>
<td>1</td>
<td>8H</td>
</tr>
</tbody>
</table>

For the vector single-precision and double-precision variant: is an arrangement specifier, encoded in "sz:Q":

<table>
<thead>
<tr>
<th>(sz)</th>
<th>(&lt;T&gt;)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 0</td>
<td>2S</td>
</tr>
<tr>
<td>0 1</td>
<td>4S</td>
</tr>
<tr>
<td>1 0</td>
<td>RESERVED</td>
</tr>
<tr>
<td>1 1</td>
<td>2D</td>
</tr>
</tbody>
</table>

\(<V_n>\) Is the name of the first SIMD&FP source register, encoded in the "Rn" field.
\(<V_m>\) Is the name of the second SIMD&FP source register, encoded in the "Rm" field.
Operation

```
CheckFPAdvSIMDEnabled64();
bits(datasize) operand1 = V[n];
bits(datasize) operand2 = V[m];
bits(datasize) result;
bits(esize) element1;
bits(esize) element2;
boolean test_passed;
for e = 0 to elements-1
    element1 = Elem[operand1, e, esize];
    element2 = Elem[operand2, e, esize];
    if abs then
        element1 = FPAbs(element1);
        element2 = FPAbs(element2);
    case cmp of
        when CompareOp_EQ test_passed = FPCompareEQ(element1, element2, FPCR);
        when CompareOp_GE test_passed = FPCompareGE(element1, element2, FPCR);
        when CompareOp_GT test_passed = FPCompareGT(element1, element2, FPCR);
        Elem[result, e, esize] = if test_passed then Ones() else Zeros();
V[d] = result;
```
FCMGE (zero)

Floating-point Compare Greater than or Equal to zero (vector). This instruction reads each floating-point value in the source SIMD&FP register and if the value is greater than or equal to zero sets every bit of the corresponding vector element in the destination SIMD&FP register to one, otherwise sets every bit of the corresponding vector element in the destination SIMD&FP register to zero.

This instruction can generate a floating-point exception. Depending on the settings in FPCR, the exception results in either a flag being set in FPSR, or a synchronous exception being generated. For more information, see Floating-point exception traps.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

It has encodings from 4 classes: Scalar half precision, Scalar single-precision and double-precision, Vector half precision and Vector single-precision and double-precision

Scalar half precision
(ARMv8.2)

```
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0  | 1  | 1  | 1  | 1  | 1  | 0  | 1  | 1  | 1  | 1  | 1  | 0  | 0  | 1  | 1  | 0  | 0  | 1  | 0  | 0  | 1  | 0  | Rn | Rd |
```

Rn | Rd |
---|---|

```
Scalar single-precision and double-precision

```

if !HaveFP16Ext() then UNDEFINED;
integer d = -1 then UnallocatedEncoding();
integer d = UInt(Rd);
integer n = UInt(Rn);
integer esize = 16;
integer datasize = esize;
integer elements = 1;

CompareOp comparison;
case op:U of
  when '00' comparison = CompareOp_GT;
  when '01' comparison = CompareOp_GE;
  when '10' comparison = CompareOp_EQ;
  when '11' comparison = CompareOp_LE;
```

Scalar single-precision and double-precision

```
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0  | 1  | 1  | 1  | 1  | 1  | 0  | 1  | sz| 1  | 0  | 0  | 0  | 0  | 0  | 1  | 1  | 0  | 0  | 1  | 0  | Rn | Rd |
```

Rn | Rd |
Scalar single-precision and double-precision

FCMGE \langle V \rangle d, \langle V \rangle n, \#0.0

integer d = UInt(Rd);
integer n = UInt(Rn);

integer esize = 32 << UInt(sz);
integer datasize = esize;
integer elements = 1;

CompareOp comparison;
case op:U of
  when '00' comparison = CompareOp_GT;
  when '01' comparison = CompareOp_GE;
  when '10' comparison = CompareOp_EQ;
  when '11' comparison = CompareOp_LE;

Vector half precision
(ARMv8.2)

<table>
<thead>
<tr>
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<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q</td>
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<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
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</tr>
<tr>
<td>U</td>
<td>op</td>
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</tr>
</tbody>
</table>

Rn   Rd

Vector half precision

FCMGE \langle Vd \rangle.T, \langle Vn \rangle.T, \#0.0

if !HaveFP16Ext() then UNDEFINED;

integer d =() then UnallocatedEncoding();

integer d = UInt(Rd);
integer n = UInt(Rn);

integer esize = 16;
integer datasize = if Q == '1' then 128 else 64;
integer elements = datasize DIV esize;

CompareOp comparison;
case op:U of
  when '00' comparison = CompareOp_GT;
  when '01' comparison = CompareOp_GE;
  when '10' comparison = CompareOp_EQ;
  when '11' comparison = CompareOp_LE;

Vector single-precision and double-precision

<table>
<thead>
<tr>
<th>31</th>
<th>30</th>
<th>29</th>
<th>28</th>
<th>27</th>
<th>26</th>
<th>25</th>
<th>24</th>
<th>23</th>
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<th>9</th>
<th>8</th>
<th>7</th>
<th>6</th>
<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>sz</td>
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</tr>
<tr>
<td>U</td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Rn   Rd

FCMGE (zero)
Vector single-precision and double-precision

FCMGE \(<Vd>.,<T>,<Vn>.,<T>,\), #0.0

```plaintext
integer d = UInt(Rd);
integer n = UInt(Rn);

if sz:Q == '10' then UNDEFINED;
integer esize = 32 << (if sz:Q == '10' then ReservedValue();
integer esize = 32 << UInt(sz);
integer datasize = if Q == '1' then 128 else 64;
integer elements = datasize DIV esize;

CompareOp comparison;
case op:U of
  when '00' comparison = CompareOp_GT;
  when '01' comparison = CompareOp_GE;
  when '10' comparison = CompareOp_EQ;
  when '11' comparison = CompareOp_LE;
```

### Assembler Symbols

- `<Hd>` Is the 16-bit name of the SIMD&FP destination register, encoded in the "Rd" field.
- `<Hn>` Is the 16-bit name of the SIMD&FP source register, encoded in the "Rn" field.
- `<V>` Is a width specifier, encoded in "sz":

<table>
<thead>
<tr>
<th>sz</th>
<th><code>&lt;V&gt;</code></th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>S</td>
</tr>
<tr>
<td>1</td>
<td>D</td>
</tr>
</tbody>
</table>

- `<d>` Is the number of the SIMD&FP destination register, encoded in the "Rd" field.
- `<n>` Is the number of the SIMD&FP source register, encoded in the "Rn" field.
- `<Vd>` Is the name of the SIMD&FP destination register, encoded in the "Rd" field.
- `<T>` For the vector half precision variant: is an arrangement specifier, encoded in “Q”:

<table>
<thead>
<tr>
<th>Q</th>
<th><code>&lt;T&gt;</code></th>
</tr>
</thead>
<tbody>
<tr>
<td>NH</td>
<td></td>
</tr>
<tr>
<td>RH</td>
<td></td>
</tr>
</tbody>
</table>

For the vector single-precision and double-precision variant: is an arrangement specifier, encoded in "sz:Q":

<table>
<thead>
<tr>
<th>sz</th>
<th>Q</th>
<th><code>&lt;T&gt;</code></th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>2S</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>4S</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>RESERVED</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>2D</td>
</tr>
</tbody>
</table>

- `<Vn>` Is the name of the SIMD&FP source register, encoded in the "Rn" field.
Operation

```c
CheckFPAdvSIMDEnabled64();
bits(datasize) operand = V[n];
bits(datasize) result;
bits(esize) zero = FPZero('0');
bits(esize) element;
boolean test_passed;
for e = 0 to elements-1
  element = Elem[operand, e, esize];
  case comparison of
    when CompareOp_GT test_passed = FPCompareGT(element, zero, FPCR);
    when CompareOp_GE test_passed = FPCompareGE(element, zero, FPCR);
    when CompareOp_EQ test_passed = FPCompareEQ(element, zero, FPCR);
    when CompareOp_LE test_passed = FPCompareGE(zero, element, FPCR);
    when CompareOp_LT test_passed = FPCompareGT(zero, element, FPCR);
  Elem[result, e, esize] = if test_passed then Ones() else Zeros();
V[d] = result;
```

Internal version only: isa v30.25; AdvSIMD v27.01; pseudocode v85-xml-00et8_rc3c35a ; Build timestamp: 2018-09-13T13:2018-06-16T09:45:45

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FCMGT (register)

Floating-point Compare Greater than (vector). This instruction reads each floating-point value in the first source SIMD&FP register and if the value is greater than the corresponding floating-point value in the second source SIMD&FP register sets every bit of the corresponding vector element in the destination SIMD&FP register to one, otherwise sets every bit of the corresponding vector element in the destination SIMD&FP register to zero.

This instruction can generate a floating-point exception. Depending on the settings in FPCR, the exception results in either a flag being set in FPSR, or a synchronous exception being generated. For more information, see Floating-point exception traps.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

It has encodings from 4 classes: Scalar half precision , Scalar single-precision and double-precision , Vector half precision and Vector single-precision and double-precision

Scalar half precision
(ARMv8.2)

|   | 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9  | 8  | 7  | 6  | 5  | 4  | 3  | 2  | 1  | 0  |
|---|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| Rm| 1  | 1  | 1  | 1  | 0  | 1  | 1  | 0  | 0  | 0  | 1  | 0  | 0  | 1  | 1  | 0  | 0  | 1  | 0  | 0  | 1  | 0  | 0  | 1  | 0  | 0  | 1  | 0  | 0  | 1  | 0  | 0  | 1  | 0  |
| Rd|    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| Rn|    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| U | 0  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 0  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  |
| E | 0  | 0  | 1  | 0  | 0  | 1  | 0  | 0  | 1  | 0  | 0  | 1  | 0  | 0  | 1  | 0  | 0  | 1  | 0  | 0  | 1  | 0  | 0  | 1  | 0  | 0  | 1  | 0  | 0  | 1  | 0  | 0  | 1  | 0  |
| ac|    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |

Scalar single-precision and double-precision

| Rm| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9  | 8  | 7  | 6  | 5  | 4  | 3  | 2  | 1  | 0  |
|---|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| Rn|    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| Rd|    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| Rm|    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| Rd|    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| U | 0  | 1  | 1  | 1  | 1  | 0  | 1  | 1  | 1  | 0  | 0  | 1  | 0  | 0  | 1  | 0  | 0  | 1  | 0  | 0  | 1  | 0  | 0  | 1  | 0  | 0  | 1  | 0  | 0  | 1  | 0  | 0  | 1  | 0  |
| E | 0  | 0  | 1  | 0  | 0  | 1  | 0  | 0  | 1  | 0  | 0  | 1  | 0  | 0  | 1  | 0  | 0  | 1  | 0  | 0  | 1  | 0  | 0  | 1  | 0  | 0  | 1  | 0  | 0  | 1  | 0  | 0  | 1  | 0  |
| ac|    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |

Scalar half precision

FCMGT <Hd>, <Hn>, <Hm>

if !HaveFP16Ext() then UNDEFINED;
integer d = 1 then UnallocatedEncoding();
integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rm);
integer esize = 16;
integer datasize = esize;
integer elements = 1;
CompareOp cmp;
boolean abs;
case E:U:ac of
  when '000' cmp = CompareOp_EQ; abs = FALSE;
  when '010' cmp = CompareOp_GE; abs = FALSE;
  when '011' cmp = CompareOp_GE; abs = TRUE;
  when '110' cmp = CompareOp_GT; abs = FALSE;
  when '111' cmp = CompareOp_GT; abs = TRUE;
otherwise UnallocatedEncoding(); abs = TRUE;
otherwise UNDEFINED();
Scalar single-precision and double-precision

\[
\text{FCMGT } \langle V \rangle \langle d \rangle, \langle V \rangle \langle n \rangle, \langle V \rangle \langle m \rangle
\]

\[
\text{integer } d = \text{UInt}(R_d); \\
\text{integer } n = \text{UInt}(R_n); \\
\text{integer } m = \text{UInt}(R_m); \\
\text{integer } esize = 32 \ll \text{UInt}(sz); \\
\text{integer } datasize = esize; \\
\text{integer } elements = 1; \\
\text{CompareOp } cmp; \\
\text{boolean } abs;
\]

case E:U:ac of
\[
\begin{array}{ll}
\text{when '000'} & \text{cmp } = \text{CompareOp EQ}; \text{abs } = \text{FALSE}; \\
\text{when '010'} & \text{cmp } = \text{CompareOp GE}; \text{abs } = \text{FALSE}; \\
\text{when '011'} & \text{cmp } = \text{CompareOp GE}; \text{abs } = \text{TRUE}; \\
\text{when '110'} & \text{cmp } = \text{CompareOp GT}; \text{abs } = \text{FALSE}; \\
\text{when '111'} & \text{cmp } = \text{CompareOp GT}; \text{abs } = \text{TRUE}; \\
\end{array}
\]
\[
\text{otherwise } \text{UNDEFINED}; \text{abs } = \text{TRUE};
\]

Vector half precision

(ARMv8.2)

Vector single-precision and double-precision

\[
\text{integer } d = \text{UInt}(R_d); \\
\text{integer } n = \text{UInt}(R_n); \\
\text{integer } m = \text{UInt}(R_m); \\
\text{integer } esize = 16; \\
\text{integer } datasize = \text{if } Q \text{ == '1'} \text{ then } 128 \text{ else } 64; \\
\text{integer } elements = \text{datasize DIV esize}; \\
\text{CompareOp } cmp; \\
\text{boolean } abs;
\]

case E:U:ac of
\[
\begin{array}{ll}
\text{when '000'} & \text{cmp } = \text{CompareOp EQ}; \text{abs } = \text{FALSE}; \\
\text{when '010'} & \text{cmp } = \text{CompareOp GE}; \text{abs } = \text{FALSE}; \\
\text{when '011'} & \text{cmp } = \text{CompareOp GE}; \text{abs } = \text{TRUE}; \\
\text{when '110'} & \text{cmp } = \text{CompareOp GT}; \text{abs } = \text{FALSE}; \\
\text{when '111'} & \text{cmp } = \text{CompareOp GT}; \text{abs } = \text{TRUE}; \\
\end{array}
\]
\[
\text{otherwise } \text{UNDEFINED}; \text{abs } = \text{TRUE};
\]

Vector single-precision and double-precision
FCMG (register) page 229

Vector single-precision and double-precision

FCMG <Vd>.<T>, <Vn>.<T>, <Vm>.<T>

integer d = UInt (Rd);
integer n = UInt (Rn);
integer m = UInt (Rm);
if sz:Q == '10' then UNDEFINED;
integer esize = 32 << (if sz:Q == '10' then ReservedValue() : UInt (sz));
integer dataszize = if Q == '1' then 128 else 64;
integer elements = dataszize DIV esize;
CompareOp cmp;
boolean abs;

case E:U:ac of
  when '000' cmp = CompareOp_EQ; abs = FALSE;
  when '010' cmp = CompareOp_GE; abs = FALSE;
  when '011' cmp = CompareOp_GE; abs = TRUE;
  when '110' cmp = CompareOp_GT; abs = FALSE;
  when '111' cmp = CompareOp_GT; abs = TRUE;
  otherwise  UnallocatedEncoding; abs = TRUE;
otherwise  UNDEFINED();

Assembler Symbols

<Hd> Is the 16-bit name of the SIMD&FP destination register, encoded in the "Rd" field.
<Hn> Is the 16-bit name of the first SIMD&FP source register, encoded in the "Rn" field.
<Hm> Is the 16-bit name of the second SIMD&FP source register, encoded in the "Rm" field.
<V> Is a width specifier, encoded in "sz":

<table>
<thead>
<tr>
<th>sz</th>
<th>&lt;V&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>S</td>
</tr>
<tr>
<td>1</td>
<td>D</td>
</tr>
</tbody>
</table>

<d> Is the number of the SIMD&FP destination register, in the "Rd" field.
<n> Is the number of the first SIMD&FP source register, encoded in the "Rn" field.
<m> Is the number of the second SIMD&FP source register, encoded in the "Rm" field.
<Vd> Is the name of the SIMD&FP destination register, encoded in the "Rd" field.
<T> For the vector half precision variant: is an arrangement specifier, encoded in "Q":

<table>
<thead>
<tr>
<th>Q</th>
<th>&lt;T&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>4H</td>
</tr>
<tr>
<td>1</td>
<td>8H</td>
</tr>
</tbody>
</table>

For the vector single-precision and double-precision variant: is an arrangement specifier, encoded in "sz:Q":

<table>
<thead>
<tr>
<th>sz</th>
<th>Q</th>
<th>&lt;T&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>2S</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>4S</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>RESERVED</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>2D</td>
</tr>
</tbody>
</table>

<Vn> Is the name of the first SIMD&FP source register, encoded in the "Rn" field.
<Vm> Is the name of the second SIMD&FP source register, encoded in the "Rm" field.
Operation

```c
CheckFPAdvSIMDEnabled64();

bits(datasize) operand1 = \text{V}[n];
bits(datasize) operand2 = \text{V}[m];
bits(datasize) result;
bits(esize) element1;
bits(esize) element2;
boolean test_passed;

for \text{e} = 0 \text{ to } \text{elements-1}
\{\
    element1 = \text{Elem}[\text{operand1}, \text{e}, \text{esize}];
    element2 = \text{Elem}[\text{operand2}, \text{e}, \text{esize}];
    if \text{abs} then
        element1 = \text{FPAbs}(element1);
        element2 = \text{FPAbs}(element2);
    case \text{cmp} of
        when \text{CompareOp EQ} test_passed = \text{FPCompareEQ}(element1, element2, FPCR);
        when \text{CompareOp GE} test_passed = \text{FPCompareGE}(element1, element2, FPCR);
        when \text{CompareOp GT} test_passed = \text{FPCompareGT}(element1, element2, FPCR);
        \text{Elem}[\text{result}, \text{e}, \text{esize}] = if \text{test_passed} then \text{Ones()} else \text{Zeros}();
\}
\text{V}[d] = result;
```

Internal version only: isa v30.25, AdvSIMD v27.0, pseudocode v85-xml-00bet8_rc3.4c; Build timestamp: 2018-09-13T13:2018-06-16T09:45:45

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FCMGT (zero)

Floating-point Compare Greater than zero (vector). This instruction reads each floating-point value in the source SIMD&FP register and if the value is greater than zero sets every bit of the corresponding vector element in the destination SIMD&FP register to one, otherwise sets every bit of the corresponding vector element in the destination SIMD&FP register to zero.

This instruction can generate a floating-point exception. Depending on the settings in FPCR, the exception results in either a flag being set in FPSR, or a synchronous exception being generated. For more information, see Floating-point exception traps.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

It has encodings from 4 classes: Scalar half precision, Scalar single-precision and double-precision, Vector half precision and Vector single-precision and double-precision.

Scalar half precision

(ARMv8.2)

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9  | 8  | 7  | 6  | 5  | 4  | 3  | 2  | 1  | 0  |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0  | 1  | 0  | 1  | 1  | 1  | 0  | 1  | 1  | 1  | 0  | 0  | 0  | 1  | 1  | 0  | 0  | 1  | 0  | 1  | 0  | Rn |   |   |   |   |   |   |
| U  | op |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   | Rd |

Scalar half precision

FCMGT <Hd>, <Hn>, #0.0

```plaintext
if !HaveFP16Ext() then UNDEFINED;

integer d = -1; then UnallocatedEncoding(1);

integer d = UInt(Rd);
integer n = UInt(Rn);

integer esize = 16;
integer datasize = esize;
integer elements = 1;

CompareOp comparison;

```
case op:U of
  when '00' comparison = CompareOp_GT;
  when '01' comparison = CompareOp_GE;
  when '10' comparison = CompareOp_EQ;
  when '11' comparison = CompareOp_LE;

```

Scalar single-precision and double-precision

<table>
<thead>
<tr>
<th>31</th>
<th>30</th>
<th>29</th>
<th>28</th>
<th>27</th>
<th>26</th>
<th>25</th>
<th>24</th>
<th>23</th>
<th>22</th>
<th>21</th>
<th>20</th>
<th>19</th>
<th>18</th>
<th>17</th>
<th>16</th>
<th>15</th>
<th>14</th>
<th>13</th>
<th>12</th>
<th>11</th>
<th>10</th>
<th>9</th>
<th>8</th>
<th>7</th>
<th>6</th>
<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>sz</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>Rn</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>U</td>
<td>op</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>sz</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>Rd</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

FCMGT (zero)
Scalar single-precision and double-precision

FCMGT `<V><d>, <V><n>, #0.0`

```
integer d = UInt(Rd);
integer n = UInt(Rn);

type esize = 32 << UInt(sz);
type datasize = esize;
type elements = 1;

CompareOp comparison;
case op:U of
  when '00' comparison = CompareOp_GT;
  when '01' comparison = CompareOp_GE;
  when '10' comparison = CompareOp_EQ;
  when '11' comparison = CompareOp_LE;
```

Vector half precision

(ARMv8.2)

```
31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
0  Q 0 0 1 1 1 0 1 1 1 1 0 0 0 1 1 0 0 1 1 0
U  op  Rn  Rd
```

Vector half precision

FCMGT `<Vd>.<T>, <Vn>.<T>, #0.0`

```
if !HaveFP16Ext() then UNDEFINED;
integer d = then UnallocatedEncoding(4);
integer d = UInt(Rd);
integer n = UInt(Rn);

type esize = 16;
type datasize = if Q == '1' then 128 else 64;
type elements = datasize DIV esize;

CompareOp comparison;
case op:U of
  when '00' comparison = CompareOp_GT;
  when '01' comparison = CompareOp_GE;
  when '10' comparison = CompareOp_EQ;
  when '11' comparison = CompareOp_LE;
```

Vector single-precision and double-precision

```
31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
0  Q 0 0 1 1 1 0 1 1 0 0 0 0 0 1 1 0 0 1 1 0
U  op  Rn  Rd
```

FCMGT (zero)
Vector single-precision and double-precision

FCMGT $<V_d>.$<$T>$, $<V_n>.$<$T>$, #0.0

integer $d = \text{UInt}(R_d)$;
integer $n = \text{UInt}(R_n)$;

if $sz:Q == '10'$ then UNDEFINED;
integer esize = 32 if $sz:Q == '10'$ then ReservedValue();
integer esize = 32 if $sz$;
integer datasize = if $Q == '1'$ then 128 else 64;
integer elements = datasize DIV esize;

CompareOp comparison;
case $op:U$ of
when '00' comparison = CompareOp_GT;
when '01' comparison = CompareOp_GE;
when '10' comparison = CompareOp_EQ;
when '11' comparison = CompareOp_LE;

Assembler Symbols

$<H_d>$ Is the 16-bit name of the SIMD&FP destination register, encoded in the "Rd" field.
$<H_n>$ Is the 16-bit name of the SIMD&FP source register, encoded in the "Rn" field.
$<V>$ Is a width specifier, encoded in "sz":

<table>
<thead>
<tr>
<th>$sz$</th>
<th>$&lt;V&gt;$</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>S</td>
</tr>
<tr>
<td>1</td>
<td>D</td>
</tr>
</tbody>
</table>

$<d>$ Is the number of the SIMD&FP destination register, encoded in the "Rd" field.

$<n>$ Is the number of the SIMD&FP source register, encoded in the "Rn" field.

$<V_d>$ Is the name of the SIMD&FP destination register, encoded in the "Rd" field.

$<T>$ For the vector half precision variant: is an arrangement specifier, encoded in “Q”:

<table>
<thead>
<tr>
<th>$Q$</th>
<th>$&lt;T&gt;$</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>NH</td>
</tr>
<tr>
<td>1</td>
<td>RH</td>
</tr>
</tbody>
</table>

For the vector single-precision and double-precision variant: is an arrangement specifier, encoded in "sz:Q":

<table>
<thead>
<tr>
<th>$sz$</th>
<th>$Q$</th>
<th>$&lt;T&gt;$</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>2S</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>4S</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>RESERVED</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>2D</td>
</tr>
</tbody>
</table>

$<V_n>$ Is the name of the SIMD&FP source register, encoded in the "Rn" field.
Operation

```c
CheckFPAdvSIMDEnabled64();
bits(datasize) operand = V[n];
bits(datasize) result;
bits(esModule) zero = FPZero('0');
bits(esModule) element;
boolean test_passed;

for e = 0 to elements-1
    element = Elem[operand, e, esize];
    case comparison of
        when CompareOp_GT test_passed = FPCompareGT(element, zero, FPCR);
        when CompareOp_GE test_passed = FPCompareGE(element, zero, FPCR);
        when CompareOp_EQ test_passed = FPCompareEQ(element, zero, FPCR);
        when CompareOp_LE test_passed = FPCompareGE(zero, element, FPCR);
        when CompareOp_LT test_passed = FPCompareGT(zero, element, FPCR);
            Elem[result, e, esize] = if test_passed then Ones() else Zeros();

V[d] = result;
```

FCMLA (by element)

Floating-point Complex Multiply Accumulate (by element).
This instruction operates on complex numbers that are represented in SIMD&FP registers as pairs of elements, with the more significant element holding the imaginary part of the number and the less significant element holding the real part of the number. Each element holds a floating-point value. It performs the following computation on complex numbers from the first source register and the destination register with the specified complex number from the second source register:

- Considering the complex number from the second source register on an Argand diagram, the number is rotated counterclockwise by 0, 90, 180, or 270 degrees.
- The two elements of the transformed complex number are multiplied by:
  - The real element of the complex number from the first source register, if the transformation was a rotation by 0 or 180 degrees.
  - The imaginary element of the complex number from the first source register, if the transformation was a rotation by 90 or 270 degrees.
- The complex number resulting from that multiplication is added to the complex number from the destination register.

The multiplication and addition operations are performed as a fused multiply-add, without any intermediate rounding.
This instruction can generate a floating-point exception. Depending on the settings in FPCR, the exception results in either a flag being set in FPSR or a synchronous exception being generated. For more information, see Floating-point exception traps.
Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

Vector (ARMv8.3)

31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0

| 0 | Q | 1 | 0 | 1 | 1 | 1 | size | L | M | Rm | 0 | rot | 1 | H | 0 | Rn | Rd |

(size == 01)
FCMLA <Vd>.<T>, <Vn>.<T>, <Vm>.<Ts>[<index>], #<rotate>

(size == 10)
FCMLA <Vd>.<T>, <Vn>.<T>, <Vm>.<Ts>[<index>], #<rotate>

if !HaveFCADDExt() then UNDEFINED;
integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(M:Rm);
if size == '00' || size == '11' then UNDEFINED;
if size == '01' then index = if size == '00' || size == '11' then ReservedValue();
if size == '01' then index = UInt(H:L);
if size == '10' then index = UInt(H);
integer esize = 8 << UInt(size);
if !HaveFP16Ext() && esize == 16 then ReservedValue();
integer datasize = if Q == '1' then 128 else 64;
integer elements = datasize DIV esize;
if size == '10' && (L == '1' || Q == '0') then ReservedValue();
if size == '01' && H == '1' && Q=='0' then ReservedValue() && esize == 16 then UNDEFINED;
integer datasize = if Q == '1' then 128 else 64;
integer elements = datasize DIV esize;
if size == '10' && (L == '1' || Q == '0') then UNDEFINED;
if size == '01' && H == '1' && Q=='0' then UNDEFINED();

Assembler Symbols

<Vd> Is the name of the SIMD&FP destination register, encoded in the “Rd” field.
<T> Is an arrangement specifier, encoded in “size-Q”:

FCMLA (by element)
<table>
<thead>
<tr>
<th>size</th>
<th>Q</th>
<th>&lt;T&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>x</td>
<td>RESERVED</td>
</tr>
<tr>
<td>01</td>
<td>0</td>
<td>4H</td>
</tr>
<tr>
<td>01</td>
<td>1</td>
<td>8H</td>
</tr>
<tr>
<td>10</td>
<td>0</td>
<td>RESERVED</td>
</tr>
<tr>
<td>10</td>
<td>1</td>
<td>4S</td>
</tr>
<tr>
<td>11</td>
<td>x</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

**<Vn>**
Is the name of the first SIMD&FP source register, encoded in the "Rn" field.

**<Vm>**
Is the name of the second SIMD&FP source register, encoded in the "M:Rm" fields.

**<Ts>**
Is an element size specifier, encoded in "size":

<table>
<thead>
<tr>
<th>size</th>
<th>&lt;Ts&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>RESERVED</td>
</tr>
<tr>
<td>01</td>
<td>H</td>
</tr>
<tr>
<td>10</td>
<td>S</td>
</tr>
<tr>
<td>11</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

**<index>**
Is the element index, encoded in "size:H:L":

<table>
<thead>
<tr>
<th>size</th>
<th>&lt;index&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>RESERVED</td>
</tr>
<tr>
<td>01</td>
<td>H:L</td>
</tr>
<tr>
<td>10</td>
<td>H</td>
</tr>
<tr>
<td>11</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

**<rotate>**
Is the rotation, encoded in "rot":

<table>
<thead>
<tr>
<th>rot</th>
<th>&lt;rotate&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>0</td>
</tr>
<tr>
<td>01</td>
<td>90</td>
</tr>
<tr>
<td>10</td>
<td>180</td>
</tr>
<tr>
<td>11</td>
<td>270</td>
</tr>
</tbody>
</table>

**Operation**

```c
CheckFPAdvSIMDEnabled64();

bits(datasize) operand1 = V[n];
bits(datasize) operand2 = V[m];
bits(datasize) operand3 = V[d];
bits(datasize) result;

for e = 0 to (elements DIV 2) -1
    case rot of
        when '00'
            element1 = Elem[operand2, index*2, esize];
            element2 = Elem[operand1, e*2, esize];
            element3 = Elem[operand2, index*2+1, esize];
            element4 = Elem[operand1, e*2, esize];
        when '01'
            element1 = FPNeg(Elem[operand2, index*2+1, esize]);
            element2 = Elem[operand1, e*2+1, esize];
            element3 = Elem[operand2, index*2, esize];
            element4 = Elem[operand1, e*2+1, esize];
        when '10'
            element1 = FPNeg(Elem[operand2, index*2, esize]);
            element2 = Elem[operand1, e*2, esize];
            element3 = FPNeg(Elem[operand2, index*2+1, esize]);
            element4 = Elem[operand1, e*2, esize];
        when '11'
            element1 = Elem[operand2, index*2+1, esize];
            element2 = Elem[operand1, e*2+1, esize];
            element3 = FPNeg(Elem[operand2, index*2, esize]);
            element4 = Elem[operand1, e*2+1, esize];

        Elem[result, e*2, esize] = FPMulAdd(Elem[operand3, e*2, esize], element2, element1, FPCR);
        Elem[result, e*2+1, esize] = FPMulAdd(Elem[operand3, e*2+1, esize], element4, element3, FPCR);

    V[d] = result;
```
Floating-point Complex Multiply Accumulate.

This instruction operates on complex numbers that are represented in SIMD&FP registers as pairs of elements, with the more significant element holding the imaginary part of the number and the less significant element holding the real part of the number. Each element holds a floating-point value. It performs the following computation on the corresponding complex number element pairs from the two source registers and the destination register:

- Considering the complex number from the second source register on an Argand diagram, the number is rotated counterclockwise by 0, 90, 180, or 270 degrees.
- The two elements of the transformed complex number are multiplied by:
  - The real element of the complex number from the first source register, if the transformation was a rotation by 0 or 180 degrees.
  - The imaginary element of the complex number from the first source register, if the transformation was a rotation by 90 or 270 degrees.
- The complex number resulting from that multiplication is added to the complex number from the destination register.

The multiplication and addition operations are performed as a fused multiply-add, without any intermediate rounding. This instruction can generate a floating-point exception. Depending on the settings in `FPCR`, the exception results in either a flag being set in `FPSR` or a synchronous exception being generated. For more information, see Floating-point exception traps.

Depending on the settings in the `CPACR_EL1`, `CPTR_EL2`, and `CPTR_EL3` registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

### Three registers of the same type

(ARMv8.3)

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0  | Q  | 1  | 0  | 1  | 1  | 1  | 0  | size | 0  | Rm | 1  | 1  | 0  | rot | 1  | Rn | 1  | Rd |

### Assembler Symbols

- `<Vd>` Is the name of the SIMD&FP destination register, encoded in the "Rd" field.
- `<T>` Is an arrangement specifier, encoded in “size:Q”:

<table>
<thead>
<tr>
<th>size</th>
<th>Q</th>
<th>&lt;T&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>x</td>
<td>RESERVED</td>
</tr>
<tr>
<td>01</td>
<td>0</td>
<td>4H</td>
</tr>
<tr>
<td>01</td>
<td>1</td>
<td>8H</td>
</tr>
<tr>
<td>10</td>
<td>0</td>
<td>2S</td>
</tr>
<tr>
<td>10</td>
<td>1</td>
<td>4S</td>
</tr>
<tr>
<td>11</td>
<td>0</td>
<td>RESERVED</td>
</tr>
<tr>
<td>11</td>
<td>1</td>
<td>2D</td>
</tr>
</tbody>
</table>

- `<Vn>` Is the name of the first SIMD&FP source register, encoded in the "Rn" field.
- `<Vm>` Is the name of the second SIMD&FP source register, encoded in the "Rm" field.
Is the rotation, encoded in "rot":

<table>
<thead>
<tr>
<th>rot</th>
<th>&lt;rotate&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>0</td>
</tr>
<tr>
<td>01</td>
<td>90</td>
</tr>
<tr>
<td>10</td>
<td>180</td>
</tr>
<tr>
<td>11</td>
<td>270</td>
</tr>
</tbody>
</table>

Operation

```c
CheckFPAdvSIMDEnabled64();
bits(datasize) operand1 = V[n];
bits(datasize) operand2 = V[m];
bits(datasize) operand3 = V[d];
bits(datasize) result;
bits(esize) element1;
bits(esize) element2;
bits(esize) element3;
bits(esize) element4;

for e = 0 to (elements DIV 2) -1
  case rot of
    when '00'
      element1 = Elem[operand2, e*2, esize];
      element2 = Elem[operand1, e*2, esize];
      element3 = Elem[operand2, e*2+1, esize];
      element4 = Elem[operand1, e*2, esize];
    when '01'
      element1 = FPNeg(Elem[operand2, e*2+1, esize]);
      element2 = Elem[operand1, e*2+1, esize];
      element3 = Elem[operand2, e*2, esize];
      element4 = Elem[operand1, e*2+1, esize];
    when '10'
      element1 = FPNeg(Elem[operand2, e*2, esize]);
      element2 = Elem[operand1, e*2+1, esize];
      element3 = FPNeg(Elem[operand2, e*2+1, esize]);
      element4 = Elem[operand1, e*2, esize];
    when '11'
      element1 = Elem[operand2, e*2+1, esize];
      element2 = Elem[operand1, e*2+1, esize];
      element3 = FPNeg(Elem[operand2, e*2, esize]);
      element4 = Elem[operand1, e*2+1, esize];

  Elem[result, e*2, esize] = FPMulAdd(Elem[operand3, e*2, esize], element2, element1, FPCR);
  Elem[result, e*2+1, esize] = FPMulAdd(Elem[operand3, e*2+1, esize], element4, element3, FPCR);

V[d] = result;
```

Internal version only: isa v30.25, AdvSIMD v27.01, pseudocode v85-xml-00bet8_rc3.3.0, Build timestamp: 2018-09-13T13:2018-06-16T09:04:45

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FCMLE (zero)

Floating-point Compare Less than or Equal to zero (vector). This instruction reads each floating-point value in the source SIMD&FP register and if the value is less than or equal to zero sets every bit of the corresponding vector element in the destination SIMD&FP register to one, otherwise sets every bit of the corresponding vector element in the destination SIMD&FP register to zero.

This instruction can generate a floating-point exception. Depending on the settings in FPCR, the exception results in either a flag being set in FPSR, or a synchronous exception being generated. For more information, see Floating-point exception traps.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

It has encodings from 4 classes: Scalar half precision, Scalar single-precision and double-precision, Vector half precision and Vector single-precision and double-precision

### Scalar half precision

(ARMv8.2)

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0  | 1  | 1  | 1  | 1  | 1  | 1  | 0  | 1  | 1  | 1  | 1  | 1  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 1  | 1  | 0  | 1  | 0  | Rn |
| U  | op |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    | Rd |

Scalar half precision

FCMLE <Hd>, <Hn>, #0.0

```plaintext
if !HaveFP16Ext() then UNDEFINED;
integer d = 1, then UnallocatedEncoding(d);
integer d = UInt(Rd);
integer n = UInt(Rn);
integer esize = 16;
integer datasize = esize;
integer elements = 1;

CompareOp comparison;
case op:U of
    when '00' comparison = CompareOp_GT;
    when '01' comparison = CompareOp_GE;
    when '10' comparison = CompareOp_EQ;
    when '11' comparison = CompareOp_LE;
```

### Scalar single-precision and double-precision

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0  | 1  | 1  | 1  | 1  | 1  | 1  | 0  | 1  | 1  | sz | 1  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 1  | 1  | 0  | 1  | 1  | 0  | Rn |
| U  | op |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    | Rd |

FCMLE (zero)
Scalar single-precision and double-precision

FCMLE <\V><d>, <\V><n>, #0.0

integer d = UInt(Rd);
integer n = UInt(Rn);

integer esize = 32 << UInt(sz);
integer datasize = esize;
integer elements = 1;

CompareOp comparison;

\begin{verbatim}
    case op:U of
        when '00' comparison = CompareOp_GT;
        when '01' comparison = CompareOp_GE;
        when '10' comparison = CompareOp_EQ;
        when '11' comparison = CompareOp_LE;
\end{verbatim}

Vector half precision

(ARMv8.2)

\begin{verbatim}
|   31   30   29   28   27   26   25   24   23   22   21   20   19   18   17   16   15   14   13   12   11   10   9   8   7   6   5   4   3   2   1   0 |
|---------------------------|---------------------------|
| Q | 1 | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 1 | 0 | Rn | Rd |
|---------------------------|---------------------------|
| op |  |
\end{verbatim}

Vector half precision

FCMLE <Vd>.<T>, <Vn>.<T>, #0.0

if !HaveFP16Ext() then UNDEFINED;

\begin{verbatim}
    integer d = UnallocatedEncoding(4);
    integer d = UInt(Rd);
    integer n = UInt(Rn);

    integer esize = 16;
    integer datasize = if Q == '1' then 128 else 64;
    integer elements = datasize DIV esize;

    CompareOp comparison;
    \end{verbatim}

\begin{verbatim}
    case op:U of
        when '00' comparison = CompareOp_GT;
        when '01' comparison = CompareOp_GE;
        when '10' comparison = CompareOp_EQ;
        when '11' comparison = CompareOp_LE;
\end{verbatim}

Vector single-precision and double-precision

\begin{verbatim}
|   31   30   29   28   27   26   25   24   23   22   21   20   19   18   17   16   15   14   13   12   11   10   9   8   7   6   5   4   3   2   1   0 |
|---------------------------|---------------------------|
| Q | 1 | 0 | 1 | 1 | 1 | 0 | 1 | sz | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 1 | 0 | Rn | Rd |
|---------------------------|---------------------------|
| op |  |
\end{verbatim}
Vector single-precision and double-precision

FCMLE \(<V_d>.<T>, \langle V_n>.<T>, \#0.0\)

```
integer d = UInt(Rd);
integer n = UInt(Rn);

if sz:Q == '10' then UNDEFINED;
integer esize = 32 << (if sz:Q == '10' then ReservedValue()::);
integer esize = 32 << UInt(sz);
integer datasize = if Q == '1' then 128 else 64;
integer elements = datasize DIV esize;

CompareOp comparison;
case op:U of
  when '00' comparison = CompareOp_GT;
  when '01' comparison = CompareOp_GE;
  when '10' comparison = CompareOp_EQ;
  when '11' comparison = CompareOp_LE;
```

Assembler Symbols

- \(<H_d>\) Is the 16-bit name of the SIMD&FP destination register, encoded in the "Rd" field.
- \(<H_n>\) Is the 16-bit name of the SIMD&FP source register, encoded in the "Rn" field.
- \(<V>\) Is a width specifier, encoded in "sz":

<table>
<thead>
<tr>
<th>sz</th>
<th>&lt;V&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>S</td>
</tr>
<tr>
<td>1</td>
<td>D</td>
</tr>
</tbody>
</table>

- \(<d>\) Is the number of the SIMD&FP destination register, encoded in the "Rd" field.
- \(<n>\) Is the number of the SIMD&FP source register, encoded in the "Rn" field.
- \(<V_d>\) Is the name of the SIMD&FP destination register, encoded in the "Rd" field.
- \(<T>\) For the vector half precision variant: is an arrangement specifier, encoded in “Q”:

<table>
<thead>
<tr>
<th>Q</th>
<th>&lt;T&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>NH</td>
</tr>
<tr>
<td>1</td>
<td>RH</td>
</tr>
</tbody>
</table>

For the vector single-precision and double-precision variant: is an arrangement specifier, encoded in "sz:Q":

<table>
<thead>
<tr>
<th>sz</th>
<th>Q</th>
<th>&lt;T&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>2S</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>4S</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>RESERVED</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>2D</td>
</tr>
</tbody>
</table>

- \(<V_n>\) Is the name of the SIMD&FP source register, encoded in the "Rn" field.
Operation

```plaintext
CheckFPAdvSIMDEnabled64();
bits(datasize) operand = V[n];
bits(datasize) result;
bits(esize) zero = FPZero('0');
bits(esize) element;
boolean test_passed;

for e = 0 to elements-1
  element = Elem[operand, e, esize];
  case comparison of
    when CompareOp_GT test_passed = FPCompareGT(element, zero, FPCR);
    when CompareOp_GE test_passed = FPCompareGE(element, zero, FPCR);
    when CompareOp_EQ test_passed = FPCompareEQ(element, zero, FPCR);
    when CompareOp_LE test_passed = FPCompareLE(zero, element, FPCR);
    when CompareOp_LT test_passed = FPCompareGT(zero, element, FPCR);
      Elem[result, e, esize] = if test_passed then Ones() else Zeros();

V[d] = result;
```

Internal version only: isa v30.25, AdvSIMD v27.01, pseudocode v85-xml-00bet8_rc3.tar ; Build timestamp: 2018-09-13T13:20:45Z

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FCMLT (zero)

Floating-point Compare Less than zero (vector). This instruction reads each floating-point value in the source SIMD&FP register and if the value is less than zero sets every bit of the corresponding vector element in the destination SIMD&FP register to one, otherwise sets every bit of the corresponding vector element in the destination SIMD&FP register to zero.

This instruction can generate a floating-point exception. Depending on the settings in FPCR, the exception results in either a flag being set in FPSR, or a synchronous exception being generated. For more information, see Floating-point exception traps.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

It has encodings from 4 classes: Scalar half precision, Scalar single-precision and double-precision, Vector half precision and Vector single-precision and double-precision

Scalar half precision
(ARMv8.2)

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9  | 8  | 7  | 6  | 5  | 4  | 3  | 2  | 1  | 0  |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0  | 1  | 0  | 1  | 1  | 1  | 1  | 0  | 1  | 1  | 1  | 1  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 1  | 1  | 1  | 0  | 1  | 0  |    |

Rn    Rd

Scalar half precision

FCMLT <Hd>, <Hn>, #0.0

if !HaveFP16Ext() then UNDEFINED;

integer d = 1 then UnallocatedEncoding(1);
integer d = UInt(Rd);
integer n = UInt(Rn);

integer esize = 16;
integer datasize = esize;
integer elements = 1;

CompareOp comparison = CompareOp_LT;

Scalar single-precision and double-precision

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9  | 8  | 7  | 6  | 5  | 4  | 3  | 2  | 1  | 0  |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0  | 1  | 0  | 1  | 1  | 1  | 1  | 0  | 1  | sz | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 1  | 1  | 1  | 0  | 1  | 0  |    |

Rn    Rd

Scalar single-precision and double-precision

FCMLT <V<d>, <V<n>, #0.0

integer d = UInt(Rd);
integer n = UInt(Rn);

integer esize = 32 << UInt(sz);
integer datasize = esize;
integer elements = 1;

CompareOp comparison = CompareOp_LT;

Vector half precision
(ARMv8.2)

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9  | 8  | 7  | 6  | 5  | 4  | 3  | 2  | 1  | 0  |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0  | Q  | 0  | 0  | 1  | 1  | 1  | 0  | 1  | 1  | 1  | 1  | 1  | 1  | 0  | 0  | 0  | 0  | 0  | 1  | 1  | 1  | 0  | 1  | 0  |    |

Rn    Rd
Vector half precision

FCMLT <Vd>.<T>, <Vn>.<T>, #0.0

if !HaveFP16Ext() then UNDEFINED;

integer d = UInt(Rd);
integer n = UInt(Rn);

integer esize = 16;
integer datasize = if Q == '1' then 128 else 64;
integer elements = datasize DIV esize;

CompareOp comparison = CompareOp_LT;

Vector single-precision and double-precision

integer d = UInt(Rd);
integer n = UInt(Rn);

if sz:Q == '10' then UNDEFINED;
integer esize = 32 << if sz:Q == '10' then ReservedValue() else UInt(sz);
integer datasize = if Q == '1' then 128 else 64;
integer elements = datasize DIV esize;

CompareOp comparison = CompareOp_LT;

Assembler Symbols

<Hd> Is the 16-bit name of the SIMD&FP destination register, encoded in the "Rd" field.

<Hn> Is the 16-bit name of the SIMD&FP source register, encoded in the "Rn" field.

<V> Is a width specifier, encoded in "sz":

<table>
<thead>
<tr>
<th>sz</th>
<th>&lt;V&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>S</td>
</tr>
<tr>
<td>1</td>
<td>D</td>
</tr>
</tbody>
</table>

<d> Is the number of the SIMD&FP destination register, encoded in the "Rd" field.

<n> Is the number of the SIMD&FP source register, encoded in the "Rn" field.

<Vd> Is the name of the SIMD&FP destination register, encoded in the "Rd" field.

<T> For the vector half precision variant: is an arrangement specifier, encoded in “Q”:

<table>
<thead>
<tr>
<th>Q</th>
<th>&lt;T&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>4H</td>
</tr>
<tr>
<td>1</td>
<td>8H</td>
</tr>
</tbody>
</table>

For the vector single-precision and double-precision variant: is an arrangement specifier, encoded in "sz:Q”:

<table>
<thead>
<tr>
<th>sz</th>
<th>Q</th>
<th>&lt;T&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>2S</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>4S</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>RESERVED</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>2D</td>
</tr>
</tbody>
</table>

<Vn> Is the name of the SIMD&FP source register, encoded in the "Rn" field.
Operation

CheckFPAdvSIMDEnabled64();
bits(datasize) operand = V[n];
bits(datasize) result;
bits(esize) zero = FPZero('0');
bits(esize) element;
boolean test_passed;

for e = 0 to elements-1
element = Elem[operand, e, esize];
case comparison of
  when CompareOp_GT test_passed = FPCompareGT(element, zero, FPCR);
  when CompareOp_GE test_passed = FPCompareGE(element, zero, FPCR);
  when CompareOp_EQ test_passed = FPCompareEQ(element, zero, FPCR);
  when CompareOp_LE test_passed = FPCompareGE(zero, element, FPCR);
  when CompareOp_LT test_passed = FPCompareGT(zero, element, FPCR);
Elem[result, e, esize] = if test_passed then Ones() else Zeros();
V[d] = result;
FCMP

Floating-point quiet Compare (scalar). This instruction compares the two SIMD&FP source register values, or the first SIMD&FP source register value and zero. It writes the result to the PSTATE\{N, Z, C, V\} flags.

It raises an Invalid Operation exception only if either operand is a signaling NaN.

A floating-point exception can be generated by this instruction. Depending on the settings in FPCR, the exception results in either a flag being set in FPSR, or a synchronous exception being generated. For more information, see Floating-point exception traps.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

```
31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
0 0 0 1 1 1 1 0 type 1 Rm 0 0 1 0 0 0 Rn 0 x 0 0 0 opc
```
Half-precision (type == 11 & opc == 00)
(ARMv8.2)
FCMP <Hn>, <Hm>

Half-precision, zero (type == 11 & Rm == (00000) & opc == 01)
(ARMv8.2)
FCMP <Hn>, #0.0

Single-precision (type == 00 & opc == 00)
FCMP <Sn>, <Sm>

Single-precision, zero (type == 00 & Rm == (00000) & opc == 01)
FCMP <Sn>, #0.0

Double-precision (type == 01 & opc == 00)
FCMP <Dn>, <Dm>

Double-precision, zero (type == 01 & Rm == (00000) & opc == 01)
FCMP <Dn>, #0.0

integer n = UInt(Rn);
integer m = UInt(Rm);  // ignored when opc0 == '1'

integer datasize;
case type of
  when '00' datasize = 32;
  when '01' datasize = 64;
  when '10' UNDEFINED;
  when '11' if when '10' UnallocatedEncoding() then
    datasize = 16;
    else
      UnallocatedEncoding() then
        datasize = 16;
        else
          UNDEFINED;

  boolean signal_all_nans = (opc1 == '1');
  boolean cmp_with_zero = (opc0 == '1');

Assembler Symbols

<Dn> For the double-precision variant: is the 64-bit name of the first SIMD&FP source register, encoded in the "Rn" field.
For the double-precision, zero variant: is the 64-bit name of the SIMD&FP source register, encoded in the "Rn" field.

<Dm> Is the 64-bit name of the second SIMD&FP source register, encoded in the "Rm" field.

<Hn> For the half-precision variant: is the 16-bit name of the first SIMD&FP source register, encoded in the "Rn" field.
For the half-precision, zero variant: is the 16-bit name of the SIMD&FP source register, encoded in the "Rn" field.

<Hm> Is the 16-bit name of the second SIMD&FP source register, encoded in the "Rm" field.

<Sn> For the single-precision variant: is the 32-bit name of the first SIMD&FP source register, encoded in the "Rn" field.
For the single-precision, zero variant: is the 32-bit name of the SIMD&FP source register, encoded in the "Rn" field.
NaNs

The IEEE 754 standard specifies that the result of a comparison is precisely one of <, =, > or unordered. If either or both of the operands are NaNs, they are unordered, and all three of (Operand1 < Operand2), (Operand1 == Operand2) and (Operand1 > Operand2) are false. This case results in the FPSCR flags being set to N=0, Z=0, C=1, and V=1.

Operation

```
CheckFPAdvSIMDEnabled64();

bits(datasize) operand1 = V[n];
bits(datasize) operand2;

operand2 = if cmp_with_zero then FPZero('0') else V[m];
PSTATE.<N,Z,C,V> = FPCompare(operand1, operand2, signal_all_nans, FPCR);
```

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FCMPE

Floating-point signaling Compare (scalar). This instruction compares the two SIMD&FP source register values, or the first SIMD&FP source register value and zero. It writes the result to the PSTATE. {N, Z, C, V} flags.

If either operand is any type of NaN, or if either operand is a signaling NaN, the instruction raises an Invalid Operation exception.

A floating-point exception can be generated by this instruction. Depending on the settings in FPCR, the exception results in either a flag being set in FPSR, or a synchronous exception being generated. For more information, see Floating-point exception traps.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.
Half-precision (type == 11 && opc == 10) (ARMv8.2)

FCMPE <Hn>, <Hm>

Half-precision, zero (type == 11 && Rm == (00000) && opc == 11) (ARMv8.2)

FCMPE <Hn>, #0.0

Single-precision (type == 00 && opc == 10)

FCMPE <Sn>, <Sm>

Single-precision, zero (type == 00 && Rm == (00000) && opc == 11)

FCMPE <Sn>, #0.0

Double-precision (type == 01 && opc == 10)

FCMPE <Dn>, <Dm>

Double-precision, zero (type == 01 && Rm == (00000) && opc == 11)

FCMPE <Dn>, #0.0

integer n = UInt(Rn);
integer m = UInt(Rm); // ignored when opc<0> == '1'

integer datasize;
case type of
  when '00' datasize = 32;
  when '01' datasize = 64;
  when '10' UNDEFINED;
  when '11'
    if when '10' UnallocatedEncoding()
      datasize = 16;
    else
      if HaveFP16Ext()
        datasize = 16;
      else
        UnallocatedEncoding() then
          datasize = 16;
        else
          UNDEFINED;
%
boolean signal_all_nans = (opc<1> == '1');
boolean cmp_with_zero = (opc<0> == '1');

Assembler Symbols

<Dn> For the double-precision variant: is the 64-bit name of the first SIMD&FP source register, encoded in the "Rn" field.
For the double-precision, zero variant: is the 64-bit name of the SIMD&FP source register, encoded in the "Rn" field.

<Dm> Is the 64-bit name of the second SIMD&FP source register, encoded in the "Rm" field.

<Hn> For the half-precision variant: is the 16-bit name of the first SIMD&FP source register, encoded in the "Rn" field.
For the half-precision, zero variant: is the 16-bit name of the SIMD&FP source register, encoded in the "Rn" field.

<Hm> Is the 16-bit name of the second SIMD&FP source register, encoded in the "Rm" field.

<Sn> For the single-precision variant: is the 32-bit name of the first SIMD&FP source register, encoded in the "Rn" field.
For the single-precision, zero variant: is the 32-bit name of the SIMD&FP source register, encoded in the "Rn" field.
NaNs
The IEEE 754 standard specifies that the result of a comparison is precisely one of \(<\), \(\leq\), \(\geq\), or unordered. If either or both of the operands are NaNs, they are unordered, and all three of \((\text{Operand1} < \text{Operand2})\), \((\text{Operand1} \leq \text{Operand2})\), and \((\text{Operand1} > \text{Operand2})\) are false. This case results in the FPSCR flags being set to \(N=0, Z=0, C=1,\) and \(V=1\).

FCMPE raises an Invalid Operation exception if either operand is any type of NaN, and is suitable for testing for \(<\), \(\leq\), \(\geq\), and other predicates that raise an exception when the operands are unordered.

Operation

```c
CheckFPAdvSIMDEnabled64();

bits(datasize) operand1 = V[n];
bites(datasize) operand2;

operand2 = if cmp_with_zero then FPZero('0') else V[m];

PSTATE.<N,Z,C,V> = FPCompare(operand1, operand2, signal_all_nans, FPCR);
```

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FCSEL

Floating-point Conditional Select (scalar). This instruction allows the SIMD&FP destination register to take the value from either one or the other of two SIMD&FP source registers. If the condition passes, the first SIMD&FP source register value is taken, otherwise the second SIMD&FP source register value is taken.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9  | 8  | 7  | 6  | 5  | 4  | 3  | 2  | 1  | 0  |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0  | 0  | 1  | 1  | 1  | 0  | type | 1  | Rm | cond | 1  | 1  | Rn | Rd |

Half-precision (type == 11)

(ARMv8.2)

FCSEL <Hd>, <Hn>, <Hm>, <cond>

Single-precision (type == 00)

FCSEL <Sd>, <Sn>, <Sm>, <cond>

Double-precision (type == 01)

FCSEL <Dd>, <Dn>, <Dm>, <cond>

integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rm);

integer datasize;
case type of
  when '00' datasize = 32;
  when '01' datasize = 64;
  when '10' UNDEFINED;
  when '11'
    if when '10' UnallocatedEncoding();
    when '11'
      if HaveFP16Ext() then
        datasize = 16;
      else
        UnallocatedEncoding() then
          datasize = 16;
      else
        UNDEFINED;
else

bits(4) condition = cond;

Assembler Symbols

<Dd> Is the 64-bit name of the SIMD&FP destination register, encoded in the "Rd" field.
<Dn> Is the 64-bit name of the first SIMD&FP source register, encoded in the "Rn" field.
<Dm> Is the 64-bit name of the second SIMD&FP source register, encoded in the "Rm" field.
<Hd> Is the 16-bit name of the SIMD&FP destination register, encoded in the "Rd" field.
<Hn> Is the 16-bit name of the first SIMD&FP source register, encoded in the "Rn" field.
<Hm> Is the 16-bit name of the second SIMD&FP source register, encoded in the "Rm" field.
<Sd> Is the 32-bit name of the SIMD&FP destination register, encoded in the "Rd" field.
<Sn> Is the 32-bit name of the first SIMD&FP source register, encoded in the "Rn" field.
Operation

```c
CheckFPAdvSIMDEnabled64();
bits(datasize) result;
result = if ConditionHolds(condition) then V[n] else V[m];
V[d] = result;
```

Operational information

If PSTATE.DIT is 1:
- The execution time of this instruction is independent of:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
- The response of this instruction to asynchronous exceptions does not vary based on:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
FCVT

Floating-point Convert precision (scalar). This instruction converts the floating-point value in the SIMD&FP source register to the precision for the destination register data type using the rounding mode that is determined by the FPCR and writes the result to the SIMD&FP destination register.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.
Half-precision to single-precision (type == 11 && opc == 00)

FCVT <Sd>, <Hn>

Half-precision to double-precision (type == 11 && opc == 01)

FCVT <Dd>, <Hn>

Single-precision to half-precision (type == 00 && opc == 11)

FCVT <Hd>, <Sn>

Single-precision to double-precision (type == 00 && opc == 01)

FCVT <Dd>, <Sn>

Double-precision to half-precision (type == 01 && opc == 11)

FCVT <Hd>, <Dn>

Double-precision to single-precision (type == 01 && opc == 00)

FCVT <Sd>, <Dn>

integer d = UInt(Rd);
integer n = UInt(Rn);
if type == opc then UNDEFINED;

integer srcsize;
case type of
  when '00' srcsize = 32;
  when '01' srcsize = 64;
  when '10' UNDEFINED;
  when '11' srcsize = 16;

integer dstsize;
case opc of
  when '00' dstsize = 32;
  when '01' dstsize = 64;
  when '10' UNDEFINED;
  when '11' dstsize = 16; if type == opc then UnallocatedEncoding();

Assembler Symbols

<Dd> Is the 64-bit name of the SIMD&FP destination register, encoded in the "Rd" field.
<Hd> Is the 16-bit name of the SIMD&FP destination register, encoded in the "Rd" field.
<Sn> Is the 32-bit name of the SIMD&FP source register, encoded in the "Rn" field.
<Sd> Is the 32-bit name of the SIMD&FP destination register, encoded in the "Rd" field.
<Hn> Is the 16-bit name of the SIMD&FP source register, encoded in the "Rn" field.

<Dn> Is the 64-bit name of the SIMD&FP source register, encoded in the "Rn" field.

**Operation**

```c
CheckFPAdvSIMDEnabled64();

bits(dstsize) result;
bits(srcsize) operand = V[n];

result = FPConvert(operand, FPCR);
V[d] = result;
```

Internal version only: isa v30.25 v29.05, AdvSIMD v27.01 v26.0, pseudocode v85-xml-00bet8_rc3v35c8 ; Build timestamp: 2018-09-13T13 2018-06-16T09 0445

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FCVTAS (vector)

Floating-point Convert to Signed integer, rounding to nearest with ties to Away (vector). This instruction converts each element in a vector from a floating-point value to a signed integer value using the Round to Nearest with Ties to Away rounding mode and writes the result to the SIMD&FP destination register.

A floating-point exception can be generated by this instruction. Depending on the settings in FPCR, the exception results in either a flag being set in FPSR, or a synchronous exception being generated. For more information, see Floating-point exception traps.

Depending on the settings on the registers CPACR_EL1, CPTR_EL2, and CPTR_EL3, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

It has encodings from 4 classes: Scalar half precision, Scalar single-precision and double-precision, Vector half precision and Vector single-precision and double-precision

### Scalar half precision (ARMv8.2)

```
<table>
<thead>
<tr>
<th>31</th>
<th>30</th>
<th>29</th>
<th>28</th>
<th>27</th>
<th>26</th>
<th>25</th>
<th>24</th>
<th>23</th>
<th>22</th>
<th>21</th>
<th>20</th>
<th>19</th>
<th>18</th>
<th>17</th>
<th>16</th>
<th>15</th>
<th>14</th>
<th>13</th>
<th>12</th>
<th>11</th>
<th>10</th>
<th>9</th>
<th>8</th>
<th>7</th>
<th>6</th>
<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>Rn</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

U
```

```
FCVTAS <Hd>, <Hn>

if !HaveFP16Ext() then UNDEFINED;

integer d = 1;

integer d = UInt(Rd);

integer n = UInt(Rn);

integer esize = 16;
integer datasize = esize;
integer elements = 1;

FPRounding rounding = FPRounding_TIEAWAY;
boolean unsigned = (U == '1');
```

### Scalar single-precision and double-precision

```
<table>
<thead>
<tr>
<th>31</th>
<th>30</th>
<th>29</th>
<th>28</th>
<th>27</th>
<th>26</th>
<th>25</th>
<th>24</th>
<th>23</th>
<th>22</th>
<th>21</th>
<th>20</th>
<th>19</th>
<th>18</th>
<th>17</th>
<th>16</th>
<th>15</th>
<th>14</th>
<th>13</th>
<th>12</th>
<th>11</th>
<th>10</th>
<th>9</th>
<th>8</th>
<th>7</th>
<th>6</th>
<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
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<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>Rn</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

U
```

```
FCVTAS <V><d>, <V><n>

integer d = UInt(Rd);

integer n = UInt(Rn);

integer esize = 32 << UInt(sz);
integer datasize = esize;
integer elements = 1;

FPRounding rounding = FPRounding_TIEAWAY;
boolean unsigned = (U == '1');
```
Vector half precision
(ARMv8.2)

31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
0 | Q | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 0 | Rn | Rd
U

Vector half precision

FCVTAS <Vd>.<T>, <Vn>.<T>

if !HaveFP16Ext() then UNDEFINED;

integer d = Uint(Rd);
integer n = Uint(Rn);

integer esize = 16;
integer datasize = if Q == '1' then 128 else 64;
integer elements = datasize DIV esize;

FPRounding rounding = FPRounding TIEAWAY;
boolean unsigned = (U == '1');

Vector single-precision and double-precision

31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
0 | Q | 0 | 0 | 1 | 1 | 1 | 0 | 0 | sz | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 1 | 0 | Rn | Rd
U

Vector single-precision and double-precision

FCVTAS <Vd>.<T>, <Vn>.<T>

integer d = Uint(Rd);
integer n = Uint(Rn);

if sz:Q == '10' then UNDEFINED;
integer esize = 32 << if sz:Q == '10' then ReservedValue() ;
integer esize = 32 << Uint(sz);
integer datasize = if Q == '1' then 128 else 64;
integer elements = datasize DIV esize;

FPRounding rounding = FPRounding TIEAWAY;
boolean unsigned = (U == '1');

Assembler Symbols

<Hd> Is the 16-bit name of the SIMD&FP destination register, encoded in the "Rd" field.

<Hn> Is the 16-bit name of the SIMD&FP source register, encoded in the "Rn" field.

<V> Is a width specifier, encoded in “sz”:

<table>
<thead>
<tr>
<th>sz</th>
<th>&lt;V&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>S</td>
</tr>
<tr>
<td>1</td>
<td>D</td>
</tr>
</tbody>
</table>

<d> Is the number of the SIMD&FP destination register, encoded in the "Rd" field.

<n> Is the number of the SIMD&FP source register, encoded in the "Rn" field.

<Vd> Is the name of the SIMD&FP destination register, encoded in the "Rd" field.

<T> For the vector half precision variant: is an arrangement specifier, encoded in “Q”:
For the vector single-precision and double-precision variant: is an arrangement specifier, encoded in "sz:Q":

<table>
<thead>
<tr>
<th>sz</th>
<th>Q</th>
<th>&lt;T&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>2S</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>4S</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>RESERVED</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>2D</td>
</tr>
</tbody>
</table>

<Vn> Is the name of the SIMD&FP source register, encoded in the "Rn" field.

**Operation**

```c
CheckFPAdvSIMDEnabled64();
bits(datasize) operand = V[n];
bits(datasize) result;
bits(esize) element;

for e = 0 to elements-1
    element = Elem[operand, e, esize];
    Elem[result, e, esize] = FPToFixed(element, 0, unsigned, FPCR, rounding);

V[d] = result;
```

Internal version only: isa v30.25-v29.05, AdvSIMD v27.01-v26.0, pseudocode v85-xml-00bet8_rc3c355 ; Build timestamp: 2018-09-13T13:2018-06:16:02 04:45

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FCVTAS (scalar)

Floating-point Convert to Signed integer, rounding to nearest with ties to Away (scalar). This instruction converts the floating-point value in the SIMD&FP source register to a 32-bit or 64-bit signed integer using the Round to Nearest with Ties to Away rounding mode, and writes the result to the general-purpose destination register.

A floating-point exception can be generated by this instruction. Depending on the settings in $FPCR$, the exception results in either a flag being set in $FPSR$, or a synchronous exception being generated. For more information, see Floating-point exception traps.

Depending on the settings in the $CPACR_EL1$, $CPTR_EL2$, and $CPTR_EL3$ registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.
Half-precision to 32-bit (sf == 0 && type == 11)  
(ARMv8.2)

FCVTAS <Wd>, <Hn>

Half-precision to 64-bit (sf == 1 && type == 11)  
(ARMv8.2)

FCVTAS <Xd>, <Hn>

Single-precision to 32-bit (sf == 0 && type == 00)

FCVTAS <Wd>, <Sn>

Single-precision to 64-bit (sf == 1 && type == 00)

FCVTAS <Xd>, <Sn>

Double-precision to 32-bit (sf == 0 && type == 01)

FCVTAS <Wd>, <Dn>

Double-precision to 64-bit (sf == 1 && type == 01)

FCVTAS <Xd>, <Dn>
integer d = UInt(Rd);
integer n = UInt(Rn);
integer intsize = if sf == '1' then 64 else 32;
integer fltsize;
FPConvOp op;
FPRounding rounding;
boolean unsigned;
integer part;
case type of
  when '00'
    fltsize = 32;
  when '01'
    fltsize = 64;
  when '10'
    if opcode<2:1>:rmode != '11 01' then UNDEFINED;
    fltsize = 128;
  when '11'
    if HaveFP16Ext() then
      fltsize = 16;
    else
      UNDEFINED;
case opcode<2:1>:rmode of
  when '00 xx'        // FCVT[NM]Z[US]
    rounding = FPDecodeRounding(rmode);
    unsigned = (opcode<0> == '1');
    op = FPConvOp_CVT_FtoI;
  when '01 00'        // [US]CVTF
    rounding = FPRoundingMode(FPCR);
    unsigned = (opcode<0> == '1');
    op = FPConvOp_CVT_ItoF;
  when '10 00'        // FCVTA[US]
    rounding = FPRounding_TIEAWAY;
    unsigned = (opcode<0> == '1');
    op = FPConvOp_CVT_FtoI;
  when '11 00'        // FMOV
    if fltsize != 16 && fltsize != intsize then UNDEFINED;
    if opcode<0> == '1' then
      if fltsize != 16 && fltsize != intsize then UnallocatedEncoding();
      op = if fltsize != 16 && fltsize != intsize then UnallocatedEncoding() else FPConvOp_MOV_FtoI;
    part = 0;
  when '11 01'        // FMOV D[1]
    if intsize != 64 || fltsize != 128 then UNDEFINED;
    if intsize != 64 || fltsize != 128 then UnallocatedEncoding();
    if intsize != 64 || fltsize != 128 then UnallocatedEncoding();
    op = if opcode<0> == '1' then FPConvOp_MOV_ItoF else FPConvOp_MOV_FtoI;
    part = 1;
    fltsize = 64; // size of D[1] is 64;
  when '11 11'        // FJCVTZS
    if !HaveFJCVTZSExt() then UNDEFINED;
    rounding = FPRounding_ZERO;
    unsigned = (opcode<0> == '1');
    op = FPConvOp_CVT_FtoI_JS;
  otherwise
    UnallocatedEncoding();
otherwise
  UNDEFINED();

Assembler Symbols

<Wd> Is the 32-bit name of the general-purpose destination register, encoded in the "Rd" field.
<Xd> Is the 64-bit name of the general-purpose destination register, encoded in the "Rd" field.

<Sn> Is the 32-bit name of the SIMD&FP source register, encoded in the "Rn" field.

<Hn> Is the 16-bit name of the SIMD&FP source register, encoded in the "Rn" field.

<Dn> Is the 64-bit name of the SIMD&FP source register, encoded in the "Rn" field.

**Operation**

```c
CheckFPAdvSIMDEnabled64();

bits(fltsize) fltval;
bits(intsize) intval;

case op of
  when FPConvOp_CVT_FtoI
    fltval = V[n];
    intval = FPToFixed(fltval, 0, unsigned, FPCR, rounding);
    X[d] = intval;
  when FPConvOp_CVT_ItoF
    intval = X[n];
    fltval = FixedToFP(intval, 0, unsigned, FPCR, rounding);
    V[d] = fltval;
  when FPConvOp_MOV_FtoI
    fltval = Vpart[n,part];
    intval = ZeroExtend(fltval, intsize);
    X[d] = intval;
  when FPConvOp_MOV_ItoF
    intval = X[n];
    fltval = intval<fltsize-1:0>;
    Vpart[d,part] = fltval;
  when FPConvOp_CVT_FtoI_JS
    fltval = V[n];
    intval = FPToFixedJS(fltval, FPCR, TRUE);
    X[d] = ZeroExtend(intval<31:0>, 64);
```

Internal version only: isa v30.25<20.05, AdvSIMD v27.0<26.0, pseudocode v85-xml-00bet8_rc3a59; Build timestamp: 2018-09-13T13:5045

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FCVTAU (vector)

Floating-point Convert to Unsigned integer, rounding to nearest with ties to Away (vector). This instruction converts each element in a vector from a floating-point value to an unsigned integer value using the Round to Nearest with Ties to Away rounding mode and writes the result to the SIMD&FP destination register.

A floating-point exception can be generated by this instruction. Depending on the settings in FPCR, the exception results in either a flag being set in FPSR, or a synchronous exception being generated. For more information, see Floating-point exception traps.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

It has encodings from 4 classes: Scalar half precision, Scalar single-precision and double-precision, Vector half precision and Vector single-precision and double-precision

Scalar half precision

(ARMv8.2)

```
31  30  29  28  27  26  25  24  23  22  21  20  19  18  17  16  15  14  13  12  11  10  9  8  7  6  5  4  3  2  1  0
 0  1  1  1  1  1  1  0  0  1  1  1  1  0  0  1  1  1  0  0  1  0                U

FCVTAU <Hd>, <Hn>
```

```java
if !HaveFP16Ext() then UNDEFINED;

integer d = 1; then unallocatedEncoding(1);

integer d = UInt(Rd);
integer n = UInt(Rn);

integer esize = 16;
integer datasize = esize;
integer elements = 1;

FPRounding rounding = FPRounding_TIEAWAY;
boolean unsigned = (U == '1');
```

Scalar single-precision and double-precision

```
31  30  29  28  27  26  25  24  23  22  21  20  19  18  17  16  15  14  13  12  11  10  9  8  7  6  5  4  3  2  1  0
 0  1  1  1  1  1  1  0  0  sz  1  0  0  0  0  1  1  1  0  0  1  0                U

FCVTAU <V>d, <V>n
```

```java
integer d = UInt(Rd);
integer n = UInt(Rn);

integer esize = 32 << UInt(sz);
integer datasize = esize;
integer elements = 1;

FPRounding rounding = FPRounding_TIEAWAY;
boolean unsigned = (U == '1');
```
Vector half precision

(ARMv8.2)

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9  | 8  | 7  | 6  | 5  | 4  | 3  | 2  | 1  | 0  |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| Q  | 1  | 0  | 1  | 1  | 1  | 0  | 0  | 1  | 1  | 1  | 0  | 0  | 1  | 1  | 0  | 0  | 1  | 0  | Rn | Rd |

Vector half precision

FCVT< Vd>.<T>, <Vn>.<T>

if !HaveFP16Ext() then UNDEFINED;
integer d = UInt(Rd);
integer n = UInt(Rn);

integer esize = 16;
integer datasize = if Q == '1' then 128 else 64;
integer elements = datasize DIV esize;
FPRounding rounding = FPRounding_TIEAWAY;
boolean unsigned = (U == '1');

Vector single-precision and double-precision

31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
| 0  | 1  | 0  | 0  | 1  | 1  | 1  | 0  | 0  | sz | 1  | 0  | 0  | 0  | 0  | 1  | 1  | 1  | 0  | 0  | 1  | 0  | Rn | Rd |

Vector single-precision and double-precision

FCVT< Vd>.<T>, <Vn>.<T>

integer d = UInt(Rd);
integer n = UInt(Rn);

if sz:Q == '10' then UNDEFINED;
integer esize = 32 << if sz:Q == '10' then ReservedValue() ;
integer esize = 32 << UInt(sz); 
integer datasize = if Q == '1' then 128 else 64;
integer elements = datasize DIV esize;
FPRounding rounding = FPRounding_TIEAWAY;
boolean unsigned = (U == '1');

Assembler Symbols

<Hd> Is the 16-bit name of the SIMD&FP destination register, encoded in the "Rd" field.
<Hn> Is the 16-bit name of the SIMD&FP source register, encoded in the "Rn" field.
<V> Is a width specifier, encoded in "sz":

<table>
<thead>
<tr>
<th>sz</th>
<th>&lt;V&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>S</td>
</tr>
<tr>
<td>1</td>
<td>D</td>
</tr>
</tbody>
</table>

<d> Is the number of the SIMD&FP destination register, encoded in the "Rd" field.
<n> Is the number of the SIMD&FP source register, encoded in the "Rn" field.
<Vd> Is the name of the SIMD&FP destination register, encoded in the "Rd" field.
<T> For the vector half precision variant: is an arrangement specifier, encoded in “Q”:
For the vector single-precision and double-precision variant: is an arrangement specifier, encoded in "sz:Q":

<table>
<thead>
<tr>
<th>sz</th>
<th>Q</th>
<th>&lt;T&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>2S</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>4S</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>RESERVED</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>2D</td>
</tr>
</tbody>
</table>

<Vn> is the name of the SIMD&FP source register, encoded in the "Rn" field.

**Operation**

```plaintext
CheckFPAdvSIMDEnabled64();
bits(datasize) operand = V[n];
bits(datasize) result;
bits(esize) element;
for e = 0 to elements-1
    element = Elem[operand, e, esize];
    Elem[result, e, esize] = FPToFixed(element, 0, unsigned, FPCR, rounding);
V[d] = result;
```

Internal version only: isa v30.25 v29.05 AdvSIMD v27.01 v26.0 pseudocode v85-xml-00bet8 rc3e353 ; Build timestamp: 2018-09-13T13:2018-06-16T08:04:15

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FCVTAU (scalar)

Floating-point Convert to Unsigned integer, rounding to nearest with ties to Away (scalar). This instruction converts the floating-point value in the SIMD&FP source register to a 32-bit or 64-bit unsigned integer using the Round to Nearest with Ties to Away rounding mode, and writes the result to the general-purpose destination register.

A floating-point exception can be generated by this instruction. Depending on the settings in FPCR, the exception results in either a flag being set in FPSR, or a synchronous exception being generated. For more information, see Floating-point exception traps.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.
Half-precision to 32-bit (sf == 0 && type == 11)  
(ARMv8.2)

```assembly
FCVTAU <Wd>, <Hn>
```

Half-precision to 64-bit (sf == 1 && type == 11)  
(ARMv8.2)

```assembly
FCVTAU <Xd>, <Hn>
```

Single-precision to 32-bit (sf == 0 && type == 00)

```assembly
FCVTAU <Wd>, <Sn>
```

Single-precision to 64-bit (sf == 1 && type == 00)

```assembly
FCVTAU <Xd>, <Sn>
```

Double-precision to 32-bit (sf == 0 && type == 01)

```assembly
FCVTAU <Wd>, <Dn>
```

Double-precision to 64-bit (sf == 1 && type == 01)

```assembly
FCVTAU <Xd>, <Dn>
```
integer d = UInt(Rd);
integer n = UInt(Rn);

integer intsize = if sf == '1' then 64 else 32;
integer fltsize;
FPConvOp op;
FPRounding rounding;
boolean unsigned;
integer part;

case type of
  when '00'
    fltsize = 32;
  when '01'
    fltsize = 64;
  when '10'
    if opcode<2:1>:rmode != '11 01' then UNDEFINED;
    fltsize = 128;
  when '11'
    if opcode<2:1>:rmode != '11 01' then UnallocatedEncoding();
    fltsize = 128;
  when '11'
    if !HaveFP16Ext() then
      fltsize = 16;
    else
      UNDEFINED;

case opcode<2:1>:rmode of
  when '00 xx'        // FCVT[NPMZ][US]
    rounding = FPDecodeRounding(rmode);
    unsigned = (opcode<0> == '1');
    op = FPConvOp_CVT_FtoI;
  when '01 00'        // [US]CVTF
    rounding = FPRoundingMode(FPCR);
    unsigned = (opcode<0> == '1');
    op = FPConvOp_CVT_ItoF;
  when '10 00'        // FCVTA[US]
    rounding = FPRounding_TIEAWAY;
    unsigned = (opcode<0> == '1');
    op = FPConvOp_CVT_FtoI;
  when '11 00'        // FMOV
    if fltsize != 16 && fltsize != intsize then UNDEFINED;
    if opcode<0> == '1' then
      if fltsize != 16 && fltsize != intsize then UnallocatedEncoding();
    op = if opcode<0> == '1' then
      if fltsize != 16 && fltsize != intsize then UnallocatedEncoding();
    else
      FPConvOp_MOV_ItoF else FPConvOp_MOV_FtoI;
    part = 0;
  when '11 01'        // FMOV D[1]
    if intsize != 64 || fltsize != 128 then UNDEFINED;
    op = if opcode<0> == '1' then
      if intsize != 64 || fltsize != 128 then UnallocatedEncoding();
    else
      FPConvOp_MOV_ItoF else FPConvOp_MOV_FtoI;
    part = 1;
    fltsize = 64; // size of D[1] is 64
  when '11 11'        // FJCVTZS
    if !HaveFJCVTZSExt[] then UNDEFINED;
    rounding = FPZero();
    unsigned = (opcode<0> == '1');
    op = FPConvOp_CVT_FtoI_JS;
  otherwise
    UnallocatedEncoding();
  otherwise
    UNDEFINED();

Assembler Symbols

<Wd> Is the 32-bit name of the general-purpose destination register, encoded in the "Rd" field.
<Xd> Is the 64-bit name of the general-purpose destination register, encoded in the “Rd” field.
<Sn> Is the 32-bit name of the SIMD&FP source register, encoded in the “Rn” field.
<Hn> Is the 16-bit name of the SIMD&FP source register, encoded in the “Rn” field.
<Dn> Is the 64-bit name of the SIMD&FP source register, encoded in the “Rn” field.

**Operation**

```c
CheckFPAdvSIMDEnabled64();

bits(fltsize) fltval;
bits(intsize) intval;

case op of
  when FPConvOp_CVT_FtoI
    fltval = V[n];
    intval = FPToFixed(fltval, 0, unsigned, FPCR, rounding);
    X[d] = intval;
  when FPConvOp_CVT_ItoF
    intval = X[n];
    fltval = FixedToFP(intval, 0, unsigned, FPCR, rounding);
    V[d] = fltval;
  when FPConvOp_MOV_FtoI
    fltval = Vpart[n, part];
    intval = ZeroExtend(fltval, intsize);
    X[d] = intval;
  when FPConvOp_MOV_ItoF
    intval = X[n];
    fltval = intval<fltsize-1:0>;
    Vpart[d, part] = fltval;
  when FPConvOp_CVT_FtoI_JS
    fltval = V[n];
    intval = FPToFixedJS(fltval, FPCR, TRUE);
    X[d] = ZeroExtend(intval<31:0>, 64);
```

Internal version only: isa v30.25, AdvSIMD v27.01, pseudocode v85-xml-00beg8_rc3_0000; Build timestamp: 2018-09-13 13:45 2018-06-16 09:45

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FCVTMS (vector)

Floating-point Convert to Signed integer, rounding toward Minus infinity (vector). This instruction converts a scalar or each element in a vector from a floating-point value to a signed integer value using the Round towards Minus Infinity rounding mode, and writes the result to the SIMD&FP destination register.

A floating-point exception can be generated by this instruction. Depending on the settings in FPCR, the exception results in either a flag being set in FPSR, or a synchronous exception being generated. For more information, see Floating-point exception traps.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the Security state and Exception level in which the instruction is executed, an attempt to execute the instruction might be trapped.

It has encodings from 4 classes: Scalar half precision, Scalar single-precision and double-precision, Vector half precision and Vector single-precision and double-precision

Scalar half precision

(ARMv8.2)

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|---|
| 0  | 1  | 0  | 1  | 1  | 1  | 1  | 1  | 0  | 0  | 0  | 1  | 1  | 0  | 1  | 1  | 0  | 1  | 1  | 0  |
| U  | o2 | o1 |

Scalar single-precision and double-precision

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|---|
| 0  | 1  | 0  | 1  | 1  | 1  | 0  | 0  | 1  | 1  | 0  | 0  | 1  | 1  | 0  | 1  | 1  | 0  |
| U  | o2 | o1 |

Scalar single-precision and double-precision

```plaintext
FCVTMS <V>d, <V>n

if !HaveFP16Ext() then UNDEFINED;
integer d = 1 then UnallocatedEncoding(1);
integer d = UInt(Rd);
integer n = UInt(Rn);
integer esize = 16;
integer datasize = esize;
integer elements = 1;
FPRounding rounding = FPDecodeRounding(o1:o2);
boolean unsigned = (U == '1');
```

```plaintext
FCVTMS <V>d, <V>n

integer d = UInt(Rd);
integer n = UInt(Rn);
integer esize = 32 << UInt(sz);
integer datasize = esize;
integer elements = 1;
FPRounding rounding = FPDecodeRounding(o1:o2);
boolean unsigned = (U == '1');
```
Vector half precision

(ARMv8.2)

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0  | Q | 0 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 0 | 1 | 1 | 0 | Rn |   | Rd |

Vector half precision

```
FCVTMS <Vd>.<T>, <Vn>.<T>
```

```haskell
if !HaveFP16Ext() then UNDEFINED;

integer d = UInt(Rd);
integer n = UInt(Rn);

integer esize = 16;
integer datasize = if Q == '1' then 128 else 64;
integer elements = datasize DIV esize;

FP Rounding rounding = FPDecodeRounding(o1:o2);
boolean unsigned = (U == '1');
```

Vector single-precision and double-precision

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0  | Q | 0 | 1 | 1 | 1 | 0 | 0 | sz | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 1 | 0 | Rn |   | Rd |

Assembler Symbols

- `<Hd>`: Is the 16-bit name of the SIMD&FP destination register, encoded in the "Rd" field.
- `<Hn>`: Is the 16-bit name of the SIMD&FP source register, encoded in the "Rn" field.
- `<V>`: Is a width specifier, encoded in "sz":

<table>
<thead>
<tr>
<th>sz</th>
<th>&lt;V&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>S</td>
</tr>
<tr>
<td>1</td>
<td>D</td>
</tr>
</tbody>
</table>

- `<d>`: Is the number of the SIMD&FP destination register, encoded in the "Rd" field.
- `<n>`: Is the number of the SIMD&FP source register, encoded in the "Rn" field.
- `<Vd>`: Is the name of the SIMD&FP destination register, encoded in the "Rd" field.
- `<T>`: For the vector half precision variant: is an arrangement specifier, encoded in “Q”:
For the vector single-precision and double-precision variant: is an arrangement specifier, encoded in \( \text{"sz:Q"} \):

<table>
<thead>
<tr>
<th>sz</th>
<th>Q</th>
<th>(&lt;T&gt;)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>2S</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>4S</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>RESERVED</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>2D</td>
</tr>
</tbody>
</table>

\(<Vn>\) Is the name of the SIMD&FP source register, encoded in the "Rn" field.

**Operation**

```plaintext
CheckFPAdvSIMDEnabled64();

bits(datasize) operand = V[n];
bits(datasize) result;
bits(esize) element;

for e = 0 to elements-1
    element = Elem[operand, e, esize];
    Elem[result, e, esize] = FPToFixed(element, 0, unsigned, FPCR, rounding);

V[d] = result;
```

Internal version only: isa v30.25 v29.05, AdvSIMD v27.01 v26.0, pseudocode v85-xml-00bet8_rc3v351; Build timestamp: 2018-09-13T13:2018-06-16T02:04:45

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FCVTMS (scalar)

Floating-point Convert to Signed integer, rounding toward Minus infinity (scalar). This instruction converts the floating-point value in the SIMD&FP source register to a 32-bit or 64-bit signed integer using the Round towards Minus Infinity rounding mode, and writes the result to the general-purpose destination register.

A floating-point exception can be generated by this instruction. Depending on the settings in FPCR, the exception results in either a flag being set in FPSR, or a synchronous exception being generated. For more information, see Floating-point exception traps.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

```
<table>
<thead>
<tr>
<th>31</th>
<th>30</th>
<th>29</th>
<th>28</th>
<th>27</th>
<th>26</th>
<th>25</th>
<th>24</th>
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</tbody>
</table>
```
Half-precision to 32-bit (sf == 0 && type == 11)  
(ARMv8.2)

FCVTMS <Wd>, <Hn>

Half-precision to 64-bit (sf == 1 && type == 11)  
(ARMv8.2)

FCVTMS <Xd>, <Hn>

Single-precision to 32-bit (sf == 0 && type == 00)

FCVTMS <Wd>, <Sn>

Single-precision to 64-bit (sf == 1 && type == 00)

FCVTMS <Xd>, <Sn>

Double-precision to 32-bit (sf == 0 && type == 01)

FCVTMS <Wd>, <Dn>

Double-precision to 64-bit (sf == 1 && type == 01)

FCVTMS <Xd>, <Dn>
integer d = UnInt(Rd);
integer n = UnInt(Rn);
integer intsize = if sf == '1' then 64 else 32;
integer fltsize;
FPConvOp op;
FPRounding rounding;
boolean unsigned;
integer part;
case type of
  when '00'
    fltsize = 32;
  when '01'
    fltsize = 64;
  when '10'
    if opcode<2:1>:rmode != '11 01' then UNDEFINED;
    fltsize = 128;
  when '11'
    if HaveFP16Ext() then
      fltsize = 16;
    else
      UNDEFINED;
  case opcode<2:1>:rmode of
    when '00 xx'        // FCVT[NPMZ][US]
      rounding = UnallocatedEncoding();
    case opcode<2:1>:rmode of
    when '00 xx'        // FCVT[NPMZ][US]
      rounding = FPDecodeRounding(rmode);
      unsigned = (opcode<0> == '1');
      op = FPConvOp_CVT_FtoI;
    when '01 00'        // [US]CVTF
      rounding = FPRoundingMode(FPCR);
      unsigned = (opcode<0> == '1');
      op = FPConvOp_CVT_ItoF;
    when '10 00'        // FCVTA[US]
      rounding = FPRounding_TIEAWAY;
      unsigned = (opcode<0> == '1');
      op = FPConvOp_CVT_FtoI;
    when '11 00'        // FMOV
      if fltsize != 16 && fltsize != intsize then UNDEFINED;
      op = if fltsize != 16 && fltsize != intsize then
        UnallocatedEncoding();
      else
        FPConvOp_MOV_ItoF else FPConvOp_MOV_FtoI;
    part = 0;
    when '11 01'        // FMOV D[1]
      if intsize != 64 || fltsize != 128 then UNDEFINED;
      op = if intsize != 64 || fltsize != 128 then
        UnallocatedEncoding();
      else
        FPConvOp_MOV_ItoF else FPConvOp_MOV_FtoI;
    part = 1;
    fltsize = 64; // size of D[1] is 64
    when '11 11'        // FJCVTZS
      if !HaveFJCVTZSExt() then UNDEFINED;
      rounding = FPRounding_ZERO;
      unsigned = (opcode<0> == '1');
      op = FPConvOp_CVT_FtoI_JS;
    otherwise
      UnallocatedEncoding();
    otherwise
      UNDEFINED();
otherwise

Assembler Symbols

<Wd> Is the 32-bit name of the general-purpose destination register, encoded in the "Rd" field.
Operation

```c
CheckFPAdvSIMDEnabled64();
bits(fltsize) fltval;
bits(intsize) intval;

case op of
  when FPConvOp_CVT_FtoI
    fltval = V[n];
    intval = FPToFixed(fltval, 0, unsigned, FPCR, rounding);
    X[d] = intval;
  when FPConvOp_CVT_ItoF
    intval = X[n];
    fltval = FixedToFP(intval, 0, unsigned, FPCR, rounding);
    V[d] = fltval;
  when FPConvOp_MOV_FtoI
    intval = Vpart[n,part];
    fltval = ZeroExtend(intval, intsize);
    X[d] = intval;
  when FPConvOp_MOV_ItoF
    intval = X[n];
    fltval = intval<fltsize-1:0>;
    Vpart[d,part] = fltval;
  when FPConvOp_CVT_FtoI_JS
    fltval = V[n];
    intval = FPToFixedJS(fltval, FPCR, TRUE);
    X[d] = ZeroExtend(intval<31:0>, 64);
```

Internal version only: isa v30.25, AdvSIMD v27.01, pseudocode v35.3; Build timestamp: 2018-09-13T13:45:04Z

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FCVTMU (vector)

Floating-point Convert to Unsigned integer, rounding toward Minus infinity (vector). This instruction converts a scalar or each element in a vector from a floating-point value to an unsigned integer value using the Round towards Minus Infinity rounding mode, and writes the result to the SIMD&FP destination register.

A floating-point exception can be generated by this instruction. Depending on the settings in FPCR, the exception results in either a flag being set in FPSR, or a synchronous exception being generated. For more information, see Floating-point exception traps. Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the Security state and Exception level in which the instruction is executed, an attempt to execute the instruction might be trapped.

It has encodings from 4 classes: Scalar half precision, Scalar single-precision and double-precision, Vector half precision and Vector single-precision and double-precision

**Scalar half precision**

(ARMv8.2)

```
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9  | 8  | 7  | 6  | 5  | 4  | 3  | 2  | 1  | 0  |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0  | 1  | 1  | 1  | 1  | 1  | 0  | 0  | 1  | 1  | 1  | 0  | 1  | 1  | 0  | 1  | 1  | 0  |    |    |    |    |    |    |    |    |    |    |    |

<table>
<thead>
<tr>
<th>U</th>
<th>o2</th>
<th>o1</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
```

**Scalar single-precision and double-precision**

```
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9  | 8  | 7  | 6  | 5  | 4  | 3  | 2  | 1  | 0  |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0  | 1  | 1  | 1  | 1  | 1  | 0  | 0  | 0  | 0  | 0  | 1  | 1  | 0  | 1  | 1  | 0  |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |

<table>
<thead>
<tr>
<th>U</th>
<th>o2</th>
<th>o1</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
```

**Vector half precision**

```
integer d = UInt(Rd);
integer n = UInt(Rn);
integer esize = 16;
integer datasize = esize;
integer elements = 1;
FPRounding rounding = FPDecodeRounding(o1:o2);
boolean unsigned = (U == '1');
```

**Vector single-precision and double-precision**

```
integer d = UInt(Rd);
integer n = UInt(Rn);
integer esize = 32 << UInt(sz);
integer datasize = esize;
integer elements = 1;
FPRounding rounding = FPDecodeRounding(o1:o2);
boolean unsigned = (U == '1');
```
Vector half precision

(ARMv8.2)

```
Vector half precision

FCVTMU \(\text{<Vd>.<T>, <Vn>.<T>}\)

if \(!\text{HaveFP16Ext()}\) then UNDEFINED;

integer \(d\) = \(\text{UInt}(\text{Rd})\);
integer \(n\) = \(\text{UInt}(\text{Rn})\);

integer \(e\) = 16;
integer datasize = if \(Q = '1'\) then 128 else 64;
integer elements = datasize DIV \(e\);

\(\text{FPRounding\ rounding = FPDecodeRounding(o1:o2);}\)
boolean \(\text{unsigned} = (U = '1');\)
```

Vector single-precision and double-precision

```
Vector single-precision and double-precision

FCVTMU \(\text{<Vd>.<T>, <Vn>.<T>}\)

integer \(d\) = \(\text{UInt}(\text{Rd})\);
integer \(n\) = \(\text{UInt}(\text{Rn})\);

if \(\text{sz:Q} = '10'\) then UNDEFINED;

integer \(e\) = 32 << \(\text{UInt}(\text{sz})\);
integer datasize = if \(Q = '1'\) then 128 else 64;
integer elements = datasize DIV \(e\);

\(\text{FPRounding\ rounding = FPDecodeRounding(o1:o2);}\)
boolean \(\text{unsigned} = (U = '1');\)
```

Assembler Symbols

\(<\text{Hd}>\) Is the 16-bit name of the SIMD&FP destination register, encoded in the "Rd" field.
\(<\text{Hn}>\) Is the 16-bit name of the SIMD&FP source register, encoded in the "Rn" field.
\(<\text{V}>\) Is a width specifier, encoded in "sz":

<table>
<thead>
<tr>
<th>(\text{sz})</th>
<th>(&lt;\text{V}&gt;)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>S</td>
</tr>
<tr>
<td>1</td>
<td>D</td>
</tr>
</tbody>
</table>

\(<\text{d}>\) Is the number of the SIMD&FP destination register, encoded in the "Rd" field.
\(<\text{n}>\) Is the number of the SIMD&FP source register, encoded in the "Rn" field.
\(<\text{Vd}>\) Is the name of the SIMD&FP destination register, encoded in the "Rd" field.
\(<\text{T}>\) For the vector half precision variant: is an arrangement specifier, encoded in “Q”:
For the vector single-precision and double-precision variant: is an arrangement specifier, encoded in "sz:Q":

<table>
<thead>
<tr>
<th>sz</th>
<th>Q</th>
<th>&lt;T&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>2S</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>4S</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>RESERVED</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>2D</td>
</tr>
</tbody>
</table>

Is the name of the SIMD&FP source register, encoded in the "Rn" field.

**Operation**

```c
CheckFPAdvSIMDEnabled64();
bits(datasize) operand = V[n];
bits(datasize) result;
bits(esize) element;

for e = 0 to elements-1
    element = Elem[operand, e, esize];
    Elem[result, e, esize] = FPToFixed(element, 0, unsigned, FPCR, rounding);
V[d] = result;
```


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FCVTMU (scalar)

Floating-point Convert to Unsigned integer, rounding toward Minus infinity (scalar). This instruction converts the floating-point value in the SIMD&FP source register to a 32-bit or 64-bit unsigned integer using the Round towards Minus Infinity rounding mode, and writes the result to the general-purpose destination register.

A floating-point exception can be generated by this instruction. Depending on the settings in FPCR, the exception results in either a flag being set in FPSR, or a synchronous exception being generated. For more information, see Floating-point exception traps.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

```
+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-------------+-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Half-precision to 32-bit (sf == 0 && type == 11)
(ARMv8.2)

FCVTMU <Wd>, <Hn>

Half-precision to 64-bit (sf == 1 && type == 11)
(ARMv8.2)

FCVTMU <Xd>, <Hn>

Single-precision to 32-bit (sf == 0 && type == 00)

FCVTMU <Wd>, <Sn>

Single-precision to 64-bit (sf == 1 && type == 00)

FCVTMU <Xd>, <Sn>

Double-precision to 32-bit (sf == 0 && type == 01)

FCVTMU <Wd>, <Dn>

Double-precision to 64-bit (sf == 1 && type == 01)

FCVTMU <Xd>, <Dn>
integer d = UInt(Rd);
integer n = UInt(Rn);

integer intsize = if sf == '1' then 64 else 32;
integer fltsize;
FPConvOp op;
FPRounding rounding;
boolean unsigned;
integer part;

case type of
    when '00'
        fltsize = 32;
    when '01'
        fltsize = 64;
    when '10'
        if opcode<2:1>:rmode != '11 01' then UNDEFINED;
        fltsize = 128;
    when '11'
        if HaveFP16Ext() then
            fltsize = 16;
        else
            UNDEFINED;

    case opcode<2:1>:rmode of
        when '00 xx'        // FCVT[NPMZ][US]
            rounding = FPDecodeRounding(rmode);
            unsigned = (opcode<0> == '1');
            op = FPConvOp_CVT_FtoI;
        when '01 00'        // [US]CVTF
            rounding = FPRoundingMode(FPCR);
            unsigned = (opcode<0> == '1');
            op = FPConvOp_CVT_ItoF;
        when '10 00'        // FCVTA[US]
            rounding = FPRounding_TIEAWAY;
            unsigned = (opcode<0> == '1');
            op = FPConvOp_CVT_FtoI;
        when '11 00'        // FMOV
            if fltsize != 16 && fltsize != intsize then UNDEFINED;
            op = if opcode<0> == '1' then
                if fltsize != 16 && fltsize != intsize then
                    UnallocatedEncoding();
                else
                    FPConvOp_MOV_ItoF else FPConvOp_MOV_FtoI;
            part = 0;
        when '11 01'        // FMOV D[1]
            if intsize != 64 || fltsize != 128 then UNDEFINED;
            op = if opcode<0> == '1' then
                if intsize != 64 || fltsize != 128 then
                    UnallocatedEncoding();
                else
                    FPConvOp_MOV_ItoF else FPConvOp_MOV_FtoI;
            part = 1;
            fltsize = 64;  // size of D[1] is 64
        when '11 11'        // FJCVTZS
            if !HaveFJCVTZEExt() then UNDEFINED;
            rounding = FPRounding_ZERO;
            unsigned = (opcode<0> == '1');
            op = FPConvOp_CVT_FtoI_JS;
        otherwise
            UnallocatedEncoding();
        otherwise
            UNDEFINED();

Assembler Symbols

<Wd> Is the 32-bit name of the general-purpose destination register, encoded in the "Rd" field.
<Xd> Is the 64-bit name of the general-purpose destination register, encoded in the "Rd" field.
<Sn> Is the 32-bit name of the SIMD&FP source register, encoded in the "Rn" field.
<Hn> Is the 16-bit name of the SIMD&FP source register, encoded in the "Rn" field.
<Dn> Is the 64-bit name of the SIMD&FP source register, encoded in the "Rn" field.

Operation

```c
CheckFPAdvSIMDEnabled64();

bits(fltsize) fltval;
bits(intsize) intval;

case op of
  when FPConvOp_CVT_FtoI
    fltval = V[n];
    intval = FPToFixed(fltval, 0, unsigned, FPCR, rounding);
    X[d] = intval;
  when FPConvOp_CVT_ItoF
    intval = X[n];
    fltval = FixedToFP(intval, 0, unsigned, FPCR, rounding);
    V[d] = fltval;
  when FPConvOp_MOV_FtoI
    fltval = Vpart[n,part];
    intval = ZeroExtend(fltval, intsize);
    X[d] = intval;
  when FPConvOp_MOV_ItoF
    intval = X[n];
    fltval = intval<fltsize-1:0>;
    Vpart[d,part] = fltval;
  when FPConvOp_CVT_FtoI_JS
    fltval = V[n];
    intval = FPFixedJS(fltval, FPCR, TRUE);
    X[d] = ZeroExtend(intval<31:0>, 64);
```

Internal version only: isa v30.25 <old> v29.05 v27.01 v26.0, AdvSIMD <old> pseudocode v85-xml-00bet8_rc3adds <old> Build timestamp: 2018-09-13T13:45
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(old) htmldiff from- (new)
FCVTNS (vector)

Floating-point Convert to Signed integer, rounding to nearest with ties to even (vector). This instruction converts a scalar or each element in a vector from a floating-point value to a signed integer value using the Round to Nearest rounding mode, and writes the result to the SIMD&FP destination register.

A floating-point exception can be generated by this instruction. Depending on the settings in FPSCR, the exception results in either a flag being set in FPSR, or a synchronous exception being generated. For more information, see Floating-point exception traps.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the Security state and Exception level in which the instruction is executed, an attempt to execute the instruction might be trapped.

It has encodings from 4 classes: Scalar half precision, Scalar single-precision and double-precision, Vector half precision and Vector single-precision and double-precision

### Scalar half precision

(ARMv8.2)

![Encoding](image)

```assembly
FCVTNS <Hd>, <Hn>
if !HaveFP16Ext() then UNDEFINED;
integer d = 1 then UnallocatedEncoding(d);
integer d = UInt(Rd);
integer n = UInt(Rn);

integer esize = 16;
integer datasize = esize;
integer elements = 1;

FP_Rounding rounding = FP_decodeRounding(o1:o2);
boolean unsigned = (U == '1');
```

### Scalar single-precision and double-precision

![Encoding](image)

```assembly
FCVTNS <V>d, <V>n
integer d = UInt(Rd);
integer n = UInt(Rn);

integer esize = 32 << UInt(sz);
integer datasize = esize;
integer elements = 1;

FP_Rounding rounding = FP_decodeRounding(o1:o2);
boolean unsigned = (U == '1');
```
Vector half precision

FCVTNS <Vd>,<T>,<Vn>,<T>

if !HaveFP16Ext() then UNDEFINED;

integer d = (Rd);
integer n = (Rn);
integer esize = 16;
integer datasize = if Q == '1' then 128 else 64;
integer elements = datasize DIV esize;

FPRounding rounding = FPDecodeRounding(o1:o2);
boolean unsigned = (U == '1');

Vector single-precision and double-precision

FCVTNS <Vd>,<T>,<Vn>,<T>

integer d = (Rd);
integer n = (Rn);
if sz:Q == '10' then UNDEFINED;
integer esize = 32 <<
integer datasize = if Q == '1' then 128 else 64;
integer elements = datasize DIV esize;

FPRounding rounding = FPDecodeRounding(o1:o2);
boolean unsigned = (U == '1');

Assembler Symbols

<Hd> Is the 16-bit name of the SIMD&FP destination register, encoded in the "Rd" field.

<Hn> Is the 16-bit name of the SIMD&FP source register, encoded in the "Rn" field.

<V> Is a width specifier, encoded in "sz":

<table>
<thead>
<tr>
<th>sz</th>
<th>&lt;V&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>S</td>
</tr>
<tr>
<td>1</td>
<td>D</td>
</tr>
</tbody>
</table>

<d> Is the number of the SIMD&FP destination register, encoded in the "Rd" field.

<n> Is the number of the SIMD&FP source register, encoded in the "Rn" field.

<Vd> Is the name of the SIMD&FP destination register, encoded in the "Rd" field.

<T> For the vector half precision variant: is an arrangement specifier, encoded in “Q”: 
For the vector single-precision and double-precision variant: is an arrangement specifier, encoded in "sz:Q":

<table>
<thead>
<tr>
<th>sz</th>
<th>Q</th>
<th>&lt;T&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>2S</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>4S</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>RESERVED</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>2D</td>
</tr>
</tbody>
</table>

<\text{V}_n> \quad \text{Is the name of the SIMD\&FP source register, encoded in the "Rn" field.}

\textbf{Operation}

\begin{verbatim}
CheckFPAdvSIMDEnabled64();
bits(datasize) operand = V[n];
bits(datasize) result;
bits(esize) element;

for e = 0 to elements-1
    element = Elem[operand, e, esize];
    Elem[result, e, esize] = FPToFixed(element, 0, unsigned, FPCR, rounding);

V[d] = result;
\end{verbatim}
FCVTNS (scalar)

Floating-point Convert to Signed integer, rounding to nearest with ties to even (scalar). This instruction converts the floating-point value in the SIMD&FP source register to a 32-bit or 64-bit signed integer using the Round to Nearest rounding mode, and writes the result to the general-purpose destination register.

A floating-point exception can be generated by this instruction. Depending on the settings in \textit{FPCR}, the exception results in either a flag being set in \textit{FPSR}, or a synchronous exception being generated. For more information, see \textit{Floating-point exception traps}.

Depending on the settings in the \textit{CPACR\_EL1}, \textit{CPTR\_EL2}, and \textit{CPTR\_EL3} registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

```
  31  30  29  28  27  26  25  24  23  22  21  20  19  18  17  16  15  14  13  12  11  10  9   8   7   6   5   4   3   2   1   0
sf  0  0  1  1  1  1  0  1  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
  rmode  opcode
```
Half-precision to 32-bit ($sf == 0$ && $type == 11$) (ARMv8.2)

`FCVTNS <Wd>, <Hn>`

Half-precision to 64-bit ($sf == 1$ && $type == 11$) (ARMv8.2)

`FCVTNS <Xd>, <Hn>`

Single-precision to 32-bit ($sf == 0$ && $type == 00$)

`FCVTNS <Wd>, <Sn>`

Single-precision to 64-bit ($sf == 1$ && $type == 00$)

`FCVTNS <Xd>, <Sn>`

Double-precision to 32-bit ($sf == 0$ && $type == 01$)

`FCVTNS <Wd>, <Dn>`

Double-precision to 64-bit ($sf == 1$ && $type == 01$)

`FCVTNS <Xd>, <Dn>`
integer d = UInt(Rd);
integer n = UInt(Rn);

integer intsize = if sf == '1' then 64 else 32;
integer faltsize;
FPConvOp op;
FPRounding rounding;
boolean unsigned;
integer part;

case type of
  when '00'
    faltsize = 32;
  when '01'
    faltsize = 64;
  when '10'
    if opcode<2:1>:rmode != '11 01' then UNDEFINED;
    faltsize = 128;
  when '11'
    if HaveFP16Ext() then
      faltsize = 16;
    else
      UNDEFINED;
    faltsize = 128;
    if opcode<2:1>:rmode != '11 01' then UnallocatedEncoding();
  when '11'
    if HaveFJCVTZSExt() then UNDEFINED;
    rounding = FPRounding_ZERO;
    unsigned = (opcode<0> == '1');
    op = FPConvOp_CVT_FtoI_JS;
  otherwise
    UnallocatedEncoding();
  otherwise
    UNDEFINED();

case opcode<2:1>:rmode of
  when '00 xx'        // FCVT[NPMZ][US]
    rounding = UnallocatedEncoding();
  when '00 xx'        // FCVT[NPMZ][US]
    rounding = FPDecodeRounding(rmode);
    unsigned = (opcode<0> == '1');
    op = FPConvOp_CVT_FtoI;
  when '01 00'        // [US]CVTF
    rounding = FPRoundingMode(FPCR);
    unsigned = (opcode<0> == '1');
    op = FPConvOp_CVT_ItoF;
  when '10 00'        // FCVTA[US]
    rounding = FPRounding_TIEAWAY;
    unsigned = (opcode<0> == '1');
    op = FPConvOp_CVT_FtoI;
  when '11 00'        // FMOV
    if faltsize != 16 && faltsize != intsize then UNDEFINED;
    op = if opcode<0> == '1' then
      if faltsize != 16 && faltsize != intsize then
        UnallocatedEncoding();
      else
        FPConvOp_MOV_ItoF
      else
        FPConvOp_MOV_FtoI;
    part = 0;
  when '11 01'        // FMOV D[1]
    if intsize != 64 || faltsize != 128 then UNDEFINED;
    op = if opcode<0> == '1' then
      if intsize != 64 || faltsize != 128 then
        UnallocatedEncoding();
      else
        FPConvOp_MOV_ItoF
      else
        FPConvOp_MOV_FtoI;
    part = 1;
    faltsize = 64; // size of D[1] is 64
  when '11 11'        // FJCVTZS
    if HaveFJCVTZSExt() then UNDEFINED;
    rounding = FPRounding ZERO;
    unsigned = (opcode<0> == '1');
    op = FPConvOp_CVT_FtoI_JS;
  otherwise
    UnallocatedEncoding();
  otherwise
    UNDEFINED();

Assembler Symbols

<Wd> Is the 32-bit name of the general-purpose destination register, encoded in the "Rd" field.
<Xd> Is the 64-bit name of the general-purpose destination register, encoded in the “Rd” field.
<Sn> Is the 32-bit name of the SIMD&FP source register, encoded in the “Rn” field.
<Hn> Is the 16-bit name of the SIMD&FP source register, encoded in the “Rn” field.
<Dn> Is the 64-bit name of the SIMD&FP source register, encoded in the “Rn” field.

Operation

```c
CheckFPAdvSIMDEnabled64();

bits(fltsize) fltval;
bits(intsize) intval;

case op of
  when FPConvOp_CVT_FtoI
    fltval = V[n];
    intval = FPToFixed(fltval, 0, unsigned, FPCR, rounding);
    X[d] = intval;
  when FPConvOp_CVT_ItoF
    intval = X[n];
    fltval = FixedToFP(intval, 0, unsigned, FPCR, rounding);
    V[d] = fltval;
  when FPConvOp_MOV_FtoI
    fltval = Vpart[n,part];
    intval = ZeroExtend(fltval, intsize);
    X[d] = intval;
  when FPConvOp_MOV_ItoF
    intval = X[n];
    fltval = intval<fltsize-1:0>;
    Vpart[d,part] = fltval;
  when FPConvOp_CVT_FtoI_JS
    fltval = V[n];
    intval = FPToFixedJS(fltval, FPCR, TRUE);
    X[d] = ZeroExtend(intval<31:0>, 64);
```

Internal version only: isa v30.35, AdvSIMD v27.01, pseudocode v85-xml-00bet8_rc3.3; Build timestamp: 2018-09-13T13:2018-06-16T09:04:45

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FCVTNU (vector)

Floating-point Convert to Unsigned integer, rounding to nearest with ties to even (vector). This instruction converts a scalar or each element in a vector from a floating-point value to an unsigned integer value using the Round to Nearest rounding mode, and writes the result to the SIMD&FP destination register.

A floating-point exception can be generated by this instruction. Depending on the settings in FPCR, the exception results in either a flag being set in FPSR, or a synchronous exception being generated. For more information, see Floating-point exception traps.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the Security state and Exception level in which the instruction is executed, an attempt to execute the instruction might be trapped.

It has encodings from 4 classes: Scalar half precision, Scalar single-precision and double-precision, Vector half precision and Vector single-precision and double-precision

### Scalar half precision

(ARMv8.2)

<table>
<thead>
<tr>
<th>31</th>
<th>30</th>
<th>29</th>
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<th>27</th>
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### Scalar single-precision and double-precision

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### Scalar single-precision and double-precision

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<td>Rn</td>
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</tr>
</tbody>
</table>
Vector half precision
(ARMv8.2)

Vector half precision

```
FCVTNU <Vd>.<T>, <Vn>.<T>

if !HaveFP16Ext() then UNDEFINED;

integer d = UInt(Rd);
integer n = UInt(Rn);
integer esize = 16;
integer datasize = if Q == '1' then 128 else 64;
integer elements = datasize DIV esize;
FPRounding rounding = FPDecodeRounding(o1:o2);
boolean unsigned = (U == '1');
```

Vector single-precision and double-precision

```
FCVTNU <Vd>.<T>, <Vn>.<T>

integer d = UInt(Rd);
integer n = UInt(Rn);

if sz:Q == '10' then UNDEFINED;
integer esize = 32 << if sz:Q == '10' then ReservedValue();
integer esize = 32 << UInt(sz);
integer datasize = if Q == '1' then 128 else 64;
integer elements = datasize DIV esize;
FPRounding rounding = FPDecodeRounding(o1:o2);
boolean unsigned = (U == '1');
```

Assembler Symbols

- `<Hd>`: Is the 16-bit name of the SIMD&FP destination register, encoded in the "Rd" field.
- `<Hn>`: Is the 16-bit name of the SIMD&FP source register, encoded in the "Rn" field.
- `<V>`: Is a width specifier, encoded in “sz”:
  
<table>
<thead>
<tr>
<th>sz</th>
<th>&lt;V&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>S</td>
</tr>
<tr>
<td>1</td>
<td>D</td>
</tr>
</tbody>
</table>

- `<d>`: Is the number of the SIMD&FP destination register, encoded in the "Rd" field.
- `<n>`: Is the number of the SIMD&FP source register, encoded in the "Rn" field.
- `<Vd>`: Is the name of the SIMD&FP destination register, encoded in the "Rd" field.
- `<T>`: For the vector half precision variant: is an arrangement specifier, encoded in “Q”:
\[ Q \quad <T> \]
\[
\begin{array}{ll}
0 & 4H \\
1 & 8H \\
\end{array}
\]

For the vector single-precision and double-precision variant: is an arrangement specifier, encoded in "sz:Q":

<table>
<thead>
<tr>
<th>sz</th>
<th>Q</th>
<th>&lt;T&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>2S</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>4S</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>RESERVED</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>2D</td>
</tr>
</tbody>
</table>

\(<Vn>\) Is the name of the SIMD&FP source register, encoded in the "Rn" field.

**Operation**

```c
CheckFPAdvSIMDEnabled64();
b depsizes operand = V[n];
b result;
b esize element;

for e = 0 to elements-1
    element = Elem[operand, e, esize];
    Elem[result, e, esize] = FPToFixed(element, 0, unsigned, FPCR, rounding);

V[d] = result;
```

Internal version only: isa v30.25 v29.05 AdvSIMD v27.01 v26.0 pseudocode v85-xml-00bet8_rc3c353 ; Build timestamp: 2018-09-13T13:2018-06-16T02:04:45

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FCVTNU (scalar)

Floating-point Convert to Unsigned integer, rounding to nearest with ties to even (scalar). This instruction converts the floating-point value in the SIMD&FP source register to a 32-bit or 64-bit unsigned integer using the Round to Nearest rounding mode, and writes the result to the general-purpose destination register.

A floating-point exception can be generated by this instruction. Depending on the settings in FPCR, the exception results in either a flag being set in FPSR, or a synchronous exception being generated. For more information, see Floating-point exception traps.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.
Half-precision to 32-bit (sf == 0 && type == 11) (ARMv8.2)

```
FCVTNU <Wd>, <Hn>
```

Half-precision to 64-bit (sf == 1 && type == 11) (ARMv8.2)

```
FCVTNU <Xd>, <Hn>
```

Single-precision to 32-bit (sf == 0 && type == 00)

```
FCVTNU <Wd>, <Sn>
```

Single-precision to 64-bit (sf == 1 && type == 00)

```
FCVTNU <Xd>, <Sn>
```

Double-precision to 32-bit (sf == 0 && type == 01)

```
FCVTNU <Wd>, <Dn>
```

Double-precision to 64-bit (sf == 1 && type == 01)

```
FCVTNU <Xd>, <Dn>
```
integer d = UInt(Rd);
integer n = UInt(Rn);

integer intsize = if sf == '1' then 64 else 32;
integer fitsize;
FPConvOp op;
FPRounding rounding;
boolean unsigned;
integer part;

case type of
  when '00'
    fitsize = 32;
  when '01'
    fitsize = 64;
  when '10'
    if opcode<2:1>:rmode != '11 01' then UNDEFINED;
    fitsize = 128;
  when '11'
    if opcode<2:1>:rmode != '11 01' then UnallocatedEncoding();
    fitsize = 128;
  when '11'
    if HaveFP16Ext() then fitsize = 16;
    else UNDEFINED;

case opcode<2:1>:rmode of
  when '00 xx' // FCVT[NPMZ][US]
    rounding = FPDecodeRounding(rmode);
    unsigned = (opcode<0> == '1');
    op = FPConvOp_CVT_FtoI;
  when '01 00' // [US]CVTF
    rounding = FPRoundingMode(FPCR);
    unsigned = (opcode<0> == '1');
    op = FPConvOp_CVT_ItoF;
  when '10 00' // FCVTA[US]
    rounding = FPRounding_TIEAWAY;
    unsigned = (opcode<0> == '1');
    op = FPConvOp_CVT_FtoI;
  when '11 00' // FMOV
    if fitsize != 16 & fitsize != intsize then UNDEFINED;
    op = if opcode<0> == '"' then FPConvOp_MOV_ItoF else FPConvOp_MOV_FtoI;
    part = 0;
  when '11 01' // FMOV D[1]
    if intsize != 64 || fitsize != 128 then UNDEFINED;
    op = if opcode<0> == '"' then FPConvOp_MOV_ItoF else FPConvOp_MOV_FtoI;
    part = 1;
    fitsize = 64; // size of D[1] is 64
  when '11 11' // FFCVTZS
    if !HaveFJCVTZSExt() then UNDEFINED;
    rounding = FPRounding_ZERO;
    unsigned = (opcode<0> == '1');
    op = FPConvOp_CVT_FtoI_JS;
  otherwise
    UnallocatedEncoding();
  otherwise
    UNDEFINED();

Assembler Symbols

<Wd> Is the 32-bit name of the general-purpose destination register, encoded in the "Rd" field.
Is the 64-bit name of the general-purpose destination register, encoded in the "Rd" field.

Is the 32-bit name of the SIMD&FP source register, encoded in the "Rn" field.

Is the 16-bit name of the SIMD&FP source register, encoded in the "Rn" field.

Is the 64-bit name of the SIMD&FP source register, encoded in the "Rn" field.

### Operation

```c
CheckFPAdvSIMDEnabled64();

bits(fltsize) fltval;
bits(intsize) intval;

case op of
  when FPConvOp_CVT_FtoI
    fltval = V[n];
    intval = FPToFixed(fltval, 0, unsigned, FPCR, rounding);
    X[d] = intval;
  when FPConvOp_CVT_ItoF
    intval = X[n];
    fltval = FixedToFP(intval, 0, unsigned, FPCR, rounding);
    V[d] = fltval;
  when FPConvOp_MOV_FtoI
    fltval = Vpart[n,part];
    intval = ZeroExtend(fltval, intsize);
    X[d] = intval;
  when FPConvOp_MOV_ItoF
    intval = X[n];
    fltval = intval<fltsize-1:0>;
    Vpart[d,part] = fltval;
  when FPConvOp_CVT_FtoI_JS
    fltval = V[n];
    intval = FPtoFixedJS(fltval, FPCR, TRUE);
    X[d] = ZeroExtend(intval<31:0>, 64);
```

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FCVTPS (vector)

Floating-point Convert to Signed integer, rounding toward Plus infinity (vector). This instruction converts a scalar or each element in a vector from a floating-point value to a signed integer value using the Round towards Plus Infinity rounding mode, and writes the result to the SIMD&FP destination register.

A floating-point exception can be generated by this instruction. Depending on the settings in FPCR, the exception results in either a flag being set in FPSR, or a synchronous exception being generated. For more information, see Floating-point exception traps.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the Security state and Exception level in which the instruction is executed, an attempt to execute the instruction might be trapped.

It has encodings from 4 classes: Scalar half precision, Scalar single-precision and double-precision, Vector half precision and Vector single-precision and double-precision.

### Scalar half precision

(ARMv8.2)

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0  | 1  | 1  | 1  | 1  | 0  | 1  | 1  | 1  | 1  | 0  | 0  | 1  | 1  | 0  | 1  | 0  | 1  | 0  | 1  | 0  | 0  | 1  | 1  | 0  | 0  | 0  | 1  | 1  | 0  | 1  | 0  |
| U  | o2 | o1 | Rn | Rd |

### Scalar single-precision and double-precision

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0  | 1  | 1  | 1  | 1  | 0  | 1  | 0  | 0  | 0  | 0  | 1  | 1  | 0  | 1  | 0  | 1  | 0  | 1  | 0  | 0  | 1  | 1  | 0  | 0  | 0  | 1  | 1  | 0  | 1  | 0  | 1  | 0  |
| U  | o2 | o1 | Rn | Rd |

### Scalar single-precision and double-precision

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0  | 1  | 1  | 1  | 1  | 0  | 1  | 0  | 0  | 0  | 0  | 0  | 1  | 1  | 0  | 1  | 0  | 1  | 0  | 1  | 0  | 0  | 1  | 1  | 0  | 0  | 0  | 1  | 1  | 0  | 1  | 0  | 1  | 0  |
| U  | o2 | o1 | Rn | Rd |

Scalar half precision

FCVTPS <Hd>, <Hn>

if !HaveFP16Ext() then UNDEFINED;

integer d =$\cdot$1 then UnallocatedEncoding(1);

integer d = UInt(Rd);
integer n = UInt(Rn);

integer esize = 16;
integer datasize = esize;
integer elements = 1;

FPRounding rounding = FPDecodeRounding(o1:o2);
boolean unsigned = (U == '1');

Scalar single-precision and double-precision

FCVTPS <V>d>, <V<n>

integer d = UInt(Rd);
integer n = UInt(Rn);

integer esize = 32 $\cdot$ UInt(sz);
integer datasize = esize;
integer elements = 1;

FPRounding rounding = FPDecodeRounding(o1:o2);
boolean unsigned = (U == '1');
Vector half precision

\[ Vd \rightarrow <V>.<T>, <Vn>.<T> \]

\[
\text{if } \neg \text{HaveFP16Ext}() \text{ then UNDEFINED;}
\]

\[
\begin{align*}
\text{integer } d &= \text{UInt}(Rd); \\
\text{integer } n &= \text{UInt}(Rn); \\
\text{integer } esize &= 16; \\
\text{integer } datasize &= \text{if } Q = '1' \text{ then } 128 \text{ else } 64; \\
\text{integer } elements &= \text{datasize} \div \text{esize}; \\
\text{FPRounding } \text{rounding} &= \text{FPDecodeRounding}(o1:o2); \\
\text{boolean } unsigned &= (U = '1');
\end{align*}
\]

Vector single-precision and double-precision

FCVTPS \(<Vd>.<T>, <Vn>.<T> \)

\[
\begin{align*}
\text{integer } d &= \text{UInt}(Rd); \\
\text{integer } n &= \text{UInt}(Rn); \\
\text{if } sz:Q = '10' \text{ then UNDEFINED;} \\
\text{integer } esize &= 32 \times \text{if } sz:Q = '10' \text{ then ReservedValue();} \\
\text{integer } esize &= 32 \times \text{UInt}(sz); \\
\text{integer } datasize &= \text{if } Q = '1' \text{ then } 128 \text{ else } 64; \\
\text{integer } elements &= \text{datasize} \div \text{esize}; \\
\text{FPRounding } \text{rounding} &= \text{FPDecodeRounding}(o1:o2); \\
\text{boolean } unsigned &= (U = '1');
\end{align*}
\]

Assembler Symbols

\(<Hd> \quad \text{Is the 16-bit name of the SIMD&FP destination register, encoded in the "Rd" field.}\)

\(<Hn> \quad \text{Is the 16-bit name of the SIMD&FP source register, encoded in the "Rn" field.}\)

\(<V> \quad \text{Is a width specifier, encoded in "sz":}\)

\[
\begin{array}{c|cc}
\text{sz} & \text{S} & \text{D} \\
0 & \text{S} & \text{D} \\
1 & \text{D} & \text{S}
\end{array}
\]

\(<d> \quad \text{Is the number of the SIMD&FP destination register, encoded in the "Rd" field.}\)

\(<n> \quad \text{Is the number of the SIMD&FP source register, encoded in the "Rn" field.}\)

\(<Vd> \quad \text{Is the name of the SIMD&FP destination register, encoded in the "Rd" field.}\)

\(<T> \quad \text{For the vector half precision variant: is an arrangement specifier, encoded in "Q":}\)
For the vector single-precision and double-precision variant: is an arrangement specifier, encoded in "sz:Q":

<table>
<thead>
<tr>
<th>sz</th>
<th>Q</th>
<th>&lt;T&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>2S</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>4S</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>RESERVED</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>2D</td>
</tr>
</tbody>
</table>

<Vn> Is the name of the SIMD&FP source register, encoded in the "Rn" field.

Operation

```c
CheckFPAdvSIMDEnabled64();
bits(datasize) operand = V[n];
bits(datasize) result;
bits(esize) element;
for e = 0 to elements-1
    element = Elem[operand, e, esize];
    Elem[result, e, esize] = FPToFixed(element, 0, unsigned, FPCR, rounding);
V[d] = result;
```

Internal version only: isa v30.25, AdvSIMD v27.01, pseudocode v85-xml-00bet8_rc3c353; Build timestamp: 2018-09-13T13:2018-06-16T09:45:45

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FCVTPS (scalar)

Floating-point Convert to Signed integer, rounding toward Plus infinity (scalar). This instruction converts the floating-point value in the SIMD&FP source register to a 32-bit or 64-bit signed integer using the Round towards Plus Infinity rounding mode, and writes the result to the general-purpose destination register.

A floating-point exception can be generated by this instruction. Depending on the settings in FPCR, the exception results in either a flag being set in FPSR, or a synchronous exception being generated. For more information, see Floating-point exception traps.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.
Half-precision to 32-bit (sf == 0 & type == 11) (ARMv8.2)

```
FCVTPS <Wd>, <Hn>
```

Half-precision to 64-bit (sf == 1 & type == 11) (ARMv8.2)

```
FCVTPS <Xd>, <Hn>
```

Single-precision to 32-bit (sf == 0 & type == 00)
```
FCVTPS <Wd>, <Sn>
```

Single-precision to 64-bit (sf == 1 & type == 00)
```
FCVTPS <Xd>, <Sn>
```

Double-precision to 32-bit (sf == 0 & type == 01)
```
FCVTPS <Wd>, <Dn>
```

Double-precision to 64-bit (sf == 1 & type == 01)
```
FCVTPS <Xd>, <Dn>
```
integer d = UInt(Rd);
integer n = UInt(Rn);
integer intsize = if sf == '1' then 64 else 32;
integer fltsize;
FPConvOp op;
FPRounding rounding;
boolean unsigned;
integer part;

case type of
  when '00'
    fltsize = 32;
  when '01'
    fltsize = 64;
  when '10'
    if opcode<2:1>rmode != '11 01' then UNDEFINED;
    fltsize = 128;
  when '11'
    if HaveFP16Ext() then
      fltsize = 16;
    else
      UNDEFINED;
  case opcode<2:1>rmode of
    when '00 xx'       // FCVT[NPMZ][US]
      rounding = FPDecodeRounding(rmode);
      unsigned = (opcode<0> == '1');
      op = FPConvOp_CVT_FtoI;
    when '01 00'       // [US]CVTF
      rounding = FPRoundingMode(FPCR);
      unsigned = (opcode<0> == '1');
      op = FPConvOp_CVT_ItoF;
    when '10 00'       // FCVTA[US]
      rounding = FPRounding_TIEAWAY;
      unsigned = (opcode<0> == '1');
      op = FPConvOp_CVT_FtoI;
    when '11 00'       // FMOV
      if fltsize != 16 && fltsize != intsize then UNDEFINED;
      op = if opcode<0> == '1' then FPConvOp_MOV_ItoF else FPConvOp_MOV_FtoI;
      part = 0;
    when '11 01'       // FMOVD[D1]
      if intsize != 64 || fltsize != 128 then UNDEFINED;
      op = if opcode<0> == '1' then FPConvOp_MOV_ItoF else FPConvOp_MOV_FtoI;
      part = 1;
      fltsize = 64;  // size of D[1] is 64
    when '11 11'       // FJCVTZS
      if HaveFJCVTZSExt() then UNDEFINED;
      rounding = FPRounding_ZERO;
      unsigned = (opcode<0> == '1');
      op = FPConvOp_CVT_FtoI_JS;
    otherwise
      UNallocatedEncoding;
  otherwise
    UNDEFINED;
  end case;

Assembler Symbols

<Wd>  Is the 32-bit name of the general-purpose destination register, encoded in the "Rd" field.

FCVTPS (scalar)
Is the 64-bit name of the general-purpose destination register, encoded in the "Rd" field.

Is the 32-bit name of the SIMD&FP source register, encoded in the "Rn" field.

Is the 16-bit name of the SIMD&FP source register, encoded in the "Rn" field.

Is the 64-bit name of the SIMD&FP source register, encoded in the "Rn" field.

**Operation**

```c
CheckFPAdvSIMDEnabled64();

bits(fltsize) fltval;
bits(intsize) intval;

case op of
  when FPConvOp_CVT_FtoI
    fltval = V[n];
    intval = FPToFixed(fltval, 0, unsigned, FPCR, rounding);
    X[d] = intval;
  when FPConvOp_CVT_ItoF
    intval = X[n];
    fltval = FixedToFP(intval, 0, unsigned, FPCR, rounding);
    V[d] = fltval;
  when FPConvOp_MOV_FtoI
    fltval = Vpart[n,part];
    intval = ZeroExtend(fltval, intsize);
    X[d] = intval;
  when FPConvOp_MOV_ItoF
    intval = X[n];
    fltval = intval<fltsize-1:0>;
    Vpart[d,part] = fltval;
  when FPConvOp_CVT_FtoI_JS
    fltval = V[n];
    intval = FPToFixedJS(fltval, FPCR, TRUE);
    X[d] = ZeroExtend(intval<31:0>, 64);
```

Internal version only: isa v30.25 v29.05 v27.01 v26.0, AdvSIMD v27.01 v26.0, pseudocode v85-xml-00b08_rc3 revise3; Build timestamp: 2018-09-13T13:20 2018-06-16T09:04:45

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FCVTPU (vector)

Floating-point Convert to Unsigned integer, rounding toward Plus infinity (vector). This instruction converts a scalar or each element in a vector from a floating-point value to an unsigned integer value using the Round towards Plus Infinity rounding mode, and writes the result to the SIMD&FP destination register.

A floating-point exception can be generated by this instruction. Depending on the settings in FPSCR, the exception results in either a flag being set in FPSR, or a synchronous exception being generated. For more information, see Floating-point exception traps.

Depending on the settings on the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the Security state and Exception level in which the instruction is executed, an attempt to execute the instruction might be trapped.

It has encodings from 4 classes: Scalar half precision, Scalar single-precision and double-precision, Vector half precision and Vector single-precision and double-precision

Scalar half precision

(ARMv8.2)

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9  | 8  | 7  | 6  | 5  | 4  | 3  | 2  | 1  | 0  |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0  | 1  | 1  | 1  | 1  | 1  | 0  | 1  | 1  | 1  | 1  | 0  | 0  | 1  | 1  | 0  | 1  | 0  | 1  | 0  | 0  | 1  | 0  | 0  | 0  | 0  | 1  | 1  | 0  | 1  | 0  |
| U  | o2 | o1 | Rd |

Scalar half precision

FCVT <Hd>, <Hn>

```plaintext
if !HaveFP16Ext() then UNDEFINED;
integer d = 1; then UnallocatedEncoding();
integer d = Uint(Rd);
integer n = Uint(Rn);
integer esize = 16;
integer datasize = esize;
integer elements = 1;
FPRounding rounding = FPDecodeRounding(o1:o2);
boolean unsigned = (U == '1');
```

Scalar single-precision and double-precision

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9  | 8  | 7  | 6  | 5  | 4  | 3  | 2  | 1  | 0  |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0  | 1  | 1  | 1  | 1  | 0  | 1  | sz | 1  | 0  | 0  | 0  | 0  | 1  | 1  | 0  | 1  | 0  | 1  | 0  | 0  | 1  | 0  | 0  | 0  | 0  | 1  | 1  | 0  | 1  | 0  |
| U  | o2 | o1 | Rd |

Scalar single-precision and double-precision

FCVT <V<d>, <V<n>

```plaintext
integer d = Uint(Rd);
integer n = Uint(Rn);
integer esize = 32 << Uint(sz);
integer datasize = esize;
integer elements = 1;
FPRounding rounding = FPDecodeRounding(o1:o2);
boolean unsigned = (U == '1');
```
Vector half precision

(ARMv8.2)

Vector half precision

FCVTPU <Vd>.<T>, <Vn>.<T>

if !HaveFP16Ext() then UNDEFINED;

integer d = UInt(Rd);
integer n = UInt(Rn);

integer esize = 16;
integer datasize = if Q == '1' then 128 else 64;
integer elements = datasize DIV esize;

FPRounding rounding = FPDecodeRounding(o1:o2);
boolean unsigned = (U == '1');

Vector single-precision and double-precision

FCVTPU <Vd>.<T>, <Vn>.<T>

integer d = UInt(Rd);
integer n = UInt(Rn);

if sz:Q == '10' then UNDEFINED;
integer esize = 32 << if sz:Q == '10' then ReservedValue();
integer esize = 32 << Uint(sz);
integer datasize = if Q == '1' then 128 else 64;
integer elements = datasize DIV esize;

FPRounding rounding = FPDecodeRounding(o1:o2);
boolean unsigned = (U == '1');

Assembler Symbols

<Hd> Is the 16-bit name of the SIMD&FP destination register, encoded in the "Rd" field.
<Hn> Is the 16-bit name of the SIMD&FP source register, encoded in the "Rn" field.
<V> Is a width specifier, encoded in "sz":

<table>
<thead>
<tr>
<th>sz</th>
<th>&lt;V&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>S</td>
</tr>
<tr>
<td>1</td>
<td>D</td>
</tr>
</tbody>
</table>

d Is the number of the SIMD&FP destination register, encoded in the "Rd" field.

n Is the number of the SIMD&FP source register, encoded in the "Rn" field.

<Vd> Is the name of the SIMD&FP destination register, encoded in the "Rd" field.
<T> For the vector half precision variant: is an arrangement specifier, encoded in “Q”:
### For the vector single-precision and double-precision variant: is an arrangement specifier, encoded in "sz:Q":

<table>
<thead>
<tr>
<th>sz</th>
<th>Q</th>
<th>&lt;T&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>2S</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>4S</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>RESERVED</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>2D</td>
</tr>
</tbody>
</table>

### <Vn>

Is the name of the SIMD&FP source register, encoded in the "Rn" field.

#### Operation

```c
CheckFPAdvSIMDEnabled64();

bits(datasize) operand = V[n];
bits(datasize) result;
bits(esize) element;

for e = 0 to elements-1
  element = Elem[operand, e, esize];
  Elem[result, e, esize] = FPToFixed(element, 0, unsigned, FPCR, rounding);

V[d] = result;
```

Internal version only: isa v30.25 v29.05, AdvSIMD v27.01 v26.0, pseudocode v85-xml-00bet8_rc3v35.3; Build timestamp: 2018-09-13T13:2018-06-16T02:04:45

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FCVTPU (scalar)

Floating-point Convert to Unsigned integer, rounding toward Plus infinity (scalar). This instruction converts the floating-point value in the SIMD&FP source register to a 32-bit or 64-bit unsigned integer using the Round towards Plus Infinity rounding mode, and writes the result to the general-purpose destination register.

A floating-point exception can be generated by this instruction. Depending on the settings in FPCR, the exception results in either a flag being set in FPSR, or a synchronous exception being generated. For more information, see Floating-point exception traps.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.
Half-precision to 32-bit (sf == 0 && type == 11)  
(ARMv8.2) 

FCVTPU <Wd>, <Hn>

Half-precision to 64-bit (sf == 1 && type == 11)  
(ARMv8.2) 

FCVTPU <Xd>, <Hn>

Single-precision to 32-bit (sf == 0 && type == 00) 

FCVTPU <Wd>, <Sn>

Single-precision to 64-bit (sf == 1 && type == 00) 

FCVTPU <Xd>, <Sn>

Double-precision to 32-bit (sf == 0 && type == 01) 

FCVTPU <Wd>, <Dn>

Double-precision to 64-bit (sf == 1 && type == 01) 

FCVTPU <Xd>, <Dn>
integer \( d = \) Uint\((Rd)\);
integer \( n = \) Uint\((Rn)\);

integer intsize = if \( sf = '1' \) then 64 else 32;
integer fltsize;
FPConvOp op;
FPRounding rounding;
boolean unsigned;
integer part;

case type of
when '00'
  fltsize = 32;
when '01'
  fltsize = 64;
when '10'
  if \( \text{opcode}<2:1>:\text{rmode} != '11 01' \) then UNDEFINED;
  fltsize = 128;
when '11'
  if \( \text{opcode}<2:1>:\text{rmode} != '11 01' \) then UnallocatedEncoding();
  fltsize = 128;
when '11'
  if HaveFP16Ext() then
    fltsize = 16;
  else
    UNDEFINED;

case \( \text{opcode}<2:1>:\text{rmode} \) of
when '00 xx' // FCVT[NPMZ][US]
  rounding = FPDecodeRounding\((\text{rmode})\);
  unsigned = (\( \text{opcode}<0> \) == '1');
  op = FPConvOp CVT FtoI;
when '01 00' // [US]CVTF
  rounding = FPRoundingMode\((\text{FPCR})\);
  unsigned = (\( \text{opcode}<0> \) == '1');
  op = FPConvOp CVT ItoF;
when '10 00' // FCVTA[US]
  rounding = FPRounding TIEAWAY;
  unsigned = (\( \text{opcode}<0> \) == '1');
  op = FPConvOp CVT FtoI;
when '11 00' // FMOV
  if fltsize != 16 \&\& fltsize != intsize then UNDEFINED;
  op = if \( \text{opcode}<0> \) == '1' then
    if fltsize != 16 \&\& fltsize != intsize then
      UnallocatedEncoding();
    else
      FPConvOp MOV ItoF;
  else
    FPConvOp MOV FtoI;
  part = 0;
when '11 01' // FMOV D[1]
  if intsize != 64 \&\& fltsize != 128 then UNDEFINED;
  op = if \( \text{opcode}<0> \) == '1' then
    if intsize != 64 \&\& fltsize != 128 then
      UnallocatedEncoding();
    else
      FPConvOp MOV ItoF;
  else
    FPConvOp MOV FtoI;
  part = 1;
  fltsize = 64; // size of \( D[1] \) is 64
when '11 11' // FJCVTZS
  if !HaveFJCVTZSExt() then UNDEFINED;
  rounding = FPRounding ZERO;
  unsigned = (\( \text{opcode}<0> \) == '1');
  op = FPConvOp CVT FtoI JS;
otherwise
  UnallocatedEncoding();
otherwise
  UNDEFINED();

Assembler Symbols

\(<Wd>\) Is the 32-bit name of the general-purpose destination register, encoded in the "Rd" field.
Is the 64-bit name of the general-purpose destination register, encoded in the "Rd" field.

Is the 32-bit name of the SIMD&FP source register, encoded in the "Rn" field.

Is the 16-bit name of the SIMD&FP source register, encoded in the "Rn" field.

Is the 64-bit name of the SIMD&FP source register, encoded in the "Rn" field.

Operation

```c
CheckFPAdvSIMDEnabled64();

bits(fltsize) fltval;
bits(intsize) intval;

case op of
  when FPConvOp_CVT_FtoI
    fltval = V[n];
    intval = FPToFixed(fltval, 0, unsigned, FPCR, rounding);
    X[d] = intval;
  when FPConvOp_CVT_ItoF
    intval = X[n];
    fltval = FixedToFP(intval, 0, unsigned, FPCR, rounding);
    V[d] = fltval;
  when FPConvOp_MOV_FtoI
    fltval = Vpart[n,part];
    intval = ZeroExtend(fltval, intsize);
    X[d] = intval;
  when FPConvOp_MOV_ItoF
    intval = X[n];
    fltval = intval<fltsize-1:0>;
    Vpart[d,part] = fltval;
  when FPConvOp_CVT_FtoI_JS
    fltval = V[n];
    intval = FPDiscussion(fltval, FPCR, TRUE);
    X[d] = ZeroExtend(intval<31:0>, 64);
```

Internal version only: isa v30.25, AdvSIMD v27.0, pseudocode v85-xml-00bet8_rc3.5
Build timestamp: 2018-09-13 13:20:45

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FCVTXN, FCVTXN2

Floating-point Convert to lower precision Narrow, rounding to odd (vector). This instruction reads each vector element in the source SIMD&FP register, narrows each value to half the precision of the source element using the Round to Odd rounding mode, writes the result to a vector, and writes the vector to the destination SIMD&FP register.

This instruction uses the Round to Odd rounding mode which is not defined by the IEEE 754-2008 standard. This rounding mode ensures that if the result of the conversion is inexact the least significant bit of the mantissa is forced to 1. This rounding mode enables a floating-point value to be converted to a lower precision format via an intermediate precision format while avoiding double rounding errors. For example, a 64-bit floating-point value can be converted to a correctly rounded 16-bit floating-point value by first using this instruction to produce a 32-bit value and then using another instruction with the wanted rounding mode to convert the 32-bit value to the final 16-bit floating-point value.

The FCVTXN instruction writes the vector to the lower half of the destination register and clears the upper half, while the FCVTXN2 instruction writes the vector to the upper half of the destination register without affecting the other bits of the register.

This instruction can generate a floating-point exception. Depending on the settings in FPCR, the exception results in either a flag being set in FPSR or a synchronous exception being generated. For more information, see Floating-point exception traps.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

It has encodings from 2 classes: **Scalar** and **Vector**

Scalar

|   |   |   |   |   |   |   |   |   |   | sz |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   | Rn |   |   | Rd |
| 0 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | sz | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 0 | 1 | 0 | Rn |   |   | Rd |

Scalar

FCVTXN <Vb><d>, <Va><n>

```plaintext
text
integer d = UInt(Rd);
integer n = UInt(Rn);
if sz == '0' then UNDEFINED;
integer esize = 32;
integer datasize = esize;
integer elements = 1;
integer part = 0;
if sz == '0' then ReservedValue();
integer esize = 32;
integer datasize = esize;
integer elements = 1;
integer part = 0;
```

Vector

|   |   |   |   |   |   |   |   |   |   | sz |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   | Rn |   |   | Rd |
| 0 | Q | 1 | 0 | 1 | 1 | 1 | 0 | 0 | sz | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 0 | 1 | 0 | Rn |   |   | Rd |
Vector

FCVTXN{2} <Vd>, <Tb>, <Vn>, <Ta>

integer d = UInt(Rd);
integer n = UInt(Rn);

if sz == '0' then UNDEFINED;
integer esize = 32;
integer datasize = 64;
integer elements = 2;
integer part = if sz == '0' then ReservedValue();
integer esize = 32;
integer datasize = 64;
integer elements = 2;
integer part = UInt(Q);

Assembler Symbols

2 Is the second and upper half specifier. If present it causes the operation to be performed on the upper 64 bits of the registers holding
the narrower elements, and is encoded in "Q":

<table>
<thead>
<tr>
<th>Q</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>[absent]</td>
</tr>
<tr>
<td>1</td>
<td>[present]</td>
</tr>
</tbody>
</table>

<Vd> Is the name of the SIMD&FP destination register, encoded in the "Rd" field.

<Tb> Is an arrangement specifier, encoded in “sz:Q”:

<table>
<thead>
<tr>
<th>sz</th>
<th>Q</th>
<th>&lt;Tb&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>x</td>
<td>RESERVED</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>2S</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>4S</td>
</tr>
</tbody>
</table>

<Vn> Is the name of the SIMD&FP source register, encoded in the "Rn" field.

<Ta> Is an arrangement specifier, encoded in “sz”:

<table>
<thead>
<tr>
<th>sz</th>
<th>&lt;Ta&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>RESERVED</td>
</tr>
<tr>
<td>1</td>
<td>2D</td>
</tr>
</tbody>
</table>

<Vb> Is the destination width specifier, encoded in “sz”:

<table>
<thead>
<tr>
<th>sz</th>
<th>&lt;Vb&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>RESERVED</td>
</tr>
<tr>
<td>1</td>
<td>S</td>
</tr>
</tbody>
</table>

<d> Is the number of the SIMD&FP destination register, encoded in the "Rd" field.

<Va> Is the source width specifier, encoded in "sz”:

<table>
<thead>
<tr>
<th>sz</th>
<th>&lt;Va&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>RESERVED</td>
</tr>
<tr>
<td>1</td>
<td>D</td>
</tr>
</tbody>
</table>

<n> Is the number of the SIMD&FP source register, encoded in the "Rn" field.

Operation

CheckFPAdvSIMDEnabled64();
bits(2*datasize) operand = V[n];
bits(datasize) result;

for e = 0 to elements-1
    Elem[result, e, esize] = FPCConvert(Elem[operand, e, 2*esize], FPCR, FPRounding_ODD);

Vpart[d, part] = result;
FCVTZS (vector, fixed-point)

Floating-point Convert to Signed fixed-point, rounding toward Zero (vector). This instruction converts a scalar or each element in a vector from floating-point to fixed-point signed integer using the Round towards Zero rounding mode, and writes the result to the SIMD&FP destination register.

A floating-point exception can be generated by this instruction. Depending on the settings in FPCR, the exception results in either a flag being set in FPSR, or a synchronous exception being generated. For more information, see Floating-point exception traps.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the Security state and Exception level in which the instruction is executed, an attempt to execute the instruction might be trapped.

It has encodings from 2 classes: Scalar and Vector

Scalar

<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th>U</th>
<th>immh</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>!= 0000</td>
<td>immb</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>Rn</td>
<td>Rd</td>
</tr>
</tbody>
</table>

Scalar

FCVTZS <V><d>, <V><n>, #<fbits>

integer d = UInt(Rd);
integer n = UInt(Rn);

if immh == '000x' || (immh == '001x' && !HaveFP16Ext()) then UNDEFINED;
integer esize = if immh == '1xxx' then 64 else if immh == '01xx' then 32 else 16;
integer datasize = esize;
integer elements = 1;
integer fracbits = (esize * 2) - ( UInt(immh:immb);)
boolean unsigned = (U == '1');
FPRounding rounding = FPRounding_ZERO;

Vector

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
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<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th>U</th>
<th>immh</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Q</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>!= 0000</td>
<td>immb</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>Rn</td>
<td>Rd</td>
<td></td>
</tr>
</tbody>
</table>
Vector

FCVTZS <Vd>.<T>, <Vn>.<T>, #<fbits>

integer d = Uint(Rd);
integer n = Uint(Rn);

if immh == '0000' then SEE(asimdimm);
if immh == '000x' || (immh == '001x' & & HaveFP16Ext()) then UNDEFINED;
if immh<3>:Q == '10' then UNDEFINED;
integer esize = if immh == '1xxx' then 64 else if immh == '01xx' then 32 else 16;
integer datasize = if Q == '1' then 128 else 64;
integer elements = datasize DIV esize;

integer fracbits = (esize * 2) - 41 then ReservedValue();
if immh<3>:Q == '10' then ReservedValue();
integer esize = if immh == '1xxx' then 64 else if immh == '01xx' then 32 else 16;
integer datasize = if Q == '1' then 128 else 64;
integer elements = datasize DIV esize;

integer fracbits = (esize * 2) -UInt(immh:immb);
boolean unsigned = (U == '1');
FPRounding rounding = FPRounding_ZERO;

Assembler Symbols

<table>
<thead>
<tr>
<th>&lt;V&gt;</th>
<th>Is a width specifier, encoded in “immh”:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>immh</td>
</tr>
<tr>
<td>-----</td>
<td>----------------------</td>
</tr>
<tr>
<td>000x</td>
<td>RESERVED</td>
</tr>
<tr>
<td>001x</td>
<td>H</td>
</tr>
<tr>
<td>01xx</td>
<td>S</td>
</tr>
<tr>
<td>1xxx</td>
<td>D</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>&lt;d&gt;</th>
<th>Is the number of the SIMD&amp;FP destination register, in the &quot;Rd&quot; field.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>&lt;n&gt; Is the number of the first SIMD&amp;FP source register, encoded in the &quot;Rn&quot; field.</td>
</tr>
<tr>
<td>&lt;Vd&gt;</td>
<td>Is the name of the SIMD&amp;FP destination register, encoded in the &quot;Rd&quot; field.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>&lt;T&gt;</th>
<th>Is an arrangement specifier, encoded in “immh:Q”:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>immh</td>
</tr>
<tr>
<td>-----</td>
<td>------</td>
</tr>
<tr>
<td>0000</td>
<td>0</td>
</tr>
<tr>
<td>0001</td>
<td>x</td>
</tr>
<tr>
<td>001x</td>
<td>0</td>
</tr>
<tr>
<td>001x</td>
<td>1</td>
</tr>
<tr>
<td>01xx</td>
<td>0</td>
</tr>
<tr>
<td>01xx</td>
<td>1</td>
</tr>
<tr>
<td>1xxx</td>
<td>0</td>
</tr>
<tr>
<td>1xxx</td>
<td>1</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>&lt;Vn&gt;</th>
<th>Is the name of the SIMD&amp;FP source register, encoded in the &quot;Rn&quot; field.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>&lt;fbits&gt; For the scalar variant: is the number of fractional bits, in the range 1 to the operand width, encoded in “immh:immb”:</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>&lt;fbits&gt;</th>
<th>immh</th>
</tr>
</thead>
<tbody>
<tr>
<td>000x</td>
<td>RESERVED</td>
</tr>
<tr>
<td>001x</td>
<td>(32=Uint(immh:immb))</td>
</tr>
<tr>
<td>01xx</td>
<td>(64=Uint(immh:immb))</td>
</tr>
<tr>
<td>1xxx</td>
<td>(128=Uint(immh:immb))</td>
</tr>
</tbody>
</table>

For the vector variant: is the number of fractional bits, in the range 1 to the element width, encoded in “immh:immb”:

<table>
<thead>
<tr>
<th>&lt;fbits&gt;</th>
<th>immh</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>0000</td>
<td>SEE Advanced SIMD modified immediate</td>
<td></td>
</tr>
<tr>
<td>0001</td>
<td>RESERVED</td>
<td></td>
</tr>
<tr>
<td>001x</td>
<td>(32=Uint(immh:immb))</td>
<td></td>
</tr>
<tr>
<td>01xx</td>
<td>(64=Uint(immh:immb))</td>
<td></td>
</tr>
<tr>
<td>1xxx</td>
<td>(128=Uint(immh:immb))</td>
<td></td>
</tr>
</tbody>
</table>
Operation

```c
CheckFPAdvSIMDEnabled64();
bits(datasize) operand = V[n];
bits(datasize) result;
bits(esize) element;

for e = 0 to elements-1
   element = Elem[operand, e, esize];
   Elem[result, e, esize] = FPToFixed(element, frachits, unsigned, FPCR, rounding);
V[d] = result;
```
FCVTZS (vector, integer)

Floating-point Convert to Signed integer, rounding toward Zero (vector). This instruction converts a scalar or each element in a vector from a floating-point value to a signed integer value using the Round towards Zero rounding mode, and writes the result to the SIMD&FP destination register.

A floating-point exception can be generated by this instruction. Depending on the settings in FPCR, the exception results in either a flag being set in FPSR, or a synchronous exception being generated. For more information, see Floating-point exception traps.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the Security state and Exception level in which the instruction is executed, an attempt to execute the instruction might be trapped.

It has encodings from 4 classes: Scalar half precision, Scalar single-precision and double-precision, Vector half precision, and Vector single-precision and double-precision.

**Scalar half precision (ARMv8.2)**

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9  | 8  | 7  | 6  | 5  | 4  | 3  | 2  | 1  | 0  |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0  | 1  | 0  | 1  | 1  | 1  | 0  | 1  | 1  | 1  | 1  | 0  | 0  | 1  | 1  | 0  | 1  | 1  | 0  | 1  | 1  | 0  | 1  | 1  | 0  | 1  | 1  | 0  | 1  | 1  |

<table>
<thead>
<tr>
<th>U</th>
<th>o2</th>
<th>Rd</th>
</tr>
</thead>
<tbody>
<tr>
<td>o1</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Scalar half precision**

```
FCVTZS <Hd>, <Hn>
```

```c
if !HaveFP16Ext() then UNDEFINED;

integer d = 1; then UnallocatedEncoding(1);

integer d = UInt(Rd);
integer n = UInt(Rn);

integer esize = 16;
integer datasize = esize;
integer elements = 1;

FPRounding rounding = FPDecodeRounding(o1:o2);
boolean unsigned = (U == '1');
```

**Scalar single-precision and double-precision**

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9  | 8  | 7  | 6  | 5  | 4  | 3  | 2  | 1  | 0  |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0  | 1  | 0  | 1  | 1  | 1  | 0  | 1  | 1  | 0  | 0  | 0  | 0  | 0  | 0  | 1  | 1  | 0  | 1  | 1  | 0  | 1  | 1  | 0  | 1  | 1  | 0  | 1  | 1  |

<table>
<thead>
<tr>
<th>U</th>
<th>o2</th>
<th>Rd</th>
</tr>
</thead>
<tbody>
<tr>
<td>o1</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Scalar single-precision and double-precision**

```
FCVTZS <V><d>, <V><n>
```

```c
integer d = UInt(Rd);
integer n = UInt(Rn);

integer esize = 32 << UInt(sz);
integer datasize = esize;
integer elements = 1;

FPRounding rounding = FPDecodeRounding(o1:o2);
boolean unsigned = (U == '1');
```
Vector half precision

(ARMv8.2)

<table>
<thead>
<tr>
<th>31</th>
<th>30</th>
<th>29</th>
<th>28</th>
<th>27</th>
<th>26</th>
<th>25</th>
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<th>10</th>
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<th>7</th>
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<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q</td>
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<td>1</td>
<td>1</td>
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<td>Rd</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>U</td>
<td>o2</td>
<td>o1</td>
<td></td>
<td></td>
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<td></td>
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<td></td>
</tr>
</tbody>
</table>

Vector half precision

FCVTZS \(<V_d>.<T>, <V_n>.<T>\)

\[\text{if } \text{!HaveFP16Ext()} \text{ then UNDEFINED};\]

\[
\begin{align*}
\text{integer } & \quad d = () \text{ then UnallocatedEncoding}(); \\
\text{integer } & \quad d = \text{UInt}(Rd); \\
\text{integer } & \quad n = \text{UInt}(Rn); \\
\end{align*}
\]

\[
\begin{align*}
\text{integer } & \quad esize = 16; \\
\text{integer } & \quad datasize = \text{if } Q == '1' \text{ then 128 else 64}; \\
\text{integer } & \quad elements = \text{datasize DIV esize}; \\
\end{align*}
\]

\[
\begin{align*}
\text{FPRounding } & \quad \text{rounding} = \text{FPDecodeRounding}(o1:o2); \\
\text{boolean } & \quad \text{unsigned} = (U == '1'); \\
\end{align*}
\]

Vector single-precision and double-precision

<table>
<thead>
<tr>
<th>31</th>
<th>30</th>
<th>29</th>
<th>28</th>
<th>27</th>
<th>26</th>
<th>25</th>
<th>24</th>
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<th>22</th>
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<th>17</th>
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<th>15</th>
<th>14</th>
<th>13</th>
<th>12</th>
<th>11</th>
<th>10</th>
<th>9</th>
<th>8</th>
<th>7</th>
<th>6</th>
<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>1</td>
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<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>Rn</td>
<td>Rd</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>U</td>
<td>o2</td>
<td>o1</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
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<td></td>
<td></td>
</tr>
</tbody>
</table>

Vector single-precision and double-precision

FCVTZS \(<V_d>.<T>, <V_n>.<T>\)

\[
\begin{align*}
\text{integer } & \quad d = \text{UInt}(Rd); \\
\text{integer } & \quad n = \text{UInt}(Rn); \\
\text{if } sz:Q == '10' \text{ then UNDEFINED}; \\
\text{integer } & \quad esize = 32 << \text{if } sz:Q == '10' \text{ then ReservedValue}(); \\
\text{integer } & \quad esize = 32 << \text{UInt}(sz); \\
\text{integer } & \quad datasize = \text{if } Q == '1' \text{ then 128 else 64}; \\
\text{integer } & \quad elements = \text{datasize DIV esize}; \\
\end{align*}
\]

\[
\begin{align*}
\text{FPRounding } & \quad \text{rounding} = \text{FPDecodeRounding}(o1:o2); \\
\text{boolean } & \quad \text{unsigned} = (U == '1'); \\
\end{align*}
\]

Assembler Symbols

\(<\text{Hd}>\quad \text{Is the 16-bit name of the SIMD&FP destination register, encoded in the "Rd" field.}\)

\(<\text{Hn}>\quad \text{Is the 16-bit name of the SIMD&FP source register, encoded in the "Rn" field.}\)

\(<\text{V}>\quad \text{Is a width specifier, encoded in "sz":}\)

<table>
<thead>
<tr>
<th>sz</th>
<th>(&lt;\text{V}&gt;)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>S</td>
</tr>
<tr>
<td>1</td>
<td>D</td>
</tr>
</tbody>
</table>

\(<\text{d}>\quad \text{Is the number of the SIMD&FP destination register, encoded in the "Rd" field.}\)

\(<\text{n}>\quad \text{Is the number of the SIMD&FP source register, encoded in the "Rn" field.}\)

\(<\text{V_d}>\quad \text{Is the name of the SIMD&FP destination register, encoded in the "Rd" field.}\)

\(<\text{T}>\quad \text{For the vector half precision variant: is an arrangement specifier, encoded in "Q":}\)
For the vector single-precision and double-precision variant: is an arrangement specifier, encoded in "sz:Q":

<table>
<thead>
<tr>
<th>sz</th>
<th>Q</th>
<th>&lt;T&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>2S</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>4S</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>RESERVED</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>2D</td>
</tr>
</tbody>
</table>

<Vn> Is the name of the SIMD&FP source register, encoded in the "Rn" field.

Operation

```c
CheckFPAdvSIMDEnabled64();
bits(datasize) operand = V[n];
bits(datasize) result;
bits(esize) element;
for e = 0 to elements-1
    element = Elem[operand, e, esize];
    Elem[result, e, esize] = FPToFixed(element, 0, unsigned, FPCR, rounding);
V[d] = result;
```

Internal version only: isa v30.25, AdvSIMD v27.01, pseudocode v85-xml-00bet8_rc3c355 ; Build timestamp: 2018-09-13T13:2018-06-16T02:04:45

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FCVTZS (scalar, fixed-point)

Floating-point Convert to Signed fixed-point, rounding toward Zero (scalar). This instruction converts the floating-point value in the SIMD&FP source register to a 32-bit or 64-bit fixed-point signed integer using the Round towards Zero rounding mode, and writes the result to the general-purpose destination register.

A floating-point exception can be generated by this instruction. Depending on the settings in FPCR, the exception results in either a flag being set in FPSR, or a synchronous exception being generated. For more information, see Floating-point exception traps.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the Security state and Exception level in which the instruction is executed, an attempt to execute the instruction might be trapped.

```
<table>
<thead>
<tr>
<th>sf</th>
<th>0</th>
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<th>1</th>
<th>0</th>
<th>type</th>
<th>0</th>
<th>1</th>
<th>1</th>
<th>0</th>
<th>0</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td>Rn</td>
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<td></td>
</tr>
<tr>
<td></td>
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<td></td>
<td></td>
<td></td>
<td>Rd</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
```

`sf` - Sign flag
`type` - Precision type
`scale` - Scale
`Rn` - Source register
`Rd` - Destination register

rmode  opcode
Half-precision to 32-bit (sf == 0 && type == 11) (ARMv8.2)

    FCVTZS <Wd>, <Hn>, #<fbits>

Half-precision to 64-bit (sf == 1 && type == 11) (ARMv8.2)

    FCVTZS <Xd>, <Hn>, #<fbits>

Single-precision to 32-bit (sf == 0 && type == 00)

    FCVTZS <Wd>, <Sn>, #<fbits>

Single-precision to 64-bit (sf == 1 && type == 00)

    FCVTZS <Xd>, <Sn>, #<fbits>

Double-precision to 32-bit (sf == 0 && type == 01)

    FCVTZS <Wd>, <Dn>, #<fbits>

Double-precision to 64-bit (sf == 1 && type == 01)

    FCVTZS <Xd>, <Dn>, #<fbits>
integer d = UInt(Rd);
integer n = UInt(Rn);

integer intsize = if sf == '1' then 64 else 32;
integer fltsize;
FPConvOp op;
FPRounding rounding;
boolean unsigned;

case type of
  when '00' fltsize = 32;
  when '01' fltsize = 64;
  when '10' UNDEFINED;
  when '11'
    if HaveFP16Ext() then 
      fltsize = 16;
    else 
      UNDEFINED;
if sf == '0' & scale<5> == '0' then UNDEFINED;
integer fracbits = 64 - UInt(scale);

case opcode<2:1>:rmode of
  when '00 11' // FCVTZ
    rounding = FPRounding_ZERO;
    unsigned = (opcode<0> == '1');
    op = FPConvOp_CVT_FtoI;
  when '01 00' // [US]CVTF
    rounding = FPRoundingMode(FPCR);
    unsigned = (opcode<0> == '1');
    op = FPConvOp_CVT_ItoF;
  otherwise
    UnallocatedEncoding;
  otherwise 
    UNDEFINED();

Assembler Symbols

<Wd> Is the 32-bit name of the general-purpose destination register, encoded in the "Rd" field.
<Xd> Is the 64-bit name of the general-purpose destination register, encoded in the "Rd" field.
<Sn> Is the 32-bit name of the SIMD&FP source register, encoded in the "Rn" field.
<Hn> Is the 16-bit name of the SIMD&FP source register, encoded in the "Rn" field.
<Dn> Is the 64-bit name of the SIMD&FP source register, encoded in the "Rn" field.
<fbits> For the double-precision to 32-bit, half-precision to 32-bit and single-precision to 32-bit variant: is the number of bits after the binary point in the fixed-point destination, in the range 1 to 32, encoded as 64 minus "scale".
For the double-precision to 64-bit, half-precision to 64-bit and single-precision to 64-bit variant: is the number of bits after the binary point in the fixed-point destination, in the range 1 to 64, encoded as 64 minus "scale".
CheckFPAdvSIMEnabled64();
bits(fltsize) fltval;
bits(intsize) intval;

case op of
    when FPConvOp_CVT_FtoI
        fltval = Y[n];
        intval = FPToFixed(fltval, fracbits, unsigned, FPCR, rounding);
        X[d] = intval;
    when FPConvOp_CVT_ItoF
        intval = X[n];
        fltval = FixedToFP(intval, fracbits, unsigned, FPCR, rounding);
        V[d] = fltval;

FCVTZS (scalar, integer)

Floating-point Convert to Signed integer, rounding toward Zero (scalar). This instruction converts the floating-point value in the SIMD&FP source register to a 32-bit or 64-bit signed integer using the Round towards Zero rounding mode, and writes the result to the general-purpose destination register.

A floating-point exception can be generated by this instruction. Depending on the settings in FPCR, the exception results in either a flag being set in FPSR, or a synchronous exception being generated. For more information, see Floating-point exception traps.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.
Half-precision to 32-bit (sf == 0 && type == 11)  
(ARMv8.2)

FCVTZS  <Wd>, <Hn>

Half-precision to 64-bit (sf == 1 && type == 11)  
(ARMv8.2)

FCVTZS  <Xd>, <Hn>

Single-precision to 32-bit (sf == 0 && type == 00)

FCVTZS  <Wd>, <Sn>

Single-precision to 64-bit (sf == 1 && type == 00)

FCVTZS  <Xd>, <Sn>

Double-precision to 32-bit (sf == 0 && type == 01)

FCVTZS  <Wd>, <Dn>

Double-precision to 64-bit (sf == 1 && type == 01)

FCVTZS  <Xd>, <Dn>
integer d = UInt(Rd);
integer n = UInt(Rn);

integer intsize = if sf == '1' then 64 else 32;
integer fltsize;  
FPConvOp op;
FPRounding rounding;
boolean unsigned;
integer part;

case type of
  when '00'
    fltsize = 32;
  when '01'
    fltsize = 64;
  when '10'
    if opcode<2:1>:rmode != '11 01' then UNDEFINED;
    fltsize = 128;
  when '11'
    if HaveFP16Ext() then
      fltsize = 16;
    else
      UNDEFINED;
  case opcode<2:1>:rmode of
    when '00 xx'        // FCVT[NPMZ][US]
      rounding = FPDecodeRounding(rmode);
      unsigned = (opcode<0> == '1');
      op = FPConvOp_CVT_FtoI;
    when '01 00'        // [US]CVTF
      rounding = FPRoundingMode(FPCR);
      unsigned = (opcode<0> == '1');
      op = FPConvOp_CVT_ItoF;
    when '10 00'        // FCVTA[US]
      rounding = FPRounding_TIEAWAY;
      unsigned = (opcode<0> == '1');
      op = FPConvOp_CVT_FtoI;
    when '11 00'        // FMOV
      if fltsize != 16 && fltsize != intsize then UNDEFINED;
      op = if opcode<0> == '1' then
          if fltsize != 16 && fltsize != intsize then
            UnallocatedEncoding();
          else
            FPConvOp_MOV_ItoF else FPConvOp_MOV_FtoI;
      part = 0;
    when '11 01'        // FMOV D[1]
      if intsize != 64 || fltsize != 128 then UNDEFINED;
      op = if opcode<0> == '1' then
          if intsize != 64 || fltsize != 128 then
            UnallocatedEncoding();
          else
            FPConvOp_MOV_ItoF else FPConvOp_MOV_FtoI;
      part = 1;
      fltsize = 64;  // size of D[1] is 64
    when '11 11'        // FJCVTZS
      if HaveFJCVTZSExt() then UNDEFINED;
      rounding = FPRounding_ZERO;
      unsigned = (opcode<0> == '1');
      op = FPConvOp_CVT_FtoI_JS;
  otherwise
    UnallocatedEncoding();
  otherwise
    UNDEFINED();
  end case;

Assembler Symbols

<Wd> Is the 32-bit name of the general-purpose destination register, encoded in the "Rd" field.
<Xd> Is the 64-bit name of the general-purpose destination register, encoded in the "Rd" field.
<Sn> Is the 32-bit name of the SIMD&FP source register, encoded in the "Rn" field.
<Hn> Is the 16-bit name of the SIMD&FP source register, encoded in the "Rn" field.
<Dn> Is the 64-bit name of the SIMD&FP source register, encoded in the "Rn" field.

**Operation**

```c
CheckFPAdvSIMDEnabled64();

bits(fltsize) fltval;
bits(intsize) intval;

case op of
    when FPConvOp_CVT_FtoI
        fltval = V[n];
        intval = FPToFixed(fltval, 0, unsigned, FPCR, rounding);
        X[d] = intval;
    when FPConvOp_CVT_ItoF
        intval = X[n];
        fltval = FixedToFP(intval, 0, unsigned, FPCR, rounding);
        V[d] = fltval;
    when FPConvOp_MOV_FtoI
        fltval = Vpart[n,part];
        intval = ZeroExtend(fltval, intsize);
        X[d] = intval;
    when FPConvOp_MOV_ItoF
        intval = X[n];
        fltval = intval<fltsize-1:0>;
        Vpart[d,part] = fltval;
    when FPConvOp_CVT_FtoI_JS
        fltval = V[n];
        intval = FPtoFixedJS(fltval, FPCR, TRUE);
        X[d] = ZeroExtend(intval<31:0>, 64);
```

Internal version only: isa v30.25 v29.05, AdvSIMD v27.01 v26.0, pseudocode v85-xml-00beta8_rc3a3; Build timestamp: 2018-09-13T13:2018-06-16T09:04:45

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FCVTZU (vector, fixed-point)

Floating-point Convert to Unsigned fixed-point, rounding toward Zero (vector). This instruction converts a scalar or each element in a vector from floating-point to fixed-point unsigned integer using the Round towards Zero rounding mode, and writes the result to the general-purpose destination register.

A floating-point exception can be generated by this instruction. Depending on the settings in FPCR, the exception results in either a flag being set in FPSR, or a synchronous exception being generated. For more information, see Floating-point exception traps.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the Security state and Exception level in which the instruction is executed, an attempt to execute the instruction might be trapped.

It has encodings from 2 classes: Scalar and Vector

Scalar

FCVTZU <V><d>, <V><n>, #<fbits>

integer d = UInt(Rd);
integer n = UInt(Rn);

if immh == '000x' || (immh == '001x' && !HaveFP16Ext()) then UNDEFINED;
integer esize = if immh == '1xxx' then 64 else if immh == '01xx' then 32 else 16;
integer datasize = esize;
integer elements = 1;
integer fracbits = (esize * 2) - (U == '1') then ReservedValue();
integer fracbits = (esize * 2) - UInt(immh:immb);
boolean unsigned = (U == '1');
FPRounding rounding = FPRounding ZERO;

Vector
Vector

FCVTZU <Vd>.<T>, <Vn>.<T>, #<fbits>

integer d = UInt(Rd);
integer n = UInt(Rn);

if immh == '0000' then SEE(asimdimm);
if immh == '000x' || (immh == '001x' & & HaveFP16Ext()) then UNDEFINED;
if immh<3>:Q == '10' then UNDEFINED;
integer esize = if immh == '1xxx' then 64 else if immh == '01xx' then 32 else 16;
integer datasize = if Q == '1' then 128 else 64;
integer elements = datasize DIV esize;

integer fracbits = (esize * 2) -41 then ReservedValue();
if immh<3>:Q == '10' then ReservedValue();
integer esize = if immh == '1xxx' then 64 else if immh == '01xx' then 32 else 16;
integer datasize = if Q == '1' then 128 else 64;
integer elements = datasize DIV esize;

integer fracbits = (esize * 2) -41 then ReservedValue();
if immh<3>:Q == '10' then ReservedValue();
integer esize = if immh == '1xxx' then 64 else if immh == '01xx' then 32 else 16;
integer datasize = if Q == '1' then 128 else 64;
integer elements = datasize DIV esize;

integer esize = if immh == '1xxx' then 64 else if immh == '01xx' then 32 else 16;
integer datasize = if Q == '1' then 128 else 64;
integer elements = datasize DIV esize;

boolean unsigned = (U == '1');
FPRounding rounding = FPRounding_ZERO;

Assembler Symbols

<V> Is a width specifier, encoded in “immh”:

<table>
<thead>
<tr>
<th>immh</th>
<th>&lt;V&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>000x</td>
<td>RESERVED</td>
</tr>
<tr>
<td>001x</td>
<td>H</td>
</tr>
<tr>
<td>01xx</td>
<td>S</td>
</tr>
<tr>
<td>1xxx</td>
<td>D</td>
</tr>
</tbody>
</table>

<d> Is the number of the SIMD&FP destination register, in the "Rd" field.

<n> Is the number of the first SIMD&FP source register, encoded in the "Rn" field.

<Vd> Is the name of the SIMD&FP destination register, encoded in the "Rd" field.

<T> Is an arrangement specifier, encoded in “immh:Q”:

<table>
<thead>
<tr>
<th>immh</th>
<th>Q</th>
<th>&lt;T&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0000</td>
<td>x</td>
<td>SEE Advanced SIMD modified immediate</td>
</tr>
<tr>
<td>0001</td>
<td>x</td>
<td>RESERVED</td>
</tr>
<tr>
<td>001x</td>
<td>0</td>
<td>4H</td>
</tr>
<tr>
<td>001x</td>
<td>1</td>
<td>8H</td>
</tr>
<tr>
<td>01xx</td>
<td>0</td>
<td>2S</td>
</tr>
<tr>
<td>01xx</td>
<td>1</td>
<td>4S</td>
</tr>
<tr>
<td>1xxx</td>
<td>0</td>
<td>RESERVED</td>
</tr>
<tr>
<td>1xxx</td>
<td>1</td>
<td>2D</td>
</tr>
</tbody>
</table>

<Vn> Is the name of the SIMD&FP source register, encoded in the "Rn" field.

<fbits> For the scalar variant: is the number of fractional bits, in the range 1 to the operand width, encoded in “immh:immb”:

<table>
<thead>
<tr>
<th>immh</th>
<th>&lt;fbits&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>000x</td>
<td>RESERVED</td>
</tr>
<tr>
<td>001x</td>
<td>(32-UInt(immh:immb))</td>
</tr>
<tr>
<td>01xx</td>
<td>(64-UInt(immh:immb))</td>
</tr>
<tr>
<td>1xxx</td>
<td>(128-UInt(immh:immb))</td>
</tr>
</tbody>
</table>

For the vector variant: is the number of fractional bits, in the range 1 to the element width, encoded in “immh:immb”:

<table>
<thead>
<tr>
<th>immh</th>
<th>&lt;fbits&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0000</td>
<td>SEE Advanced SIMD modified immediate</td>
</tr>
<tr>
<td>0001</td>
<td>RESERVED</td>
</tr>
<tr>
<td>001x</td>
<td>(32-UInt(immh:immb))</td>
</tr>
<tr>
<td>01xx</td>
<td>(64-UInt(immh:immb))</td>
</tr>
<tr>
<td>1xxx</td>
<td>(128-UInt(immh:immb))</td>
</tr>
</tbody>
</table>
Operation

```c
CheckFPAdvSIMDEnabled64();
bits(datasize) operand = V[n];
bits(datasize) result;
bits(esize) element;
for e = 0 to elements-1
    element = Elem[operand, e, esize];
    Elem[result, e, esize] = FPToFixed(element, fracbits, unsigned, FPCR, rounding);
V[d] = result;
```

Internal version only: isa v30.25, AdvSIMD v27.01, pseudocode v85-xml-00bet8_rc3b3c ; Build timestamp: 2018-09-13T13:25:04Z

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FCVTZU (vector, integer)

Floating-point Convert to Unsigned integer, rounding toward Zero (vector). This instruction converts a scalar or each element in a vector from a floating-point value to an unsigned integer value using the Round towards Zero rounding mode, and writes the result to the SIMD&FP destination register.

A floating-point exception can be generated by this instruction. Depending on the settings in FPCR, the exception results in either a flag being set in FPSR, or a synchronous exception being generated. For more information, see Floating-point exception traps.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the Security state and Exception level in which the instruction is executed, an attempt to execute the instruction might be trapped.

It has encodings from 4 classes: Scalar half precision, Scalar single-precision and double-precision, Vector half precision and Vector single-precision and double-precision.

Scalar half precision
(ARMv8.2)

```
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9  | 8  | 7  | 6  | 5  | 4  | 3  | 2  | 1  | 0  |
|-----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0   | 1  | 1  | 1  | 1  | 0  | 0  | 1  | 1  | 1  | 0  | 0  | 1  | 1  | 0  | 1  | 1  | 0  | Rn | Rd |
| U   | o2 | o1 |
```

Scalar half precision

```
FCVTZU <Hd>, <Hn>

if !HaveFP16Ext() then UNDEFINED;

integer d = 0;
integer n = UInt(Rn);
integer elements = 1;
FPRounding rounding = FPDecodeRounding(o1:o2);
boolean unsigned = (U == '1');
```

Scalar single-precision and double-precision

```
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9  | 8  | 7  | 6  | 5  | 4  | 3  | 2  | 1  | 0  |
|-----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0   | 1  | 1  | 1  | 1  | 0  | 0  | 0  | 1  | 0  | 1  | 1  | 0  | Rn | Rd |
| U   | o2 | o1 |
```

Scalar single-precision and double-precision

```
FCVTZU <V<d>, <V<n>

integer d = UInt(Rd);
integer n = UInt(Rn);
integer esize = 32 << UInt(sz);
integer elements = 1;
FPRounding rounding = FPDecodeRounding(o1:o2);
boolean unsigned = (U == '1');
```
Vector half precision

(ARMv8.2)

31  30  29  28  27  26  25  24  23  22  21  20  19  18  17  16  15  14  13  12  11  10  9  8  7  6  5  4  3  2  1  0
0   Q  1  0  1  1  1  0  1  1  1  1  1  0  0  1  1  0  1  1  1  0  Rn  Rd

Vector half precision

FCVTZU <Vd>.<T>, <Vn>.<T>

if !HaveFP16Ext() then UNDEFINED;

integer d = () then UnallocatedEncoding();
integer d = UInt (Rd);
integer n = UInt(Rn);

integer esize = 16;
integer datasize = if Q == '1' then 128 else 64;
integer elements = datasize DIV esize;

FPRounding rounding = FPDecodeRounding(o1:o2);
boolean unsigned = (U == '1');

Vector single-precision and double-precision

31  30  29  28  27  26  25  24  23  22  21  20  19  18  17  16  15  14  13  12  11  10  9  8  7  6  5  4  3  2  1  0
0   Q  1  0  1  1  1  0  1  sz  1  0  0  0  0  1  1  0  1  1  1  0  Rn  Rd

Vector single-precision and double-precision

FCVTZU <Vd>.<T>, <Vn>.<T>

integer d = UInt(Rd);
integer n = UInt(Rn);

if sz:Q == '10' then UNDEFINED;
integer esize = 32 << if sz:Q == '10' then ReservedValue();
integer esize = 32 << UInt(sz);
integer datasize = if Q == '1' then 128 else 64;
integer elements = datasize DIV esize;

FPRounding rounding = FPDecodeRounding(o1:o2);
boolean unsigned = (U == '1');

Assembler Symbols

<Hd> Is the 16-bit name of the SIMD&FP destination register, encoded in the "Rd" field.

<Hn> Is the 16-bit name of the SIMD&FP source register, encoded in the "Rn" field.

<V> Is a width specifier, encoded in "sz":

<table>
<thead>
<tr>
<th>sz</th>
<th>&lt;V&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>S</td>
</tr>
<tr>
<td>1</td>
<td>D</td>
</tr>
</tbody>
</table>

<d> Is the number of the SIMD&FP destination register, encoded in the "Rd" field.

<n> Is the number of the SIMD&FP source register, encoded in the "Rn" field.

<Vd> Is the name of the SIMD&FP destination register, encoded in the "Rd" field.

<T> For the vector half precision variant: is an arrangement specifier, encoded in “Q”:
For the vector single-precision and double-precision variant: is an arrangement specifier, encoded in "sz:Q":

<table>
<thead>
<tr>
<th>sz</th>
<th>Q</th>
<th>&lt;T&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>2S</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>4S</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>RESERVED</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>2D</td>
</tr>
</tbody>
</table>

<Vn> Is the name of the SIMD&FP source register, encoded in the "Rn" field.

**Operation**

```c
CheckFPAdvSIMDEnabled64();
bits(datasize) operand = V[n];
bits(datasize) result;
bits(esize) element;
for e = 0 to elements-1
    element = Elem[operand, e, esize];
    Elem[result, e, esize] = FPToFixed(element, 0, unsigned, FPCR, rounding);
V[d] = result;
```

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FCVTZU (scalar, fixed-point)

Floating-point Convert to Unsigned fixed-point, rounding toward Zero (scalar). This instruction converts the floating-point value in the SIMD&FP source register to a 32-bit or 64-bit fixed-point unsigned integer using the Round towards Zero rounding mode, and writes the result to the general-purpose destination register.

A floating-point exception can be generated by this instruction. Depending on the settings in FPCR, the exception results in either a flag being set in FPSR, or a synchronous exception being generated. For more information, see Floating-point exception traps.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the Security state and Exception level in which the instruction is executed, an attempt to execute the instruction might be trapped.

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9  | 8  | 7  | 6  | 5  | 4  | 3  | 2  | 1  | 0  |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| sf | 0  | 0  | 1  | 1  | 1  | 1  | 0  | 0  | 1  | 1  | 0  | 0  | 1  | scale | Rn | Rd |  rmode | opcode |
Half-precision to 32-bit (sf == 0 && type == 11) (ARMv8.2)

FCVTZU <Wd>, <Hn>, #<fbits>

Half-precision to 64-bit (sf == 1 && type == 11) (ARMv8.2)

FCVTZU <Xd>, <Hn>, #<fbits>

Single-precision to 32-bit (sf == 0 && type == 00)

FCVTZU <Wd>, <Sn>, #<fbits>

Single-precision to 64-bit (sf == 1 && type == 00)

FCVTZU <Xd>, <Sn>, #<fbits>

Double-precision to 32-bit (sf == 0 && type == 01)

FCVTZU <Wd>, <Dn>, #<fbits>

Double-precision to 64-bit (sf == 1 && type == 01)

FCVTZU <Xd>, <Dn>, #<fbits>
integer d = Uint(Rd);
integer n = Uint(Rn);

integer intsize = if sf == '1' then 64 else 32;
integer fltsize;
FPConvOp op;
FPRounding rounding;
boolean unsigned;

case type of
  when '00' fltsize = 32;
  when '01' fltsize = 64;
  when '10' UNDEFINED;
  when '11' fltsize = 16;
else UNDEFINED;

if sf == '0' && scale<5> == '0' then UNDEFINED;
integer fracbits = 64 - scale;

case opcode<2:1>:rmode of
  when '00 11' // FCVTZ
    rounding = FPRounding_ZERO;
    unsigned = (opcode<0> == '1');
    op = FPConvOp_CVT_FtoI;
  when '01 00' // [US]CVTF
    rounding = FPRoundingMode(FPCR);
    unsigned = (opcode<0> == '1');
    op = FPConvOp_CVT_ItoF;
  otherwise
    UNDEFINED;
otherwise UNallocatedEncoding();

Assembler Symbols

<Wd> Is the 32-bit name of the general-purpose destination register, encoded in the "Rd" field.
<Xd> Is the 64-bit name of the general-purpose destination register, encoded in the "Rd" field.
<Sn> Is the 32-bit name of the SIMD&FP source register, encoded in the "Rn" field.
<Hn> Is the 16-bit name of the SIMD&FP source register, encoded in the "Rn" field.
<Dn> Is the 64-bit name of the SIMD&FP source register, encoded in the "Rn" field.
<fbits> For the double-precision to 32-bit, half-precision to 32-bit and single-precision to 32-bit variant: is the number of bits after the binary point in the fixed-point destination, in the range 1 to 32, encoded as 64 minus "scale".
For the double-precision to 64-bit, half-precision to 64-bit and single-precision to 64-bit variant: is the number of bits after the binary point in the fixed-point destination, in the range 1 to 64, encoded as 64 minus "scale".
Operation

```c
CheckFPAdvSIMDEnabled64();

bits(fltsize) fltval;
bits(intsize) intval;

case op of
    when FPConvOp_CVT_FtoI
        fltval = V[n];
        intval = FPToFixed(fltval, fracbits, unsigned, FPCR, rounding);
        X[d] = intval;
    when FPConvOp_CVT_ItoF
        intval = X[n];
        fltval = FixedToFP(intval, fracbits, unsigned, FPCR, rounding);
        V[d] = fltval;
```


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FCVTZU (scalar, integer)

Floating-point Convert to Unsigned integer, rounding toward Zero (scalar). This instruction converts the floating-point value in the SIMD&FP source register to a 32-bit or 64-bit unsigned integer using the Round towards Zero rounding mode, and writes the result to the general-purpose destination register.

A floating-point exception can be generated by this instruction. Depending on the settings in FPCR, the exception results in either a flag being set in FPSR, or a synchronous exception being generated. For more information, see Floating-point exception traps.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.
Half-precision to 32-bit (sf == 0 && type == 11) (ARMv8.2)

```
FCVTZU <Wd>, <Hn>
```

Half-precision to 64-bit (sf == 1 && type == 11) (ARMv8.2)

```
FCVTZU <Xd>, <Hn>
```

Single-precision to 32-bit (sf == 0 && type == 00)

```
FCVTZU <Wd>, <Sn>
```

Single-precision to 64-bit (sf == 1 && type == 00)

```
FCVTZU <Xd>, <Sn>
```

Double-precision to 32-bit (sf == 0 && type == 01)

```
FCVTZU <Wd>, <Dn>
```

Double-precision to 64-bit (sf == 1 && type == 01)

```
FCVTZU <Xd>, <Dn>
```
integer d = UInt(Rd);
integer n = UInt(Rn);
integer intsize = if sf == '1' then 64 else 32;
integer fltsize;
FPConvOp op;
FPRounding rounding;
boolean unsigned;
integer part;

case type of
  when '00'
    fltsize = 32;
  when '01'
    fltsize = 64;
  when '10'
    if opcode<2:1>:rmode != '11 01' then UNDEFINED;
    fltsize = 128;
  when '11'
    if HaveFP16Ext() then
      fltsize = 16;
    else
      UNDEFINED;
  when '11'
    if fltsize != 16 && fltsize != intsize then UNDEFINED;
    op = if opcode<0> == '1' then FPConvOp_MOV_ItoF else FPConvOp_MOV_FtoI;
part = 0;
when '11 01' // FMOV
  if intsize != 64 || fltsize != 128 then UNDEFINED;
  op = if opcode<0> == '1' then FPConvOp_MOV_ItoF else FPConvOp_MOV_FtoI;
part = 1;
fltsize = 64; // size of D[1] is 64
when '11 11' // FJCVTZS
  if HaveFJCVTZSExt() then UNDEFINED;
  rounding = FPRounding.ZERO;
  unsigned = (opcode<0> == '1');
  op = FPConvOp_CVT_FtoI_JS;
otherwise
  UNallocatedEncoding();
otherwise
  UNDEFINED();

Assembler Symbols

<Wd> Is the 32-bit name of the general-purpose destination register, encoded in the "Rd" field.
<Xd> Is the 64-bit name of the general-purpose destination register, encoded in the "Rd" field.

<Sn> Is the 32-bit name of the SIMD&FP source register, encoded in the "Rn" field.

<Hn> Is the 16-bit name of the SIMD&FP source register, encoded in the "Rn" field.

<Dn> Is the 64-bit name of the SIMD&FP source register, encoded in the "Rn" field.

**Operation**

```c
CheckFPAdvSIMDEnabled64();

bits(fltsize) fltval;
bits(intsize) intval;

case op of
  when FPConvOp_CVT_FtoI
    fltval = V[n];
    intval = FPToFixed(fltval, 0, unsigned, FPCR, rounding);
    X[d] = intval;
  when FPConvOp_CVT_ItoF
    intval = X[n];
    fltval = FixedToFP(intval, 0, unsigned, FPCR, rounding);
    V[d] = fltval;
  when FPConvOp_MOV_FtoI
    fltval = Vpart[n,part];
    intval = ZeroExtend(fltval, intsize);
    X[d] = intval;
  when FPConvOp_MOV_ItoF
    intval = X[n];
    fltval = intval<fltsize-1:0>;
    Vpart[d,part] = fltval;
  when FPConvOp_CVT_FtoI_JS
    fltval = V[n];
    intval = FPFixedJS(fltval, FPCR, TRUE);
    X[d] = ZeroExtend(intval<31:0>, 64);
```

Internal version only: isa v30.25 v29.05, AdvSIMD v27.01 v26.0, pseudocode v85-xml-008eb8_yc3452, Build timestamp: 2018-09-13 09:45

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FDIV (vector)

Floating-point Divide (vector). This instruction divides the floating-point values in the elements in the first source SIMD&FP register, by the floating-point values in the corresponding elements in the second source SIMD&FP register, places the results in a vector, and writes the vector to the destination SIMD&FP register.

This instruction can generate a floating-point exception. Depending on the settings in FPSCR, the exception results in either a flag being set in FPSR, or a synchronous exception being generated. For more information, see Floating-point exception traps.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

It has encodings from 2 classes: Half-precision and Single-precision and double-precision

### Half-precision (ARMv8.2)

<table>
<thead>
<tr>
<th>31</th>
<th>30</th>
<th>29</th>
<th>28</th>
<th>27</th>
<th>26</th>
<th>25</th>
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<th>14</th>
<th>13</th>
<th>12</th>
<th>11</th>
<th>10</th>
<th>9</th>
<th>8</th>
<th>7</th>
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<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
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<td>1</td>
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<td>Rm</td>
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<td>1</td>
<td>1</td>
<td>1</td>
<td>Rn</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>Rd</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### Half-precision

FDIV <Vd>.<T>, <Vn>.<T>, <Vm>.<T>

```plaintext
if !HaveFP16Ext() then UNDEFINED;
integer d = 0; then UnallocatedEncoding();
integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rm);
integer esize = 16;
integer datasize = if Q == '1' then 128 else 64;
integer elements = datasize DIV esize;
```

### Single-precision and double-precision

<table>
<thead>
<tr>
<th>31</th>
<th>30</th>
<th>29</th>
<th>28</th>
<th>27</th>
<th>26</th>
<th>25</th>
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<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Q</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>sz</td>
<td>1</td>
<td>Rm</td>
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<td>1</td>
<td>Rn</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>Rd</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### Single-precision and double-precision

FDIV <Vd>.<T>, <Vn>.<T>, <Vm>.<T>

```plaintext
integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rm);
if sz:Q == '10' then UNDEFINED;
integer esize = 32 << if sz:Q == '10' then ReservedValue();
integer esize = 32 << UInt(sz);
integer datasize = if Q == '1' then 128 else 64;
integer elements = datasize DIV esize;
```

#### Assembler Symbols

- `<Vd>` Is the name of the SIMD&FP destination register, encoded in the "Rd" field.
- `<T>` For the half-precision variant: is an arrangement specifier, encoded in "Q":

<table>
<thead>
<tr>
<th>Q</th>
<th><code>&lt;T&gt;</code></th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>4H</td>
</tr>
<tr>
<td>1</td>
<td>8H</td>
</tr>
</tbody>
</table>

For the single-precision and double-precision variant: is an arrangement specifier, encoded in “sz:Q”:
<table>
<thead>
<tr>
<th>sz</th>
<th>Q</th>
<th>&lt;T&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>2S</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>4S</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>RESERVED</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>2D</td>
</tr>
</tbody>
</table>

<Vn> Is the name of the first SIMD&FP source register, encoded in the "Rn" field.

<Vm> Is the name of the second SIMD&FP source register, encoded in the "Rm" field.

**Operation**

```c
CheckFPAdvSIMDEnabled64();

bits(datasize) operand1 = V[n];
bits(datasize) operand2 = V[m];
bits(datasize) result;
bits(esize) element1;
bits(esize) element2;

for e = 0 to elements-1
    element1 = Elem[operand1, e, esize];
    element2 = Elem[operand2, e, esize];
    Elem[result, e, esize] = FPDiv(element1, element2, FPCR);

V[d] = result;
```


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FDIV (scalar)

Floating-point Divide (scalar). This instruction divides the floating-point value of the first source SIMD&FP register by the floating-point value of the second source SIMD&FP register, and writes the result to the destination SIMD&FP register.

This instruction can generate a floating-point exception. Depending on the settings in FPCR, the exception results in either a flag being set in FPSR, or a synchronous exception being generated. For more information, see Floating-point exception traps.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
type 1 Rm 0 0 0 1 1 0 Rd

Half-precision (type == 11)
(ARMv8.2)

FDIV <Hd>, <Hn>, <Hm>

Single-precision (type == 00)

FDIV <Sd>, <Sn>, <Sm>

Double-precision (type == 01)

FDIV <Dd>, <Dn>, <Dm>

integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rm);

integer datasize;

case type of
  when '00' datasize = 32;
  when '01' datasize = 64;
  when '10' UNDEFINED;
  when '11' if when '10' UnallocatedEncoding();
  when '11' if HaveFP16Ext() then
datasize = 16;
else
datasize = 16;
else UNDEFINED();

Assembler Symbols

<IDd> Is the 64-bit name of the SIMD&FP destination register, encoded in the "Rd" field.
<IDn> Is the 64-bit name of the first SIMD&FP source register, encoded in the "Rn" field.
<IDm> Is the 64-bit name of the second SIMD&FP source register, encoded in the "Rm" field.
<HD> Is the 16-bit name of the SIMD&FP destination register, encoded in the "Rd" field.
<HN> Is the 16-bit name of the first SIMD&FP source register, encoded in the "Rn" field.
<Hm> Is the 16-bit name of the second SIMD&FP source register, encoded in the "Rm" field.
<SD> Is the 32-bit name of the SIMD&FP destination register, encoded in the "Rd" field.
<SN> Is the 32-bit name of the first SIMD&FP source register, encoded in the "Rn" field.
<SM> Is the 32-bit name of the second SIMD&FP source register, encoded in the "Rm" field.
Operation

```c
CheckFPAdvSIMDEnabled64();
bits(datasize) result;
bits(datasize) operand1 = V[n];
bits(datasize) operand2 = V[m];
result = FPDiv(operand1, operand2, FPCR);
V[d] = result;
```
FJCVTZS

Floating-point Javascript Convert to Signed fixed-point, rounding toward Zero. This instruction converts the double-precision floating-point value in the SIMD&FP source register to a 32-bit signed integer using the Round towards Zero rounding mode, and writes the result to the general-purpose destination register. If the result is too large to be accommodated as a signed 32-bit integer, then the result is the integer modulo $2^{32}$, as held in a 32-bit signed integer.

This instruction can generate a floating-point exception. Depending on the settings in FPCR, the exception results in either a flag being set in FPSR or a synchronous exception being generated. For more information, see Floating-point exception traps.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

Double-precision to 32-bit
(ARMv8.3)

```
31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
0 0 0 1 1 1 1 0 0 1 1 1 1 1 1 0 0 0 0 0 0 Rn  Rd
sf type rmode opcode
```
Double-precision to 32-bit

FJCVTZS <Wd>, <Dn>

integer d = UInt(Rd);
integer n = UInt(Rn);

integer intsize = if sf == '1' then 64 else 32;
integer fltsize;
FPConvOp op;
FPRounding rounding;
boolean unsigned;
integer part;

case type of
  when '00'
    fltsize = 32;
  when '01'
    fltsize = 64;
  when '10'
    if opcode<2:1>:rmode != '11 01' then UNDEFINED;
    fltsize = 128;
  when '11'
    if !HaveFP16Ext() then
      fltsize = 16;
    else
      UNDEFINED;

case opcode<2:1>:rmode of
  when '00 xx'     // FCVT[NPMZ][US]
    rounding = UnallocatedEncoding();
  when '01 xx'     // [US]CVTF
    rounding = FPRoundingMode(FPCR);
  when '10 00'     // FCVTA[US]
    rounding = FPRounding_TIEAWAY;
  when '11 00'     // FMOV
    if fltsize != 16 && fltsize != intsize then UNDEFINED;
    op = if opcode<0> == '1' then
      FPConvOp_MOV_ItoF else FPConvOp_MOV_FtoI;
    part = 0;
  when '11 01'     // FMOV D[1]
    if intsize != 64 || fltsize != 128 then UNDEFINED;
    op = if opcode<0> == '1' then
      if intsize != 64 || fltsize != 128 then UnallocatedEncoding();
      FPConvOp_MOV_ItoF else FPConvOp_MOV_FtoI;
    part = 1;
    fltsize = 64; // size of D[1] is 64
  when '11 11'     // FJCVTZS
    if !HaveFJCVTZSExt() then UNDEFINED;
    rounding = FPRounding_ZERO;
    unsigned = (opcode<0> == '1');
    op = FPConvOp_CVT_FtoI_JS;
  otherwise
    UnallocatedEncoding();
  otherwise
    UNDEFINED();
Assembler Symbols

<Wd> Is the 32-bit name of the general-purpose destination register, encoded in the "Rd" field.
<Dn> Is the 64-bit name of the SIMD&FP source register, encoded in the "Rn" field.

Operation

```c
CheckFPAdvSIMEnabled64();

bits(fltsize) fltval;
bits(intsize) intval;

case op of
  when FPConvOp_CVT_FtoI
    fltval = V[n];
    intval = FPToFixed(fltval, 0, unsigned, FPCR, rounding);
    X[d] = intval;
  when FPConvOp_CVT_ItoF
    intval = X[n];
    fltval = FixedToFP(intval, 0, unsigned, FPCR, rounding);
    V[d] = fltval;
  when FPConvOp_MOV_FtoI
    fltval = Vpart[n,part];
    intval = ZeroExtend(fltval, intsize);
    X[d] = intval;
  when FPConvOp_MOV_ItoF
    intval = X[n];
    fltval = Intval<fltsize-1:0>;
    Vpart[d,part] = fltval;
  when FPConvOp_CVT_FtoI_JS
    fltval = V[n];
    intval = FPToFixedJS(fltval, FPCR, TRUE);
    X[d] = ZeroExtend(intval<31:0>, 64);
```

Internal version only: isa v30.25, AdvSIMD v27.01, pseudocode v85-xml-00bet8_rc3b352 ; Build timestamp: 2018-09-13T13:45 2018-06-16T09:45

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**FMADD**

Floating-point fused Multiply-Add (scalar). This instruction multiplies the values of the first two SIMD&FP source registers, adds the product to the value of the third SIMD&FP source register, and writes the result to the SIMD&FP destination register.

A floating-point exception can be generated by this instruction. Depending on the settings in **FPCR**, the exception results in either a flag being set in **FPSR**, or a synchronous exception being generated. For more information, see **Floating-point exception traps**.

Depending on the settings in the **CPACR_EL1**, **CPTR_EL2**, and **CPTR_EL3** registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

![Instruction format](image)

**Half-precision (type == 11)**

(ARMv8.2)

FMADD <Hd>, <Hn>, <Hm>, <Ha>

**Single-precision (type == 00)**

FMADD <Sd>, <Sn>, <Sm>, <Sa>

**Double-precision (type == 01)**

FMADD <Dd>, <Dn>, <Dm>, <Da>

```plaintext
integer d = UInt(Rd);
integer a = UInt(Ra);
integer n = UInt(Rn);
integer m = UInt(Rm);

integer datasize;
case type of
  when '00' datasize = 32;
  when '01' datasize = 64;
  when '10' UNDEFINED;
  when '11' if when '10' UnallocatedEncoding() then datasize = 16;
               when '11' if HaveFP16Ext() then datasize = 16;
               else UnallocatedEncoding() then datasize = 16;
               else UNDEFINED;

boolean opa_neg = (o1 == '1');
boolean opl_neg = (o0 != o1);
```

**Assembler Symbols**

- **<Dd>** is the 64-bit name of the SIMD&FP destination register, encoded in the "Rd" field.
- **<Dn>** is the 64-bit name of the first SIMD&FP source register holding the multiplicand, encoded in the "Rn" field.
- **<Dm>** is the 64-bit name of the second SIMD&FP source register holding the multiplier, encoded in the "Rm" field.
- **<Da>** is the 64-bit name of the third SIMD&FP source register holding the addend, encoded in the "Ra" field.
- **<Hd>** is the 16-bit name of the SIMD&FP destination register, encoded in the "Rd" field.
<Hn> Is the 16-bit name of the first SIMD&FP source register holding the multiplicand, encoded in the "Rn" field.
<Hm> Is the 16-bit name of the second SIMD&FP source register holding the multiplier, encoded in the "Rm" field.
<Ha> Is the 16-bit name of the third SIMD&FP source register holding the addend, encoded in the "Ra" field.
<Sd> Is the 32-bit name of the SIMD&FP destination register, encoded in the "Rd" field.
<Sn> Is the 32-bit name of the first SIMD&FP source register holding the multiplicand, encoded in the "Rn" field.
<Sm> Is the 32-bit name of the second SIMD&FP source register holding the multiplier, encoded in the "Rm" field.
<Sa> Is the 32-bit name of the third SIMD&FP source register holding the addend, encoded in the "Ra" field.

**Operation**

```c
CheckFPAdvSIMDEnabled64();
bits(datasize) result;
bits(datasize) operanda = V[a];
bits(datasize) operand1 = V[n];
bits(datasize) operand2 = V[m];

if opa_neg then operanda = FPNeg(operanda);
if op1_neg then operand1 = FPNeg(operand1);
result = FPMulAdd(operanda, operand1, operand2, FPCR);
V[d] = result;
```

Internal version only: isa v30.25, AdvSIMD v27.01, pseudocode v85-xml-000eb8-rc3323; Build timestamp: 2018-09-13T13:20 2018-06-16T09:04:45

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FMAX (vector)

Floating-point Maximum (vector). This instruction compares corresponding vector elements in the two source SIMD&FP registers, places the larger of each of the two floating-point values into a vector, and writes the vector to the destination SIMD&FP register.

This instruction can generate a floating-point exception. Depending on the settings in FPCR, the exception results in either a flag being set in FPSR, or a synchronous exception being generated. For more information, see Floating-point exception traps.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

It has encodings from 2 classes: Half-precision and Single-precision and double-precision

### Half-precision

(ARMv8.2)

```
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 |  9 |  8 |  7 |  6 |  5 |  4 |  3 |  2 |  1 |  0 |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0  | 0  | 1  | 1  | 1  | 0  | 0  | 1  | 1  | 0  | 1  | 0  | Rm | 0  | 0  | 1  | 1  | 0  | 1  | Rd |
| U  | o1 |
```

### Single-precision and double-precision

```
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 |  9 |  8 |  7 |  6 |  5 |  4 |  3 |  2 |  1 |  0 |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0  | 0  | 1  | 1  | 1  | 0  | 0  | 0  | sz | 1  | Rm | 1  | 1  | 1  | 0  | 1  | Rn | 1  | 1  | 0  | 1  | Rd |
| U  | o1 |
```

### Single-precision and double-precision

```
FMAX <Vd>.<T>, <Vn>.<T>, <Vm>.<T>

if !HaveFP16Ext() then UNDEFINED;
integer d = 1 then UnallocatedEncoding();
integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rm);
integer esize = 16;
integer datasize = if Q == '1' then 128 else 64;
integer elements = datasize DIV esize;

boolean pair = (U == '1');
boolean minimum = (o1 == '1');
```

```
Assembler Symbols

<\texttt{Vd}> Is the name of the SIMD&FP destination register, encoded in the "Rd" field.

<\texttt{T}> For the half-precision variant: is an arrangement specifier, encoded in “Q”:

<table>
<thead>
<tr>
<th>Q</th>
<th>\texttt{T}</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>4H</td>
</tr>
<tr>
<td>1</td>
<td>8H</td>
</tr>
</tbody>
</table>

For the single-precision and double-precision variant: is an arrangement specifier, encoded in “\texttt{sz}:Q”:

<table>
<thead>
<tr>
<th>sz</th>
<th>Q</th>
<th>&lt;\texttt{T}&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>2S</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>4S</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>RESERVED</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>2D</td>
</tr>
</tbody>
</table>

<\texttt{Vn}> Is the name of the first SIMD&FP source register, encoded in the "Rn" field.

<\texttt{Vm}> Is the name of the second SIMD&FP source register, encoded in the "Rm" field.

Operation

```c
CheckFPAdvSIMDEnabled64();
bits(datasize) operand1 = \texttt{V}[n];
bits(datasize) operand2 = \texttt{V}[m];
bits(datasize) result;
bits(2*datasize) concat = operand2:operand1;
bits(esize) element1;
bits(esize) element2;
for e = 0 to elements-1
    if pair then
        element1 = \texttt{Elem}[concat, 2*e, esize];
        element2 = \texttt{Elem}[concat, (2*e)+1, esize];
    else
        element1 = \texttt{Elem}[operand1, e, esize];
        element2 = \texttt{Elem}[operand2, e, esize];
    if minimum then
        \texttt{Elem}[result, e, esize] = FPMin(element1, element2, FPCR);
    else
        \texttt{Elem}[result, e, esize] = FPMax(element1, element2, FPCR);
\texttt{V}[d] = result;
```

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FMAX (scalar)

Floating-point Maximum (scalar). This instruction compares the two source SIMD&FP registers, and writes the larger of the two floating-point values to the destination SIMD&FP register.

This instruction can generate a floating-point exception. Depending on the settings in FPCR, the exception results in either a flag being set in FPSR, or a synchronous exception being generated. For more information, see Floating-point exception traps.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

Half-precision (type == 11) (ARMv8.2)

FMAX <Hd>, <Hn>, <Hm>

Single-precision (type == 00)

FMAX <Sd>, <Sn>, <Sm>

Double-precision (type == 01)

FMAX <Dd>, <Dn>, <Dm>

integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rm);

integer datasize;

\[
\text{case type of}
\]

\[
\begin{align*}
\text{when '00'} & \quad \text{datasize} = 32; \\
\text{when '01'} & \quad \text{datasize} = 64; \\
\text{when '10'} & \quad \text{UNDEFINED}; \\
\text{when '11'} & \quad \begin{cases}
\text{if when '10'} & \quad \text{UnallocatedEncoding();} \\
\text{when '11'} & \quad \begin{cases}
\text{if HaveFP16Ext() then} & \quad \text{datasize} = 16; \\
\text{else} & \quad \text{UnallocatedEncoding() then} \\
\text{else} & \quad \text{UNDEFINED();}
\end{cases}
\end{cases}
\end{align*}
\]

FPMaxMinOp operation;

\[
\text{case op of}
\]

\[
\begin{align*}
\text{when '00'} & \quad \text{operation} = \text{FPMaxMinOp_MAX}; \\
\text{when '01'} & \quad \text{operation} = \text{FPMaxMinOp_MIN}; \\
\text{when '10'} & \quad \text{operation} = \text{FPMaxMinOp_MAXNUM}; \\
\text{when '11'} & \quad \text{operation} = \text{FPMaxMinOp_MINNUM};
\end{align*}
\]

Assembler Symbols

**<Dd>** Is the 64-bit name of the SIMD&FP destination register, encoded in the "Rd" field.

**<Dn>** Is the 64-bit name of the first SIMD&FP source register, encoded in the "Rn" field.

**<Dm>** Is the 64-bit name of the second SIMD&FP source register, encoded in the "Rm" field.

**<Hd>** Is the 16-bit name of the SIMD&FP destination register, encoded in the "Rd" field.
Is the 16-bit name of the first SIMD&FP source register, encoded in the "Rn" field.

Is the 16-bit name of the second SIMD&FP source register, encoded in the "Rm" field.

Is the 32-bit name of the SIMD&FP destination register, encoded in the "Rd" field.

Is the 32-bit name of the first SIMD&FP source register, encoded in the "Rn" field.

Is the 32-bit name of the second SIMD&FP source register, encoded in the "Rm" field.

**Operation**

```c
CheckFPAdvSIMDEnabled64();
bis(datasize) result;
bis(datasize) operand1 = V[n];
bis(datasize) operand2 = V[m];

case operation of
  when FPMaxMinOp_MAX result = FPMax(operand1, operand2, FPCR);
  when FPMaxMinOp_MIN result = FPMin(operand1, operand2, FPCR);
  when FPMaxMinOp_MAXNUM result = FPMaxNum(operand1, operand2, FPCR);
  when FPMaxMinOp_MINNUM result = FPMinNum(operand1, operand2, FPCR);
  
V[d] = result;
```

Internal version only: isa v30.25 v29.05, AdvSIMD v27.01 v26.0, pseudocode v85-xml-00bet8_rc3a3554 ; Build timestamp: 2018-09-13T13:2018-06-16T09:04:45

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FMAXNM (vector)

Floating-point Maximum Number (vector). This instruction compares corresponding vector elements in the two source SIMD&FP registers, writes the larger of the two floating-point values into a vector, and writes the vector to the destination SIMD&FP register. NaNs are handled according to the IEEE 754-2008 standard. If one vector element is numeric and the other is a quiet NaN, the result placed in the vector is the numerical value, otherwise the result is identical to FMAX (scalar). This instruction can generate a floating-point exception. Depending on the settings in FPCR, the exception results in either a flag being set in FPSR, or a synchronous exception being generated. For more information, see Floating-point exception traps. Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

It has encodings from 2 classes: Half-precision and Single-precision and double-precision

Half-precision
(ARMv8.2)

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<td>1</td>
<td>1</td>
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<td>a</td>
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</tbody>
</table>

Half-precision

FMAXNM <Vd>.<T>, <Vn>.<T>, <Vm>.<T>

if !HaveFP16Ext() then UNDEFINED;
integer d = -1 then UnallocatedEncoding();
integer d = Uint(Rd);
integer n = Uint(Rn);
integer m = Uint(Rm);
integer esize = 16;
integer datasize = if Q == 'L' then 128 else 64;
integer elements = datasize DIV esize;

boolean pair = (U == 'L');
boolean minimum = (a == 'L');

Single-precision and double-precision

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<th>2</th>
<th>1</th>
<th>0</th>
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</thead>
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<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
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<td>sz</td>
<td>1</td>
<td>Rm</td>
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</tbody>
</table>

Single-precision and double-precision

FMAXNM <Vd>.<T>, <Vn>.<T>, <Vm>.<T>

integer d = Uint(Rd);
integer n = Uint(Rn);
integer m = Uint(Rm);
if sz:Q == '10' then UNDEFINED;
integer esize = 32 << if sz:Q == '10' then ReservedValue();
integer esize = 32 << Uint(sz);
integer datasize = if Q == 'L' then 128 else 64;
integer elements = datasize DIV esize;

boolean pair = (U == 'L');
boolean minimum = (o1 == 'L');
Assembler Symbols

<\text{Vd}> \quad \text{Is the name of the SIMD\&FP destination register, encoded in the "Rd" field.}

<\text{T}> \quad \text{For the half-precision variant: is an arrangement specifier, encoded in "Q":}

\begin{array}{c|c}
\text{Q} & <\text{T}> \\
\hline
0 & 4H \\
1 & 8H \\
\end{array}

\text{For the single-precision and double-precision variant: is an arrangement specifier, encoded in "sz:Q":}

\begin{array}{c|c|c}
sz & Q & <\text{T}> \\
\hline
0 & 0 & 2S \\
0 & 1 & 4S \\
1 & 0 & \text{RESERVED} \\
1 & 1 & 2D \\
\end{array}

<\text{Vn}> \quad \text{Is the name of the first SIMD\&FP source register, encoded in the "Rn" field.}

<\text{Vm}> \quad \text{Is the name of the second SIMD\&FP source register, encoded in the "Rm" field.}

Operation

```c
CheckFPAdvSIMDEnabled64();
bits(datasize) operand1 = \text{V}[n];
bits(datasize) operand2 = \text{V}[m];
bits(datasize) result;
bits(2*datasize) concat = operand2:operand1;
bits(esize) element1;
bits(esize) element2;
for e = 0 to elements-1
  if pair then
    element1 = \text{Elem}[concat, 2*e, esize];
    element2 = \text{Elem}[concat, (2*e)+1, esize];
  else
    element1 = \text{Elem}[operand1, e, esize];
    element2 = \text{Elem}[operand2, e, esize];
  if minimum then
    \text{Elem}[result, e, esize] = FPMinNum(element1, element2, FPCR);
  else
    \text{Elem}[result, e, esize] = FPMaxNum(element1, element2, FPCR);
\text{V}[d] = result;
```

Internal version only: isa e36.25,v29.05, AdvSIMD e27.01,v26.0, pseudocode e85-xml-00bet8_rc3v85; Build timestamp: 2018-09-13T13:20:45Z
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FMAXNM (scalar)

Floating-point Maximum Number (scalar). This instruction compares the first and second source SIMD&FP register values, and writes the larger of the two floating-point values to the destination SIMD&FP register.

NaNs are handled according to the IEEE 754-2008 standard. If one vector element is numeric and the other is a quiet NaN, the result that is placed in the vector is the numerical value, otherwise the result is identical to FMAX (scalar).

This instruction can generate a floating-point exception. Depending on the settings in FPCR, the exception results in either a flag being set in FPSR, or a synchronous exception being generated. For more information, see Floating-point exception traps.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

**Half-precision (type == 11)**
(ARMv8.2)

FMAXNM <Hd>, <Hn>, <Hm>

**Single-precision (type == 00)**

FMAXNM <Sd>, <Sn>, <Sm>

**Double-precision (type == 01)**

FMAXNM <Dd>, <Dn>, <Dm>

Integer d = UInt(Rd);
Integer n = UInt(Rn);
Integer m = UInt(Rm);

Integer datasize;
Case type of
  When '00' datasize = 32;
  When '01' datasize = 64;
  When '10' UNDEFINED;
  When '11' if when '10' UnallocatedEncoding();
  When '11' if HaveFP16Ext() then
data size = 16;
  Else UnallocatedEncoding() then
data size = 16;
  Else UNDEFINED();

FPMAXMINOp operation;
Case op of
  When '00' operation = FPMAXMINOp_MAX;
  When '01' operation = FPMAXMINOp_MIN;
  When '10' operation = FPMAXMINOp_MAXNUM;
  When '11' operation = FPMAXMINOp_MINNUM;

Assembler Symbols

<Dd> Is the 64-bit name of the SIMD&FP destination register, encoded in the "Rd" field.
<Dn> Is the 64-bit name of the first SIMD&FP source register, encoded in the "Rn" field.
Is the 64-bit name of the second SIMD&FP source register, encoded in the "Rm" field.

Is the 16-bit name of the SIMD&FP destination register, encoded in the "Rd" field.

Is the 16-bit name of the first SIMD&FP source register, encoded in the "Rn" field.

Is the 16-bit name of the second SIMD&FP source register, encoded in the "Rm" field.

Is the 32-bit name of the SIMD&FP destination register, encoded in the "Rd" field.

Is the 32-bit name of the first SIMD&FP source register, encoded in the "Rn" field.

Is the 32-bit name of the second SIMD&FP source register, encoded in the "Rm" field.

**Operation**

```c
CheckFPAdvSIMDEnabled64();
bits(datasize) result;
bits(datasize) operand1 = V[n];
bits(datasize) operand2 = V[m];

case operation of
    when FPMaxMinOp_MAX    result = FPMax(operand1, operand2, FPCR);
    when FPMaxMinOp_MIN    result = FPMin(operand1, operand2, FPCR);
    when FPMaxMinOp_MAXNUM result = FPMaxNum(operand1, operand2, FPCR);
    when FPMaxMinOp_MINNUM result = FPMinNum(operand1, operand2, FPCR);

V[d] = result;
```

Internal version only: isa v30.25 v30.25, AdvSIMD v27.01 v27.01, pseudocode v85-xml-00bet8_rc3b555 ; Build timestamp: 2018-09-13T13:2018-06-16T09:04:45

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FMAXNMP (scalar)

Floating-point Maximum Number of Pair of elements (scalar). This instruction compares two vector elements in the source SIMD&FP register and writes the largest of the floating-point values as a scalar to the destination SIMD&FP register.

This instruction can generate a floating-point exception. Depending on the settings in FPCR, the exception results in either a flag being set in FPSR or a synchronous exception being generated. For more information, see Floating-point exception traps.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

It has encodings from 2 classes: Half-precision and Single-precision and double-precision

**Half-precision**

(ARMv8.2)

```
0 1 0 1 1 1 0 0 1 1 0 0 0 1 1 0 1 0 | Rn | Rd
```

```
o1 sz
```

**Single-precision and double-precision**

```
0 1 1 1 1 1 0 0 | sz | 1 1 0 0 0 0 1 1 0 0 1 0 | Rn | Rd
```

```
o1
```

```
FMAXNMP <V><d>, <Vn>.<T>

if !HaveFP16Ext() then UNDEFINED;
integer d = 1; then UnallocatedEncoding();
integer d = UInt(Rd);
integer n = UInt(Rn);
integer esize = 16;
if sz == '1' then ReservedValue(Rn);
integer esize = 16;
if sz == '1' then UNDEFINED;
integer datasize = esize * 2;
integer elements = 2;
ReduceOp op = if o1 == '1' then ReduceOp_FMINNUM else ReduceOp_FMAXNUM;

FMAXNMP <V><d>, <Vn>.<T>

integer d = UInt(Rd);
integer n = UInt(Rn);
integer esize = 32 << UInt(sz);
integer datasize = esize * 2;
integer elements = 2;
ReduceOp op = if o1 == '1' then ReduceOp_FMINNUM else ReduceOp_FMAXNUM;
```
Assembler Symbols

For the half-precision variant: is the destination width specifier, encoded in “sz”:

<table>
<thead>
<tr>
<th>sz</th>
<th>V</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>H</td>
</tr>
<tr>
<td>1</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

For the single-precision and double-precision variant: is the destination width specifier, encoded in “sz”:

<table>
<thead>
<tr>
<th>sz</th>
<th>V</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>S</td>
</tr>
<tr>
<td>1</td>
<td>D</td>
</tr>
</tbody>
</table>

<d>
Is the number of the SIMD&FP destination register, encoded in the "Rd" field.

<Vn>
Is the name of the SIMD&FP source register, encoded in the "Rn" field.

<T>
For the half-precision variant: is the source arrangement specifier, encoded in “sz”:

<table>
<thead>
<tr>
<th>sz</th>
<th>T</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>2H</td>
</tr>
<tr>
<td>1</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

For the single-precision and double-precision variant: is the source arrangement specifier, encoded in “sz”:

<table>
<thead>
<tr>
<th>sz</th>
<th>T</th>
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</thead>
<tbody>
<tr>
<td>0</td>
<td>2S</td>
</tr>
<tr>
<td>1</td>
<td>2D</td>
</tr>
</tbody>
</table>

Operation

```c
CheckFPAdvSIMDEnabled64();
bits(datasize) operand = V[n];
V[d] = Reduce(op, operand, esize);
```

Internal version only: isa v30.25 v29.05, AdvSIMD v27.01 v26.0, pseudocode v85-xml-00bet8_rc30258 ; Build timestamp: 2018-09-13T13:45:04Z 2018-06-16T09:45:45

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FMAXNMP (vector)

Floating-point Maximum Number Pairwise (vector). This instruction creates a vector by concatenating the vector elements of the first source SIMD&FP register after the vector elements of the second source SIMD&FP register, reads each pair of adjacent vector elements in the two source SIMD&FP registers, writes the largest of each pair of values into a vector, and writes the vector to the destination SIMD&FP register. All the values in this instruction are floating-point values.

NaNs are handled according to the IEEE 754-2008 standard. If one vector element is numeric and the other is a quiet NaN, the result is the numerical value, otherwise the result is identical to FMAX (scalar).

This instruction can generate a floating-point exception. Depending on the settings in FPCR, the exception results in either a flag being set in FPSR or a synchronous exception being generated. For more information, see Floating-point exception traps.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

It has encodings from 2 classes: Half-precision and Single-precision and double-precision

Half-precision

(ARMv8.2)

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</tbody>
</table>

Half-precision

FMAXNMP <Vd>.<T>, <Vn>.<T>, <Vm>.<T>

if !HaveFP16Ext() then UNDEFINED;

integer d = 0 then UnallocatedEncoding();
integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rm);
integer esize = 16;
integer datasize = if Q == '1' then 128 else 64;
integer elements = datasize DIV esize;

boolean pair = (U == '1');
boolean minimum = (a == '1');

Single-precision and double-precision

<table>
<thead>
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<th>15</th>
<th>14</th>
<th>13</th>
<th>12</th>
<th>11</th>
<th>10</th>
<th>9</th>
<th>8</th>
<th>7</th>
<th>6</th>
<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Q</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>sz</td>
<td>1</td>
<td>Rm</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>Rn</td>
<td>Rd</td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>U</td>
<td>o1</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Single-precision and double-precision

FMAXNMP <Vd>.<T>, <Vn>.<T>, <Vm>.<T>

integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rm);
if sz:Q == '10' then UNDEFINED;
integer esize = 32 << if sz:Q == '10' then ReservedValue();
integer esize = 32 << UInt(sz);
integer datasize = if Q == '1' then 128 else 64;
integer elements = datasize DIV esize;

boolean pair = (U == '1');
boolean minimum = (o1 == '1');
Assembler Symbols

(Vd) Is the name of the SIMD&FP destination register, encoded in the "Rd" field.

(T) For the half-precision variant: is an arrangement specifier, encoded in “Q”:

<table>
<thead>
<tr>
<th>Q</th>
<th>&lt;T&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>4H</td>
</tr>
<tr>
<td>1</td>
<td>8H</td>
</tr>
</tbody>
</table>

For the single-precision and double-precision variant: is an arrangement specifier, encoded in “sz:Q”:

<table>
<thead>
<tr>
<th>sz</th>
<th>Q</th>
<th>&lt;T&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>2S</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>4S</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>RESERVED</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>2D</td>
</tr>
</tbody>
</table>

(Vn) Is the name of the first SIMD&FP source register, encoded in the "Rn" field.

(Vm) Is the name of the second SIMD&FP source register, encoded in the "Rm" field.

Operation

```c
CheckFPAdvSIMDEnabled64();
bits(datasize) operand1 = V[n];
bits(datasize) operand2 = V[m];
bits(datasize) result;
bits(2*datasize) concat = operand2:operand1;
bits(esize) element1;
bits(esize) element2;
for e = 0 to elements-1
    if pair then
        element1 = Elem[concat, 2*e, esize];
        element2 = Elem[concat, (2*e)+1, esize];
    else
        element1 = Elem[operand1, e, esize];
        element2 = Elem[operand2, e, esize];
    if minimum then
        Elem[result, e, esize] = FPMinNum(element1, element2, FPCR);
    else
        Elem[result, e, esize] = FPMaxNum(element1, element2, FPCR);
V[d] = result;
```

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FMAXNMV

Floating-point Maximum Number across Vector. This instruction compares all the vector elements in the source SIMD&FP register, and writes the largest of the values as a scalar to the destination SIMD&FP register. All the values in this instruction are floating-point values. NaNs are handled according to the IEEE 754-2008 standard. If one vector element is numeric and the other is a quiet NaN, the result of the comparison is the numerical value, otherwise the result is identical to FMAX (scalar).

This instruction can generate a floating-point exception. Depending on the settings in FPCR, the exception results in either a flag being set in FPSR or a synchronous exception being generated. For more information, see Floating-point exception traps.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

It has encodings from 2 classes: Half-precision and Single-precision and double-precision

Half-precision
(ARMv8.2)

<table>
<thead>
<tr>
<th></th>
<th>31</th>
<th>30</th>
<th>29</th>
<th>28</th>
<th>27</th>
<th>26</th>
<th>25</th>
<th>24</th>
<th>23</th>
<th>22</th>
<th>21</th>
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<th>18</th>
<th>17</th>
<th>16</th>
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<th>14</th>
<th>13</th>
<th>12</th>
<th>11</th>
<th>10</th>
<th>9</th>
<th>8</th>
<th>7</th>
<th>6</th>
<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
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<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>Rn</td>
<td>Rd</td>
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<td>o1</td>
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</tbody>
</table>

Single-precision and double-precision

<table>
<thead>
<tr>
<th></th>
<th>31</th>
<th>30</th>
<th>29</th>
<th>28</th>
<th>27</th>
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<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
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</tr>
<tr>
<td>o1</td>
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<td></td>
</tr>
</tbody>
</table>

Single-precision and double-precision

FMAXNMV <V><d>, <Vn>.<T>

FMAXNMV <V><d>, <Vn>.<T>

if !HaveFP16Ext() then UNDEFINED;

integer d = Int(Rd);
integer n = Int(Rn);

integer esize = 16;
integer datasize = if Q == '1' then 128 else 64;
integer elements = datasize DIV esize;

ReduceOp op = if o1 == '1' then ReduceOp_FMINNUM else ReduceOp_FMAXNUM;

FMAXNMV <V><d>, <Vn>.<T>

integer d = Int(Rd);
integer n = Int(Rn);

if sz:Q != '01' then UNDEFINED; // .4S only

integer esize = 32 << (if sz:Q != '01' then ReservedValue(); // .4S only)
integer esize = 32 << (Int(sz);
integer datasize = if Q == '1' then 128 else 64;
integer elements = datasize DIV esize;

ReduceOp op = if o1 == '1' then ReduceOp_FMINNUM else ReduceOp_FMAXNUM;
Assembler Symbols

For the half-precision variant: is the destination width specifier, H.
For the single-precision and double-precision variant: is the destination width specifier, encoded in “sz”:

<table>
<thead>
<tr>
<th>sz</th>
<th>&lt;V&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>S</td>
</tr>
<tr>
<td>1</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

Is the number of the SIMD&FP destination register, encoded in the "Rd" field.

Is the name of the SIMD&FP source register, encoded in the "Rn" field.

For the half-precision variant: is an arrangement specifier, encoded in “Q”:

<table>
<thead>
<tr>
<th>Q</th>
<th>&lt;T&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>4H</td>
</tr>
<tr>
<td>1</td>
<td>8H</td>
</tr>
</tbody>
</table>

For the single-precision and double-precision variant: is an arrangement specifier, encoded in “Q:sz”:

<table>
<thead>
<tr>
<th>Q</th>
<th>sz</th>
<th>&lt;T&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>x</td>
<td>RESERVED</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>4S</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

Operation

```
CheckFPAdvSIMDEnabled64();
bits(datasize) operand = V[n];
V[d] = Reduce(op, operand, esize);
```

Internal version only: isa v30.25 v29.05, AdvSIMD v27.01 v26.0, pseudocode v85-xml-00bet8_rc3+352 ; Build timestamp: 2018-09-13T13:2018-06-16T09:45

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FMAXP (scalar)

Floating-point Maximum of Pair of elements (scalar). This instruction compares two vector elements in the source SIMD&FP register and writes the largest of the floating-point values as a scalar to the destination SIMD&FP register.

This instruction can generate a floating-point exception. Depending on the settings in FPSCR, the exception results in either a flag being set in FPSR or a synchronous exception being generated. For more information, see Floating-point exception traps.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

It has encodings from 2 classes: Half-precision and Single-precision and double-precision

Half-precision

(ARMv8.2)

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9  | 8  | 7  | 6  | 5  | 4  | 3  | 2  | 1  | 0  |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0  | 1  | 0  | 1  | 1  | 1  | 1  | 0  | 0  | 0  | 1  | 1  | 0  | 0  | 0  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 0  | Rn  |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |

o1 sz

Half-precision

FMAXP <V><d>, <Vn>.<T>

if !HaveFP16Ext() then UNDEFINED;

integer d = Integer(Rd);
integer n = Integer(Rn);

integer esize = 16;
if sz == '1' then ReservedValue(Rn);

integer esize = 16;
if sz == '1' then UNDEFINED;
else
integer datasize = esize * 2;
integer elements = 2;

ReduceOp op = if o1 == '1' then ReduceOp_FMIN else ReduceOp_FMAX;

Single-precision and double-precision

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9  | 8  | 7  | 6  | 5  | 4  | 3  | 2  | 1  | 0  |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0  | 1  | 1  | 1  | 1  | 1  | 1  | 0  | 0  | 0  | 1  | 1  | 0  | 0  | 0  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 0  | Rn  |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |

Single-precision and double-precision

FMAXP <V><d>, <Vn>.<T>

integer d = UInt(Rd);
integer n = UInt(Rn);

integer esize = 32 << UInt(sz);
integer datasize = esize * 2;
integer elements = 2;

ReduceOp op = if o1 == '1' then ReduceOp_FMIN else ReduceOp_FMAX;
Assembler Symbols

For the half-precision variant: is the destination width specifier, encoded in “sz”:

<table>
<thead>
<tr>
<th>sz</th>
<th>&lt;V&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>H</td>
</tr>
<tr>
<td>1</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

For the single-precision and double-precision variant: is the destination width specifier, encoded in “sz”:

<table>
<thead>
<tr>
<th>sz</th>
<th>&lt;V&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>S</td>
</tr>
<tr>
<td>1</td>
<td>D</td>
</tr>
</tbody>
</table>

<d> Is the number of the SIMD&FP destination register, encoded in the "Rd" field.

<Vn> Is the name of the SIMD&FP source register, encoded in the "Rn" field.

<T> For the half-precision variant: is the source arrangement specifier, encoded in “sz”:

<table>
<thead>
<tr>
<th>sz</th>
<th>&lt;T&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>2H</td>
</tr>
<tr>
<td>1</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

For the single-precision and double-precision variant: is the source arrangement specifier, encoded in “sz”:

<table>
<thead>
<tr>
<th>sz</th>
<th>&lt;T&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>2S</td>
</tr>
<tr>
<td>1</td>
<td>2D</td>
</tr>
</tbody>
</table>

Operation

```c
CheckFPAdvSIMDEnabled64();
bits(datasize) operand = V[n];
V[d] = Reduce(op, operand, esize);
```

Internal version only: isa v30.25 v29.11, AdvSIMD v27.01, pseudocode v85-xml-00bet8-rc30354 ; Build timestamp: 2018-09-13T13:2018-06-16T09:45

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FMAXP (vector)

Floating-point Maximum Pairwise (vector). This instruction creates a vector by concatenating the vector elements of the first source SIMD&FP register after the vector elements of the second source SIMD&FP register, reads each pair of adjacent vector elements from the concatenated vector, writes the larger of each pair of values into a vector, and writes the vector to the destination SIMD&FP register. All the values in this instruction are floating-point values.

This instruction can generate a floating-point exception. Depending on the settings in FPCR, the exception results in either a flag being set in FPSR or a synchronous exception being generated. For more information, see Floating-point exception traps.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

It has encodings from 2 classes: Half-precision and Single-precision and double-precision

### Half-precision

(ARMv8.2)

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0  | Q  | 1  | 0  | 1  | 1  | 0  | 0  | 1  | 0  | Rm | 0  | 0  | 1  | 1  | 0  | 1  | Rn | Rd |

U: o1

### Single-precision and double-precision

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0  | Q  | 1  | 0  | 1  | 1  | 0  | 0  | sz | 1  | Rm | 1  | 1  | 1  | 0  | 1  | Rn | Rd |

U: o1

### Single-precision and double-precision

```plaintext
if !HaveFP16Ext() then UNDEFINED;
integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rm);
integer esize = 16;
integer datasize = if Q == '1' then 128 else 64;
integer elements = datasize DIV esize;

boolean pair = (U == '1');
boolean minimum = (o1 == '1');
```

```plaintext
if sz:Q == '10' then UNDEFINED;
integer esize = 32 << if sz:Q == '10' then ReservedValue else UInt(sz);
integer datasize = if Q == '1' then 128 else 64;
integer elements = datasize DIV esize;

boolean pair = (U == '1');
boolean minimum = (o1 == '1');
```
**Assembler Symbols**

<\texttt{Vd}> Is the name of the SIMD&FP destination register, encoded in the “Rd” field.

<\texttt{T}> For the half-precision variant: is an arrangement specifier, encoded in “Q”:

<table>
<thead>
<tr>
<th>Q</th>
<th>T</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0H</td>
</tr>
<tr>
<td>1</td>
<td>8H</td>
</tr>
</tbody>
</table>

For the single-precision and double-precision variant: is an arrangement specifier, encoded in “sz:Q”:

<table>
<thead>
<tr>
<th>sz</th>
<th>Q</th>
<th>T</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>2S</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>4S</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>RESERVED</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>2D</td>
</tr>
</tbody>
</table>

<\texttt{Vn}> Is the name of the first SIMD&FP source register, encoded in the “Rn” field.

<\texttt{Vm}> Is the name of the second SIMD&FP source register, encoded in the “Rm” field.

**Operation**

```plaintext
CheckFPAdvSIMDEnabled64();
bits(datasize) operand1 = \texttt{V}[n];
bits(datasize) operand2 = \texttt{V}[m];
bits(datasize) result;
bits(2*datasize) concat = operand2:operand1;
bits(esize) element1;
bits(esize) element2;
for e = 0 to elements-1
    if pair then
        element1 = \texttt{Elem}[concat, 2*e, esize];
        element2 = \texttt{Elem}[concat, (2*e)+1, esize];
    else
        element1 = \texttt{Elem}[operand1, e, esize];
        element2 = \texttt{Elem}[operand2, e, esize];
    if minimum then
        \texttt{Elem}[result, e, esize] = \texttt{FPMin}(element1, element2, FPCR);
    else
        \texttt{Elem}[result, e, esize] = \texttt{FPMax}(element1, element2, FPCR);
\texttt{V}[d] = result;
```

FMAXV

Floating-point Maximum across Vector. This instruction compares all the vector elements in the source SIMD&FP register, and writes the largest of the values as a scalar to the destination SIMD&FP register. All the values in this instruction are floating-point values.

This instruction can generate a floating-point exception. Depending on the settings in FPCR, the exception results in either a flag being set in FPSR or a synchronous exception being generated. For more information, see Floating-point exception traps.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

It has encodings from 2 classes: Half-precision and Single-precision and double-precision

### Half-precision

(ARMv8.2)

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9  | 8  | 7  | 6  | 5  | 4  | 3  | 2  | 1  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 1  | 1  | 0  | 0  | 0  | 0  | 0  | 1  | 1  | 1  | 0  |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
|    | 0  | 1  | 1  | 1  | 1  | 0  | 0  | 1  | 1  | 0  | 0  | 0  | 0  | 1  | 1  | 1  | 1  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 1  | 1  | 0  | 0  | 0  | 0  | 0  | 1  | 1  | 0  | 0  | 0  | 0  | 0  | 1  | 1  | 0  | 0  | 0  | 0  | 1  | 1  |

#### Half-precision

FMAXV <V><d>, <Vn>.<T>

if !HaveFP16Ext() then UNDEFINED;

integer d = -1 then UnallocatedEncoding(1);

integer d = UInt(Rd);

integer n = UInt(Rn);

integer esize = 16;

integer datasize = if Q == '1' then 128 else 64;

integer elements = datasize DIV esize;

ReduceOp op = if o1 == '1' then ReduceOp_FMIN else ReduceOp_FMAX;

### Single-precision and double-precision

(ARMv8.2)

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9  | 8  | 7  | 6  | 5  | 4  | 3  | 2  | 1  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 1  | 1  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 1  | 1  | 1  | 0  |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
|    | 0  | 1  | 0  | 1  | 1  | 1  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 1  | 1  | 1  | 1  | 1  | 1  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  |

#### Single-precision and double-precision

FMAXV <V><d>, <Vn>.<T>

integer d = UInt(Rd);

integer n = UInt(Rn);

if sz:Q != '01' then UNDEFINED;

integer esize = 32 << if sz:Q != '01' then ReservedValue();

integer esize = 32 << UInt(sz);

integer datasize = if Q == '1' then 128 else 64;

integer elements = datasize DIV esize;

ReduceOp op = if o1 == '1' then ReduceOp_FMIN else ReduceOp_FMAX;
Assembler Symbols

For the half-precision variant: is the destination width specifier, H.
For the single-precision and double-precision variant: is the destination width specifier, encoded in “sz”:

<table>
<thead>
<tr>
<th>sz</th>
<th>&lt;V&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>S</td>
</tr>
<tr>
<td>1</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

<d>
Is the number of the SIMD&FP destination register, encoded in the "Rd" field.

<Vn>
Is the name of the SIMD&FP source register, encoded in the "Rn" field.

<T>
For the half-precision variant: is an arrangement specifier, encoded in “Q”:

<table>
<thead>
<tr>
<th>Q</th>
<th>&lt;T&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>4H</td>
</tr>
<tr>
<td>1</td>
<td>8H</td>
</tr>
</tbody>
</table>

For the single-precision and double-precision variant: is an arrangement specifier, encoded in “Q:sz”:

<table>
<thead>
<tr>
<th>Q</th>
<th>sz</th>
<th>&lt;T&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>x</td>
<td>RESERVED</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>4S</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

Operation

```
CheckFPAdvSIMDEnabled64();
bits(datasize) operand = V[n];
V[d] = Reduce(op, operand, esize);
```

Internal version only: isa v30.25 v27.01 v26.01, pseudocode v85-xml-00bec8 rc3-e35f; Build timestamp: 2018-09-13T13:2018-06-16T09:04:45

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**FMIN (vector)**

Floating-point minimum (vector). This instruction compares corresponding elements in the vectors in the two source SIMD&FP registers, places the smaller of each of the two floating-point values into a vector, and writes the vector to the destination SIMD&FP register.

This instruction can generate a floating-point exception. Depending on the settings in FPCR, the exception results in either a flag being set in FPSR, or a synchronous exception being generated. For more information, see **Floating-point exception traps**.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

It has encodings from 2 classes: **Half-precision** and **Single-precision and double-precision**

### Half-precision (ARMv8.2)

<table>
<thead>
<tr>
<th>31</th>
<th>30</th>
<th>29</th>
<th>28</th>
<th>27</th>
<th>26</th>
<th>25</th>
<th>24</th>
<th>23</th>
<th>22</th>
<th>21</th>
<th>20</th>
<th>19</th>
<th>18</th>
<th>17</th>
<th>16</th>
<th>15</th>
<th>14</th>
<th>13</th>
<th>12</th>
<th>11</th>
<th>10</th>
<th>9</th>
<th>8</th>
<th>7</th>
<th>6</th>
<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Q</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>Rm</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>Rn</td>
<td>0</td>
<td>Rd</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Half-precision**

```
FMIN <Vd>.<T>, <Vn>.<T>, <Vm>.<T>

if !HaveFP16Ext() then UNDEFINED;

integer d = -1 then UnallocatedEncoding(1);
integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rm);
integer esize = 16;
integer datasize = if Q == '1' then 128 else 64;
integer elements = datasize DIV esize;
boolean pair = (U == '1');
boolean minimum = (o1 == '1');
```

### Single-precision and double-precision

<table>
<thead>
<tr>
<th>31</th>
<th>30</th>
<th>29</th>
<th>28</th>
<th>27</th>
<th>26</th>
<th>25</th>
<th>24</th>
<th>23</th>
<th>22</th>
<th>21</th>
<th>20</th>
<th>19</th>
<th>18</th>
<th>17</th>
<th>16</th>
<th>15</th>
<th>14</th>
<th>13</th>
<th>12</th>
<th>11</th>
<th>10</th>
<th>9</th>
<th>8</th>
<th>7</th>
<th>6</th>
<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Q</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>sz</td>
<td>1</td>
<td>Rm</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>Rn</td>
<td>1</td>
<td>Rd</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Single-precision and double-precision**

```
FMIN <Vd>.<T>, <Vn>.<T>, <Vm>.<T>

integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rm);
if sz:Q == '10' then UNDEFINED;
integer esize = 32 << if sz:Q == '10' then ReservedValue();
integer esize = 32 << UInt(sz);
integer datasize = if Q == '1' then 128 else 64;
integer elements = datasize DIV esize;
boolean pair = (U == '1');
boolean minimum = (o1 == '1');
```
Assembler Symbols

<Vd>  Is the name of the SIMD&FP destination register, encoded in the "Rd" field.

<T>  For the half-precision variant: is an arrangement specifier, encoded in “Q”:

<table>
<thead>
<tr>
<th>Q</th>
<th>&lt;T&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>4H</td>
</tr>
<tr>
<td>1</td>
<td>8H</td>
</tr>
</tbody>
</table>

For the single-precision and double-precision variant: is an arrangement specifier, encoded in “sz:Q”:

<table>
<thead>
<tr>
<th>sz</th>
<th>Q</th>
<th>&lt;T&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>2S</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>4S</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>RESERVED</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>2D</td>
</tr>
</tbody>
</table>

<Vn>  Is the name of the first SIMD&FP source register, encoded in the "Rn" field.

<Vm>  Is the name of the second SIMD&FP source register, encoded in the "Rm" field.

Operation

```c
CheckFPAdvSIMDEnabled64();
bits(datasize) operand1 = V[n];
bits(datasize) operand2 = V[m];
bits(datasize) result;
bits(2*datasize) concat = operand2:operand1;
bits(esize) element1;
bits(esize) element2;
for e = 0 to elements-1
  if pair then
    element1 = Elem[concat, 2*e, esize];
    element2 = Elem[concat, (2*e)+1, esize];
  else
    element1 = Elem[operand1, e, esize];
    element2 = Elem[operand2, e, esize];
  if minimum then
    Elem[result, e, esize] = FPMin(element1, element2, FPCR);
  else
    Elem[result, e, esize] = FPMax(element1, element2, FPCR);
V[d] = result;
```

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FMIN (scalar)

Floating-point Minimum (scalar). This instruction compares the first and second source SIMD&FP register values, and writes the smaller of the two floating-point values to the destination SIMD&FP register.

This instruction can generate a floating-point exception. Depending on the settings in FPCR, the exception results in either a flag being set in FPSR, or a synchronous exception being generated. For more information, see Floating-point exception traps.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

|   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| 31| 30| 29| 28| 27| 26| 25| 24| 23| 22| 21| 20| 19| 18| 17| 16| 15| 14| 13| 12| 11| 10|  9|  8|  7|  6|  5|  4|  3|  2|  1|  0|
| 0 | 0 | 0 | 1 | 1 | 1 | 1 | 0 |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |

Half-precision (type == 11)
(ARMv8.2)

FMIN <Hd>, <Hn>, <Hm>

Single-precision (type == 00)

FMIN <Sd>, <Sn>, <Sm>

Double-precision (type == 01)

FMIN <Dd>, <Dn>, <Dm>

    integer d = Uint(Rd);
    integer n = Uint(Rn);
    integer m = Uint(Rm);

    integer datasize;
    case type of
      when '00' datasize = 32;
      when '01' datasize = 64;
      when '10' UNDEFINED;
      when '11' if when '10' UnallocatedEncoding() then
      datasize = 16;
      else UnallocatedEncoding() then
      datasize = 16;
      else UNDEFINED();
    FPMaxMinOp operation;
    case op of
      when '00' operation = FPMaxMinOp_MAX;
      when '01' operation = FPMaxMinOp_MIN;
      when '10' operation = FPMaxMinOp_MAXNUM;
      when '11' operation = FPMaxMinOp_MINNUM;

Assembler Symbols

<Dd> Is the 64-bit name of the SIMD&FP destination register, encoded in the "Rd" field.
<Sd> Is the 64-bit name of the first SIMD&FP source register, encoded in the "Rn" field.
<Dm> Is the 64-bit name of the second SIMD&FP source register, encoded in the "Rm" field.
<Hd> Is the 16-bit name of the SIMD&FP destination register, encoded in the "Rd" field.
Is the 16-bit name of the first SIMD&FP source register, encoded in the "Rn" field.

Is the 16-bit name of the second SIMD&FP source register, encoded in the "Rm" field.

Is the 32-bit name of the SIMD&FP destination register, encoded in the "Rd" field.

Is the 32-bit name of the first SIMD&FP source register, encoded in the "Rn" field.

Is the 32-bit name of the second SIMD&FP source register, encoded in the "Rm" field.

Operation

```c
CheckFPAdvSIMDEnabled64();
bits(datasize) result;
bits(datasize) operand1 = V[n];
bits(datasize) operand2 = V[m];

case operation of
  when FPMaxMinOp_MAX result = FPMax(operand1, operand2, FPCR);
  when FPMaxMinOp_MIN result = FPMin(operand1, operand2, FPCR);
  when FPMaxMinOp_MAXNUM result = FPMaxNum(operand1, operand2, FPCR);
  when FPMaxMinOp_MINNUM result = FPMinNum(operand1, operand2, FPCR);

V[d] = result;
```

Internal version only: isa v30.25,v29.05,AdvSIMD v27.01,v26.0,pseudocode v85-xml-00bet8_rc3v3532; Build timestamp: 2018-09-13T13:20:45

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FMNNM (vector)

Floating-point Minimum Number (vector). This instruction compares corresponding vector elements in the two source SIMD&FP registers, writes the smaller of the two floating-point values into a vector, and writes the vector to the destination SIMD&FP register. NaNs are handled according to the IEEE 754-2008 standard. If one vector element is numeric and the other is a quiet NaN, the result placed in the vector is the numerical value, otherwise the result is identical to FMIN (scalar). This instruction can generate a floating-point exception. Depending on the settings in FPCR, the exception results in either a flag being set in FPSR or a synchronous exception being generated. For more information, see Floating-point exception traps. Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

It has encodings from 2 classes: Half-precision and Single-precision and double-precision

Half-precision
(ARMv8.2)

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9  | 8  | 7  | 6  | 5  | 4  | 3  | 2  | 1  | 0  |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0  | Q  | 0  | 0  | 1  | 1  | 1  | 0  | 1  | 1  | 0  | Rm | 0  | 0  | 0  | 0  | 0  | 1  | Rn | Rd |
U   a

Half-precision

FMNNM <Vd>.<T>, <Vn>.<T>, <Vm>.<T>

if !HaveFP16Ext() then UNDEFINED;
integer d = 1l then UnallocatedEncoding();
integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rm);
integer esize = 16;
integer datasize = if Q == '1' then 128 else 64;
integer elements = datasize DIV esize;

boolean pair = (U == '1');
boolean minimum = (a == '1');

Single-precision and double-precision

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9  | 8  | 7  | 6  | 5  | 4  | 3  | 2  | 1  | 0  |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0  | Q  | 0  | 0  | 1  | 1  | 1  | 0  | 1  | sz | Rm | 1  | 1  | 0  | 0  | 0  | 1  | Rn | Rd |
| U   o1 |

Single-precision and double-precision

FMNNM <Vd>.<T>, <Vn>.<T>, <Vm>.<T>

integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rm);
if sz:Q == '10' then UNDEFINED;
integer esize = 32 << if sz:Q == '10' then ReservedValue();
integer esize = 32 << UInt(sz);
integer datasize = if Q == '1' then 128 else 64;
integer elements = datasize DIV esize;

boolean pair = (U == '1');
boolean minimum = (o1 == '1');
Assembler Symbols

<VD>
Is the name of the SIMD&FP destination register, encoded in the "Rd" field.

<T>
For the half-precision variant: is an arrangement specifier, encoded in "Q":

\[
\begin{array}{c|c}
Q & T \\
0 & 4H \\
1 & 8H \\
\end{array}
\]

For the single-precision and double-precision variant: is an arrangement specifier, encoded in "sz:Q":

\[
\begin{array}{c|c|c}
sz & Q & T \\
0 & 0 & 2S \\
0 & 1 & 4S \\
1 & 0 & RESERVED \\
1 & 1 & 2D \\
\end{array}
\]

<Vn>
Is the name of the first SIMD&FP source register, encoded in the "Rn" field.

<Vm>
Is the name of the second SIMD&FP source register, encoded in the "Rm" field.

Operation

CheckFPAdvSIMDEnabled64();
bits(datasize) operand1 = V[n];
bits(datasize) operand2 = V[m];
bits(datasize) result;
bits(2*datasize) concat = operand2:operand1;
bits(esize) element1;
bits(esize) element2;
for e = 0 to elements-1
  if pair then
    element1 = Elem[concat, 2*e, esize];
    element2 = Elem[concat, (2*e)+1, esize];
  else
    element1 = Elem[operand1, e, esize];
    element2 = Elem[operand2, e, esize];
  if minimum then
    Elem[result, e, esize] = FPMinNum(element1, element2, FPCR);
  else
    Elem[result, e, esize] = FPMaxNum(element1, element2, FPCR);
V[d] = result;
FMINNM (scalar)

Floating-point Minimum Number (scalar). This instruction compares the first and second source SIMD&FP register values, and writes the smaller of the two floating-point values to the destination SIMD&FP register.

NaNs are handled according to the IEEE 754-2008 standard. If one vector element is numeric and the other is a quiet NaN, the result that is placed in the vector is the numerical value, otherwise the result is identical to FMIN (scalar).

This instruction can generate a floating-point exception. Depending on the settings in FPCR, the exception results in either a flag being set in FPSR or a synchronous exception being generated. For more information, see Floating-point exception traps.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

Half-precision (type == 11) (ARMv8.2)

FMINNM <Hd>, <Hn>, <Hm>

Single-precision (type == 00)

FMINNM <Sd>, <Sn>, <Sm>

Double-precision (type == 01)

FMINNM <Dd>, <Dn>, <Dm>

Assembler Symbols

<Dd> Is the 64-bit name of the SIMD&FP destination register, encoded in the "Rd" field.

<Dn> Is the 64-bit name of the first SIMD&FP source register, encoded in the "Rn" field.
Is the 64-bit name of the second SIMD&FP source register, encoded in the "Rm" field.

Is the 16-bit name of the SIMD&FP destination register, encoded in the "Rd" field.

Is the 16-bit name of the first SIMD&FP source register, encoded in the "Rn" field.

Is the 16-bit name of the second SIMD&FP source register, encoded in the "Rm" field.

Is the 32-bit name of the SIMD&FP destination register, encoded in the "Rd" field.

Is the 32-bit name of the first SIMD&FP source register, encoded in the "Rn" field.

Is the 32-bit name of the second SIMD&FP source register, encoded in the "Rm" field.

**Operation**

```c
CheckFPAdvSIMDEnabled64();
bits(datasize) result;
bits(datasize) operand1 = V[n];
bits(datasize) operand2 = V[m];

case operation of
  when FPMaxMinOp_MAX result = FPMax(operand1, operand2, FPCR);
  when FPMaxMinOp_MIN result = FPMin(operand1, operand2, FPCR);
  when FPMaxMinOp_MAXNUM result = FPMaxNum(operand1, operand2, FPCR);
  when FPMaxMinOp_MINNUM result = FPMinNum(operand1, operand2, FPCR);
V[d] = result;
```

Internal version only: isa v30.25, AdvSIMD v27.01, pseudocode v85-xml-00bet8_rc3333 ; Build timestamp: 2018-09-13T13:2018-06-16T09:45

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FMNNMP (scalar)

Floating-point Minimum Number of Pair of elements (scalar). This instruction compares two vector elements in the source SIMD&FP register and writes the smallest of the floating-point values as a scalar to the destination SIMD&FP register. This instruction can generate a floating-point exception. Depending on the settings in FPCR, the exception results in either a flag being set in FPSR or a synchronous exception being generated. For more information, see Floating-point exception traps. Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

It has encodings from 2 classes: Half-precision and Single-precision and double-precision

**Half-precision**

(ARMv8.2)

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9  | 8  | 7  | 6  | 5  | 4  | 3  | 2  | 1  | 0  |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0  | 1  | 0  | 1  | 1  | 1  | 1  | 1  | 1  | 0  | 1  | 0  | 1  | 0  | 0  | 0  | 0  | 0  | 1  | 1  | 0  | 0  | 1  | 0  | |   |

Rn Rd

**o1 sz**

Half-precision

FMNNMP <V><d>, <Vn>.<T>

if !HaveFP16Ext() then UNDEFINED;

integer d = 1 then UnallocatedEncoding(1);
integer d = UInt(Rd);
integer n = UInt(Rn);

integer esize = 16;
if sz == '1' then ReservedValue(Rn);

integer esize = 16;
if sz == '1' then UNDEFINED;

datasize = esize * 2;
elements = 2;

ReduceOp op = if o1 == '1' then ReduceOp_FMINNUM else ReduceOp_FMAXNUM;

Single-precision and double-precision

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9  | 8  | 7  | 6  | 5  | 4  | 3  | 2  | 1  | 0  |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0  | 1  | 1  | 1  | 1  | 1  | 0  | 1  | sz| 1  | 1  | 0  | 0  | 0  | 0  | 0  | 0  | 1  | 1  | 0  | 0  | 1  | 0  | |   |

Rn Rd

Single-precision and double-precision

FMNNMP <V><d>, <Vn>.<T>

integer d = UInt(Rd);
integer n = UInt(Rn);

integer esize = 32 << UInt(sz);
integer datasize = esize * 2;
elements = 2;

ReduceOp op = if o1 == '1' then ReduceOp_FMINNUM else ReduceOp_FMAXNUM;
Assembler Symbols

For the half-precision variant: is the destination width specifier, encoded in “sz”:

<table>
<thead>
<tr>
<th>sz</th>
<th>&lt;V&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>H</td>
</tr>
<tr>
<td>1</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

For the single-precision and double-precision variant: is the destination width specifier, encoded in “sz”:

<table>
<thead>
<tr>
<th>sz</th>
<th>&lt;V&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>S</td>
</tr>
<tr>
<td>1</td>
<td>D</td>
</tr>
</tbody>
</table>

<d> Is the number of the SIMD&FP destination register, encoded in the "Rd" field.

<Vn> Is the name of the SIMD&FP source register, encoded in the "Rn" field.

<T> For the half-precision variant: is the source arrangement specifier, encoded in “sz”:

<table>
<thead>
<tr>
<th>sz</th>
<th>&lt;T&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>2H</td>
</tr>
<tr>
<td>1</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

For the single-precision and double-precision variant: is the source arrangement specifier, encoded in “sz”:

<table>
<thead>
<tr>
<th>sz</th>
<th>&lt;T&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>2S</td>
</tr>
<tr>
<td>1</td>
<td>2D</td>
</tr>
</tbody>
</table>

Operation

```c
CheckFPAdvSIMDEnabled64();
bits(datasize) operand = V[n];
V[d] = Reduce(op, operand, esize);
```


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FMINNMP (vector)

Floating-point Minimum Number Pairwise (vector). This instruction creates a vector by concatenating the vector elements of the first source SIMD&FP register after the vector elements of the second source SIMD&FP register, reads each pair of adjacent vector elements in the two source SIMD&FP registers, writes the smallest of each pair of floating-point values into a vector, and writes the vector to the destination SIMD&FP register. All the values in this instruction are floating-point values.

NaNs are handled according to the IEEE 754-2008 standard. If one vector element is numeric and the other is a quiet NaN, the result is the numerical value, otherwise the result is identical to FMIN (scalar).

This instruction can generate a floating-point exception. Depending on the settings in FPCR, the exception results in either a flag being set in FPSR or a synchronous exception being generated. For more information, see Floating-point exception traps.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

It has encodings from 2 classes: Half-precision and Single-precision and double-precision

Half-precision

(ARMv8.2)

Single-precision and double-precision

Single-precision and double-precision
Assembler Symbols

\(<V_d>\)
Is the name of the SIMD&FP destination register, encoded in the "Rd" field.

\(<T>\)
For the half-precision variant: is an arrangement specifier, encoded in "Q":

\[
\begin{array}{c|c}
Q & <T> \\
0 & 4H \\
1 & 8H \\
\end{array}
\]

For the single-precision and double-precision variant: is an arrangement specifier, encoded in "sz:Q":

\[
\begin{array}{c|c|c|c}
sz & Q & <T> \\
0 & 0 & 2S \\
0 & 1 & 4S \\
1 & 0 & RESERVED \\
1 & 1 & 2D \\
\end{array}
\]

\(<V_n>\)
Is the name of the first SIMD&FP source register, encoded in the "Rn" field.

\(<V_m>\)
Is the name of the second SIMD&FP source register, encoded in the "Rm" field.

Operation

```c
CheckFPAdvSIMDEnabled64();
bits(datasize) operand1 = V[n];
bits(datasize) operand2 = V[m];
bits(datasize) result;
bits(2*datasize) concat = operand2:operand1;
bits(esize) element1;
bits(esize) element2;
for e = 0 to elements-1
    if pair then
        element1 = Elem[concat, 2*e, esize];
        element2 = Elem[concat, (2*e)+1, esize];
    else
        element1 = Elem[operand1, e, esize];
        element2 = Elem[operand2, e, esize];
    
    if minimum then
        Elem[result, e, esize] = FPMinNum(element1, element2, FPCR);
    else
        Elem[result, e, esize] = FPMaxNum(element1, element2, FPCR);
V[d] = result;
```

Internal version only: isa v30.25 v29.05, AdvSIMD v27.01 v26.0, pseudocode v85-xml-00bet8_rc3 v35.3; Build timestamp: 2018-09-13T13:45:45 2018-06-16T09:04:45

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FMINNMV

Floating-point Minimum Number across Vector. This instruction compares all the vector elements in the source SIMD&FP register, and writes the smallest of the values as a scalar to the destination SIMD&FP register. All the values in this instruction are floating-point values. NaNs are handled according to the IEEE 754-2008 standard. If one vector element is numeric and the other is a quiet NaN, the result of the comparison is the numerical value, otherwise the result is identical to \textit{FMIN (scalar)}.

This instruction can generate a floating-point exception. Depending on the settings in \textit{FPCR}, the exception results in either a flag being set in \textit{FPSR} or a synchronous exception being generated. For more information, see \textit{Floating-point exception traps}.

Depending on the settings in the \textit{CPACR_EL1}, \textit{CPTR_EL2}, and \textit{CPTR_EL3} registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

It has encodings from 2 classes: \textit{Half-precision} and \textit{Single-precision and double-precision}

### Half-precision (ARMv8.2)

<table>
<thead>
<tr>
<th>31</th>
<th>30</th>
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<th>7</th>
<th>6</th>
<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Q</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
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</tbody>
</table>

**Half-precision**

\[
\text{FMINNMV } \langle V \rangle < d >, < Vn >. < T >
\]

\[
\text{if } ! \text{HaveFP16Ext()} \text{ then UNDEFINED;}
\]

\[
\text{integer } d = i \text{ then UnallocatedEncoding()};
\]

\[
\text{integer } d = \text{UInt}(Rd);
\]

\[
\text{integer } n = \text{UInt}(Rn);
\]

\[
\text{integer esize} = 16;
\]

\[
\text{integer datasize} = \text{if Q} = \text{'l'} \text{ then 128 else 64};
\]

\[
\text{integer elements} = \text{datasize DIV esize} ;
\]

\[
\text{ReduceOp } op = \text{if o1} = \text{'l'} \text{ then ReduceOp_FMINNUM else ReduceOp_FMAXNUM};
\]

### Single-precision and double-precision

<table>
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<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Q</td>
<td>1</td>
<td>0</td>
<td>1</td>
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<td>1</td>
<td>0</td>
<td>1</td>
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<td>o1</td>
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</tr>
</tbody>
</table>

**Single-precision and double-precision**

\[
\text{FMINNMV } \langle V \rangle < d >, < Vn >. < T >
\]

\[
\text{integer } d = \text{UInt}(Rd);
\]

\[
\text{integer } n = \text{UInt}(Rn);
\]

\[
\text{if sz:Q} != \text{'01'} \text{ then UNDEFINED; } // .4S only
\]

\[
\text{integer esize} = 32 \text{ if sz:Q} \text{ is '01' then ReservedValue(); } // .4S only
\]

\[
\text{integer esize} = 32 \text{ if sz:Q} \text{ is '01' then ReservedValue(); } // .4S only
\]

\[
\text{integer esize} = 32 \text{ if sz:Q} \text{ is '01' then ReservedValue(); } // .4S only
\]

\[
\text{integer datasize} = \text{if Q} = \text{'l'} \text{ then 128 else 64};
\]

\[
\text{integer elements} = \text{datasize DIV esize} ;
\]

\[
\text{ReduceOp } op = \text{if o1} = \text{'l'} \text{ then ReduceOp_FMINNUM else ReduceOp_FMAXNUM};
\]
Assembler Symbols

<V> For the half-precision variant: is the destination width specifier, H.
    For the single-precision and double-precision variant: is the destination width specifier, encoded in “sz”:

<table>
<thead>
<tr>
<th>sz</th>
<th>&lt;V&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>S</td>
</tr>
<tr>
<td>1</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

<d> Is the number of the SIMD&FP destination register, encoded in the "Rd" field.

<Vn> Is the name of the SIMD&FP source register, encoded in the "Rn" field.

<T> For the half-precision variant: is an arrangement specifier, encoded in “Q”:

<table>
<thead>
<tr>
<th>Q</th>
<th>&lt;T&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>4H</td>
</tr>
<tr>
<td>1</td>
<td>8H</td>
</tr>
</tbody>
</table>

For the single-precision and double-precision variant: is an arrangement specifier, encoded in “Q:sz”:

<table>
<thead>
<tr>
<th>Q</th>
<th>sz</th>
<th>&lt;T&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>x</td>
<td>RESERVED</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>4S</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

Operation

```c
CheckFPAdvSIMDEnabled64();
bits(datasize) operand = V[n];
V[d] = Reduce(op, operand, esize);
```

Internal version only: isa v30.25, AdvSIMD v27.01, pseudocode v85-xml-00bet8_rc3-v35; Build timestamp: 2018-09-13T13:20:45

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FMINP (scalar)

Floating-point Minimum of Pair of elements (scalar). This instruction compares two vector elements in the source SIMD&FP register and writes the smallest of the floating-point values as a scalar to the destination SIMD&FP register.

This instruction can generate a floating-point exception. Depending on the settings in **FPCR**, the exception results in either a flag being set in **FPSR** or a synchronous exception being generated. For more information, see **Floating-point exception traps**.

Depending on the settings in the **CPACR_EL1**, **CPTR_EL2**, and **CPTR_EL3** registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

It has encodings from 2 classes: **Half-precision** and **Single-precision and double-precision**

### Half-precision

**(ARMv8.2)**

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9  | 8  | 7  | 6  | 5  | 4  | 3  | 2  | 1  | 0  |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0  | 1  | 0  | 1  | 1  | 1  | 1  | 0  | 1  | 0  | 1  | 0  | 0  | 0  | 0  | 0  | 1  | 1  | 1  | 1  | 1  | 0  | Rn | Rd |

**o1** sz

#### FMNP <V><d>, <Vn>.

if !HaveFP16Ext() then UNDEFINED;

integer d = 1; then UnallocatedEncoding(1);

integer d = UInt(Rd);

integer n = UInt(Rn);

integer esize = 16;
if sz == '1' then ReservedValue(Rn);

integer esize = 16;
if sz == '1' then UNDEFINED;

integer datasize = esize * 2;
integer elements = 2;

ReduceOp op = if o1 == '1' then ReduceOp_FMIN else ReduceOp_FMAX;

### Single-precision and double-precision

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9  | 8  | 7  | 6  | 5  | 4  | 3  | 2  | 1  | 0  |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0  | 1  | 1  | 1  | 1  | 1  | 0  | 1  | sz| 1  | 1  | 0  | 0  | 0  | 0  | 0  | 1  | 1  | 1  | 1  | 1  | 0  | Rn | Rd |

**o1**

#### FMNP <V><d>, <Vn>.

integer d = UInt(Rd);

integer n = UInt(Rn);

integer esize = 32 << UInt(sz);

integer datasize = esize * 2;

integer elements = 2;

ReduceOp op = if o1 == '1' then ReduceOp_FMIN else ReduceOp_FMAX;
Assembler Symbols

For the half-precision variant: is the destination width specifier, encoded in “sz”:

<table>
<thead>
<tr>
<th>sz</th>
<th>V</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>H</td>
</tr>
<tr>
<td>1</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

For the single-precision and double-precision variant: is the destination width specifier, encoded in “sz”:

<table>
<thead>
<tr>
<th>sz</th>
<th>V</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>S</td>
</tr>
<tr>
<td>1</td>
<td>D</td>
</tr>
</tbody>
</table>

<d>
Is the number of the SIMD&FP destination register, encoded in the "Rd" field.

<Vn>
Is the name of the SIMD&FP source register, encoded in the "Rn" field.

<T>
For the half-precision variant: is the source arrangement specifier, encoded in “sz”:

<table>
<thead>
<tr>
<th>sz</th>
<th>T</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>2H</td>
</tr>
<tr>
<td>1</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

For the single-precision and double-precision variant: is the source arrangement specifier, encoded in “sz”:

<table>
<thead>
<tr>
<th>sz</th>
<th>T</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>2S</td>
</tr>
<tr>
<td>1</td>
<td>2D</td>
</tr>
</tbody>
</table>

Operation

```
CheckFPAdvSIMDEnabled64();
bits(datasize) operand = V[n];
V[d] = Reduce(op, operand, esize);
```

Internal version only: isa v30.25 v29.05, AdvSIMD v27.01 v26.0, pseudocode v85-xml-00bet8_rc3i385 ; Build timestamp: 2018-09-13T13:04:45 2018-06-16T09:45:45

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### FMINP (vector)

Floating-point Minimum Pairwise (vector). This instruction creates a vector by concatenating the vector elements of the first source SIMD&FP register after the vector elements of the second source SIMD&FP register, reads each pair of adjacent vector elements from the concatenated vector, writes the smaller of each pair of values into a vector, and writes the vector to the destination SIMD&FP register. All the values in this instruction are floating-point values.

This instruction can generate a floating-point exception. Depending on the settings in **FPCR**, the exception results in either a flag being set in **FPSR** or a synchronous exception being generated. For more information, see [Floating-point exception traps](#). Depending on the settings in the **CPACR_EL1**, **CPTR_EL2**, and **CPTR_EL3** registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

It has encodings from 2 classes: **Half-precision** and **Single-precision and double-precision**

#### Half-precision

**(ARMv8.2)**

<table>
<thead>
<tr>
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<th>31</th>
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<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
</tr>
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<tr>
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<td>U</td>
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<td></td>
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<td>o1</td>
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<td></td>
</tr>
</tbody>
</table>

**Half-precision**

FMINP \(<Vd>\;<T>, \;<Vn>\;<T>, \;<Vm>\;<T>\)

if !HaveFP16Ext() then UNDEFINED;

integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rm);
integer esize = 16;
integer datasize = if Q == '1' then 128 else 64;
integer elements = datasize DIV esize;

boolean pair = (U == '1');
boolean minimum = (o1 == '1');

#### Single-precision and double-precision

<table>
<thead>
<tr>
<th></th>
<th>31</th>
<th>30</th>
<th>29</th>
<th>28</th>
<th>27</th>
<th>26</th>
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<th>6</th>
<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
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<td>1</td>
<td>Rm</td>
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<td>1</td>
<td>1</td>
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<td>0</td>
<td>1</td>
<td>Rd</td>
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<td></td>
</tr>
<tr>
<td>U</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td>o1</td>
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<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Single-precision and double-precision**

FMINP \(<Vd>\;<T>, \;<Vn>\;<T>, \;<Vm>\;<T>\)

integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rm);
if sz:Q == '10' then UNDEFINED;
integer esize = 32 << if sz:Q == '10' then ReservedValue();
integer esize = 32 << UInt(sz);
integer datasize = if Q == '1' then 128 else 64;
integer elements = datasize DIV esize;

boolean pair = (U == '1');
boolean minimum = (o1 == '1');
Assembler Symbols

<Vd> Is the name of the SIMD&FP destination register, encoded in the "Rd" field.

<T> For the half-precision variant: is an arrangement specifier, encoded in "Q":

<table>
<thead>
<tr>
<th>Q</th>
<th>&lt;T&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>4H</td>
</tr>
<tr>
<td>1</td>
<td>8H</td>
</tr>
</tbody>
</table>

For the single-precision and double-precision variant: is an arrangement specifier, encoded in "sz:Q":

<table>
<thead>
<tr>
<th>sz</th>
<th>Q</th>
<th>&lt;T&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>2S</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>4S</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>RESERVED</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>2D</td>
</tr>
</tbody>
</table>

<Vn> Is the name of the first SIMD&FP source register, encoded in the "Rn" field.

<Vm> Is the name of the second SIMD&FP source register, encoded in the "Rm" field.

Operation

```
CheckFPAdvSIMDEnabled64();
bits(datasize) operand1 = V[n];
bits(datasize) operand2 = V[m];
bits(datasize) result;
bits(2*datasize) concat = operand2:operand1;
bits(esize) element1;
bits(esize) element2;
for e = 0 to elements-1
    if pair then
        element1 = Elem[concat, 2*e, esize];
        element2 = Elem[concat, (2*e)+1, esize];
    else
        element1 = Elem[operand1, e, esize];
        element2 = Elem[operand2, e, esize];
    if minimum then
        Elem[result, e, esize] = FPMin(element1, element2, FPCR);
    else
        Elem[result, e, esize] = FPMax(element1, element2, FPCR);
V[d] = result;
```

Internal version only: isa v30.25 v30.25, AdvSIMD v27.01 v27.01, pseudocode s85-xml-00bet8_rc3525c; Build timestamp: 2018-09-13T13:20 2018-06-16T04:45

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Floating-point Minimum across Vector. This instruction compares all the vector elements in the source SIMD&FP register, and writes the smallest of the values as a scalar to the destination SIMD&FP register. All the values in this instruction are floating-point values.

This instruction can generate a floating-point exception. Depending on the settings in FPCR, the exception results in either a flag being set in FPSR or a synchronous exception being generated. For more information, see Floating-point exception traps.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

It has encodings from 2 classes: Half-precision and Single-precision and double-precision

**Half-precision**

(ARMv8.2)

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0  | Q  | 0  | 0  | 1  | 1  | 1  | 0  | 1  | 0  | 0  | 0  | 0  | 1  | 1  | 1  | 1  | 1  | 0  | Rn | Rd |

01

**Single-precision and double-precision**

FMINV <V><d>, <Vn>.<T>

integer d = UInt(Rd);
integer n = UInt(Rn);
if sz:Q != '01' then UNDEFINED;
integer esize = 32 << if sz:Q != '01' then ReservedValue();
integer esize = 32 << UInt(sz);
integer datatasize = if Q == '1' then 128 else 64;
integer elements = datatasize DIV esize;
ReduceOp op = if o1 == '1' then ReduceOp_FMIN else ReduceOp_FMAX;
Assembler Symbols

For the half-precision variant: is the destination width specifier, H.

<table>
<thead>
<tr>
<th>sz</th>
<th>&lt;V&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>S</td>
</tr>
<tr>
<td>1</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

For the single-precision and double-precision variant: is the destination width specifier, encoded in “sz”:

For the half-precision variant: is the number of the SIMD&FP destination register, encoded in the "Rd" field.

For the single-precision and double-precision variant: is the name of the SIMD&FP source register, encoded in the "Rn" field.

For the half-precision variant: is an arrangement specifier, encoded in “Q”:

<table>
<thead>
<tr>
<th>Q</th>
<th>&lt;T&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>4H</td>
</tr>
<tr>
<td>1</td>
<td>8H</td>
</tr>
</tbody>
</table>

For the single-precision and double-precision variant: is an arrangement specifier, encoded in “Q:sz”:

<table>
<thead>
<tr>
<th>Q</th>
<th>sz</th>
<th>&lt;T&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>x</td>
<td>RESERVED</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>4S</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

Operation

```c
CheckFPAdvSIMDEnabled64();
bits(datasize) operand = V[n];
V[d] = Reduce(op, operand, esize);
```

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FMLA (by element)

Floating-point fused Multiply-Add to accumulator (by element). This instruction multiplies the vector elements in the first source SIMD&FP register by the specified value in the second source SIMD&FP register, and accumulates the results in the vector elements of the destination SIMD&FP register. All the values in this instruction are floating-point values.

This instruction can generate a floating-point exception. Depending on the settings in FPCR, the exception results in either a flag being set in FPSR or a synchronous exception being generated. For more information, see Floating-point exception traps.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

It has encodings from 4 classes: Scalar, half-precision, Scalar, single-precision and double-precision, Vector, half-precision and Vector, single-precision and double-precision

Scalar, half-precision
(ARMv8.2)

```
31   30   29   28   27   26   25   24   23   22   21   20   19   18   17   16   15   14   13   12   11   10   9    8    7    6    5    4    3    2    1    0
 0  1  1  1  1  1  1  0  0  L  M  Rm  0  0  0  1  H  0  Rn  Rd
```
o2

Scalar, half-precision

```
FMLA <Hd>, <Hn>, <Vm>.H[<index>]

if !HaveFP16Ext() then UNDEFINED;
integer idxdsize = if H == '1' then 128 else 64;
integer index;
index = if then UnallocatedEncoding();
integer idxdsize = if H == '1' then 128 else 64;
integer index;
index = Uint(H:L:M);

integer d = Uint(Rd);
integer n = Uint(Rn);
integer m = Uint(Rm);

integer esize = 16;
integer datasize = esize;
integer elements = 1;
boolean sub_op = (o2 == '1');
```

Scalar, single-precision and double-precision

```
31   30   29   28   27   26   25   24   23   22   21   20   19   18   17   16   15   14   13   12   11   10   9    8    7    6    5    4    3    2    1    0
 0  1  1  1  1  1  1  1  sz  L  M  Rm  0  0  0  1  H  0  Rn  Rd
```
o2

FMLA (by element)
Scalar, single-precision and double-precision

FMLA \langle V\rangle_{\langle d \rangle}, \langle V\rangle_{\langle n \rangle}, \langle Vm\rangle_{\langle Ts \rangle}[\langle \text{index} \rangle]

```c
integer idxdsize = if H == '1' then 128 else 64;
integer index;
bit Rmhi = M;
case sz:L of
  when '0x' index = UInt(H:L);
  when '10' index = UInt(H);
  when '11' UNDEFINED;
```

```c
integer d = when '11' UnallocatedEncoding();
integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rmhi:Rm);
```

```c
integer esize = 32 << UInt(sz);
integer datasize = esize;
integer elements = 1;
boolean sub_op = (o2 == '1');
```

Vector, half-precision
(ARMv8.2)

```
<table>
<thead>
<tr>
<th>31</th>
<th>30</th>
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<th>6</th>
<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Q</td>
<td>0</td>
<td>0</td>
<td>1</td>
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<td>L</td>
<td>M</td>
<td>Rm</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>H</td>
<td>0</td>
<td>Rn</td>
<td>Rm</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
```

o2

Vector, half-precision

FMLA \langle Vd\rangle_{\langle T \rangle}, \langle Vn\rangle_{\langle T \rangle}, \langle Vm\rangle.H[\langle \text{index} \rangle]

```
if !HaveFP16Ext() then UNDEFINED;
```

```c
integer idxdsize = if H == '1' then 128 else 64;
integer index;
index = 0 then UnallocatedEncoding();
```

```c
integer idxdsize = if H == '1' then 128 else 64;
integer index;
index = UInt(H:L:M);
```

```c
integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rm);
```

```c
integer esize = 16;
integer datasize = if Q == '1' then 128 else 64;
integer elements = datasize DIV esize;
boolean sub_op = (o2 == '1');
```

Vector, single-precision and double-precision

```
<table>
<thead>
<tr>
<th>31</th>
<th>30</th>
<th>29</th>
<th>28</th>
<th>27</th>
<th>26</th>
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<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Q</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>sz</td>
<td>L</td>
<td>M</td>
<td>Rm</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>H</td>
<td>0</td>
<td>Rn</td>
<td>Rm</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
```

o2
Vector, single-precision and double-precision

FMLA <Vd>,<T>, <Vn>,<T>, <Vm>,<Ts>[<index>]

```plaintext
integer idxdsize = if H == '1' then 128 else 64;
integer index;
bit Rmhi = M;
case sz:L of
  when '0x' index = UInt(H:L);
  when '10' index = UInt(H);
  when '11' UNDEFINED;

integer d = when '11' UnallocatedEncoding(A);
integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rmhi:Rmi);
if sz:Q == '10' then ReservedValue(Rmhi:Rm);
if sz:Q == '10' then UNDEFINED;

integer esize = 32 << UInt(sz);
integer datasize = if Q == '1' then 128 else 64;
integer elements = datasize DIV esize;
boolean sub_op = (o2 == '1');
```

Assembler Symbols

- `<Hd>`: Is the 16-bit name of the SIMD&FP destination register, encoded in the "Rd" field.
- `<Hn>`: Is the 16-bit name of the first SIMD&FP source register, encoded in the "Rn" field.
- `<V>`: Is a width specifier, encoded in "sz":
  
<table>
<thead>
<tr>
<th>sz</th>
<th>&lt;V&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>S</td>
</tr>
<tr>
<td>1</td>
<td>D</td>
</tr>
</tbody>
</table>

- `<d>`: Is the number of the SIMD&FP destination register, encoded in the "Rd" field.
- `<n>`: Is the number of the first SIMD&FP source register, encoded in the "Rn" field.
- `<Vd>`: Is the name of the SIMD&FP destination register, encoded in the "Rd" field.
- `<T>`: For the vector, half-precision variant: is an arrangement specifier, encoded in “Q”:

<table>
<thead>
<tr>
<th>Q</th>
<th>&lt;T&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>4H</td>
</tr>
<tr>
<td>1</td>
<td>8H</td>
</tr>
</tbody>
</table>

For the vector, single-precision and double-precision variant: is an arrangement specifier, encoded in “Q:sz”:

<table>
<thead>
<tr>
<th>Q</th>
<th>sz</th>
<th>&lt;T&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>2S</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>RESERVED</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>4S</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>2D</td>
</tr>
</tbody>
</table>

- `<Vn>`: Is the name of the first SIMD&FP source register, encoded in the "Rn" field.
- `<Vm>`: For the half-precision variant: is the name of the second SIMD&FP source register, in the range V0 to V15, encoded in the "Rm" field.
  
  For the single-precision and double-precision variant: is the name of the second SIMD&FP source register, encoded in the "M:Rm" fields.

- `<Ts>`: Is an element size specifier, encoded in “sz”:

<table>
<thead>
<tr>
<th>sz</th>
<th>&lt;Ts&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>S</td>
</tr>
<tr>
<td>1</td>
<td>D</td>
</tr>
</tbody>
</table>

- `<index>`: For the half-precision variant: is the element index, in the range 0 to 7, encoded in the "H:L:M" fields.
For the single-precision and double-precision variant: is the element index, encoded in “sz:L:H”:

<table>
<thead>
<tr>
<th>sz</th>
<th>L</th>
<th>&lt;index&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>x</td>
<td>H:L</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>H</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

**Operation**

```c
CheckFPAdvSIMDEnabled64();

bits(datasize) operand1 = V[n];
bits(idxdsize) operand2 = V[m];
bits(datasize) operand3 = V[d];
bits(datasize) result;
bits(esize) element1;
bits(esize) element2 = Elem[operand2, index, esize];

for e = 0 to elements-1
    element1 = Elem[operand1, e, esize];
    if sub_op then element1 = FPNeg(element1);
    Elem[result, e, esize] = FPMulAdd(Elem[operand3, e, esize], element1, element2, FPCR);
V[d] = result;
```

Internal version only: isa v30.25, AdvSIMD v27.01, pseudocode v85-xml-00beta_rc3; Build timestamp: 2018-09-13T13:2018-06-16T09:45:45

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FMLA (vector)

Floating-point fused Multiply-Add to accumulator (vector). This instruction multiplies corresponding floating-point values in the vectors in the two source SIMD&FP registers, adds the product to the corresponding vector element of the destination SIMD&FP register, and writes the result to the destination SIMD&FP register.

A floating-point exception can be generated by this instruction. Depending on the settings in FPCR, the exception results in either a flag being set in FPSR, or a synchronous exception being generated. For more information, see Floating-point exception traps.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

It has encodings from 2 classes: Half-precision and Single-precision and double-precision

Half-precision

(ARMv8.2)

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<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
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<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
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<td>0</td>
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<td>Rn</td>
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</tbody>
</table>

Half-precision

FMLA <Vd>.<T>, <Vn>.<T>, <Vm>.<T>

if !HaveFP16Ext() then UNDEFINED;
integer d = 1 then UnallocatedEncoding();
integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rm);
integer esize = 16;
integer datasize = if Q == '1' then 128 else 64;
integer elements = datasize DIV esize;

boolean sub_op = (a == '1');

Single-precision and double-precision

<table>
<thead>
<tr>
<th>31</th>
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<th>25</th>
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<th>6</th>
<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Q</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>sz</td>
<td>1</td>
<td>Rm</td>
<td>1</td>
<td>1</td>
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<td>0</td>
<td>1</td>
<td>1</td>
<td>Rn</td>
<td>1</td>
<td>Rd</td>
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<td></td>
</tr>
</tbody>
</table>

Single-precision and double-precision

FMLA <Vd>.<T>, <Vn>.<T>, <Vm>.<T>

integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rm);
if sz:Q == '10' then UNDEFINED;
integer esize = 32 << if sz:Q == '10' then ReservedValue();
integer esize = 32 << UInt(sz);
integer datasize = if Q == '1' then 128 else 64;
integer elements = datasize DIV esize;

boolean sub_op = (op == '1');

Assembler Symbols

<Vd> Is the name of the SIMD&FP destination register, encoded in the "Rd" field.
For the half-precision variant: is an arrangement specifier, encoded in “Q”:

```
<table>
<thead>
<tr>
<th>Q</th>
<th>&lt;T&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>4H</td>
</tr>
<tr>
<td>1</td>
<td>8H</td>
</tr>
</tbody>
</table>
```

For the single-precision and double-precision variant: is an arrangement specifier, encoded in “sz:Q”:

```
<table>
<thead>
<tr>
<th>sz</th>
<th>Q</th>
<th>&lt;T&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>2S</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>4S</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>RESERVED</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>2D</td>
</tr>
</tbody>
</table>
```

<Vn> Is the name of the first SIMD&FP source register, encoded in the "Rn" field.

<Vm> Is the name of the second SIMD&FP source register, encoded in the "Rm" field.

Operation

```c
CheckFPAdvSIMDEnabled64();
bits(datasize) operand1 = V[n];
bits(datasize) operand2 = V[m];
bits(datasize) operand3 = V[d];
bits(datasize) result;
bits(esize) element1;
bits(esize) element2;
for e = 0 to elements-1
    element1 = Elem[operand1, e, esize];
    element2 = Elem[operand2, e, esize];
    if sub_op then element1 = FPNeg(element1);
    Elem[result, e, esize] = FPMulAdd(Elem[operand3, e, esize], element1, element2, FPCR);
V[d] = result;
```

Internal version only: isa v30.25 v29.05, AdvSIMD v27.01 v26.0, pseudocode v85-xml-00bet8_rc335; Build timestamp: 2018-09-13T13:2018-06-16T09:45

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FMLAL, FMLAL2 (by element)

Floating-point fused Multiply-Add Long to accumulator (by element). This instruction multiplies the vector elements in the first source SIMD&FP register by the specified value in the second source SIMD&FP register, and accumulates the product to the corresponding vector element of the destination SIMD&FP register. The instruction does not round the result of the multiply before the accumulation.

A floating-point exception can be generated by this instruction. Depending on the settings in FPCR, the exception results in either a flag being set in FPSR, or a synchronous exception being generated. For more information, see Floating-point exception traps.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

In ARMv8.2 and ARMv8.3, this is an OPTIONAL instruction. From ARMv8.4 it is mandatory for all implementations to support it. ID_AA64ISAR0_EL1.FHM indicates whether this instruction is supported.

It has encodings from 2 classes: FMLAL and FMLAL2

FMLAL

(ARMv8.2)

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9  | 8  | 7  | 6  | 5  | 4  | 3  | 2  | 1  | 0  |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0  | Q  | 0  | 1  | 1  | 1  | 1  | 0  | Sz | L  | M  | Rm | 0  | 0  | 0  | 0  | H  | 0  | Rn | Rd |

FMLAL

FMLAL <Vd>.<Ta>, <Vn>.<Tb>, <Vm>.H[<index>]

if !HaveFP16MulNoRoundingToFP32Ext() then UNDEFINED;
integer d = 1; then UnallocatedEncoding();
integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(0:Rm); // Vm can only be in bottom 16 registers.
if sz == '1' then ReservedValue('0':Rm); // Vm can only be in bottom 16 registers.
if sz == '1' then UNDEFINED;
integer index = UInt(H:L:M);
integer esize = 32;
integer datasize = if Q=='1' then 128 else 64;
integer elements = datasize DIV esize;
boolean sub_op = (S == '1');
integer part = 0;

FMLAL2

(ARMv8.2)

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9  | 8  | 7  | 6  | 5  | 4  | 3  | 2  | 1  | 0  |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0  | Q  | 1  | 0  | 1  | 1  | 1  | 1  | 0  | Sz | L  | M  | Rm | 1  | 0  | 0  | 0  | H  | 0  | Rn | Rd |

FMLAL, FMLAL2 (by element)
FMLAL2 <Vd>, <Ta>, <Vn>, <Tb>, <Vm>.H(<index>)

if !HaveFP16MulNoRoundingToFP32Ext() then UNDEFINED;
integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rm); // Vm can only be in bottom 16 registers.
if sz == '1' then ReservedValue('0':Rm); // Vm can only be in bottom 16 registers.
if sz == '1' then UNDEFINED;
integer index = UInt(H:L:M);
integer esize = 32;
integer datasize = if Q=='1' then 128 else 64;
integer elements = datasize DIV esize;
boolean sub_op = (S == '1');
integer part = 1;

Assembler Symbols

<Vd> Is the name of the SIMD&FP destination register, encoded in the "Rd" field.
<Ta> Is an arrangement specifier, encoded in “Q”:

<table>
<thead>
<tr>
<th>Q</th>
<th>&lt;Ta&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>2S</td>
</tr>
<tr>
<td>1</td>
<td>4S</td>
</tr>
</tbody>
</table>

<Vn> Is the name of the first SIMD&FP source register, encoded in the "Rn" field.
<Tb> Is an arrangement specifier, encoded in “Q”:

<table>
<thead>
<tr>
<th>Q</th>
<th>&lt;Tb&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>2H</td>
</tr>
<tr>
<td>1</td>
<td>4H</td>
</tr>
</tbody>
</table>

<Vm> Is the name of the second SIMD&FP source register, encoded in the "Rm" field.
<index> Is the element index, encoded in the "H:L:M" fields.

Operation

CheckFPAdvSIMDEnabled64();
bits(datasize DIV 2) operand1 = Vpart[n,part];
bits(128) operand2 = V[m];
bits(datasize) operand3 = V[d];
bits(datasize) result;
bits(esize DIV 2) element1;
bits(esize DIV 2) element2 = Elem[operand2, index, esize DIV 2];
for e = 0 to elements-1
    element1 = Elem[operand1, e, esize DIV 2];
    if sub_op then element1 = FPNeg(element1);
    Elem[result, e, esize] = FPMulAddH(Elem[operand3, e, esize], element1, element2, FPCR);
V[d] = result;

Internal version only: isa v30.25 v29.05 AdvSIMD v27.01 v26.0 pseudocode v85-xml-00vet8_rc3255 ; Build timestamp: 2018-09-13T13:2018-06-16T09:04:45
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FMLAL, FMLAL2 (vector)

Floating-point fused Multiply-Add Long to accumulator (vector). This instruction multiplies corresponding half-precision floating-point values in the vectors in the two source SIMD&FP registers, and accumulates the product to the corresponding vector element of the destination SIMD&FP register. The instruction does not round the result of the multiply before the accumulation.

A floating-point exception can be generated by this instruction. Depending on the settings in FPCR, the exception results in either a flag being set in FPSR, or a synchronous exception being generated. For more information, see Floating-point exception traps.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

In ARMv8.2 and ARMv8.3, this is an OPTIONAL instruction. From ARMv8.4 it is mandatory for all implementations to support it. ID_AA64ISAR0_EL1.FHM indicates whether this instruction is supported.

It has encodings from 2 classes: FMLAL and FMLAL2

FMLAL
(ARMv8.2)

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<th>1</th>
<th>0</th>
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</tbody>
</table>

FMLAL

FMLAL $<Vd>,<Ta>, <Vn>,<Tb>, <Vm><Tb>$

```plaintext
if !HaveFP16MulNoRoundingToFP32Ext() then UNDEFINED;
integer d = (d_int(Rd));
integer n = (d_int(Rn));
integer m = (d_int(Rm));
if sz == '1' then ReservedValue(Rm);
if sz == '1' then UNDEFINED;

integer esize = 32;
integer datasize = if Q == '1' then 128 else 64;
integer elements = datasize DIV esize;
boolean sub_op = (S == '1');
integer part = 0;
```

FMLAL2
(ARMv8.2)

<table>
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<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
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<td>0</td>
<td>Q</td>
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<td>0</td>
<td>1</td>
<td>1</td>
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<td>0</td>
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<td>S</td>
<td>sz</td>
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</tr>
</tbody>
</table>

FMLAL, FMLAL2 (vector)
FMLAL2

FMLAL2 <Vd>, <Ta>, <Vn>, <Tb>

if !HaveFP16MulNoRoundingToFP32Ext() then UNDEFINED;
integer d = Uint(Rd);
integer n = Uint(Rn);
integer m = Uint(Rm);
if sz == '1' then ReservedValue(Rm);
integer esize = 32;
integer datasize = if Q == '1' then 128 else 64;
integer elements = datasize DIV esize;
boolean sub_op = (S == '1');
integer part = 1;

Assembler Symbols

<Vd> Is the name of the SIMD&FP destination register, encoded in the "Rd" field.
<Ta> Is an arrangement specifier, encoded in “Q”:

<table>
<thead>
<tr>
<th>Q</th>
<th>&lt;Ta&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>2S</td>
</tr>
<tr>
<td>1</td>
<td>4S</td>
</tr>
</tbody>
</table>

<Vn> Is the name of the first SIMD&FP source register, encoded in the "Rn" field.
<Tb> Is an arrangement specifier, encoded in “Q”:

<table>
<thead>
<tr>
<th>Q</th>
<th>&lt;Tb&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>2H</td>
</tr>
<tr>
<td>1</td>
<td>4H</td>
</tr>
</tbody>
</table>

<Vm> Is the name of the second SIMD&FP source register, encoded in the "Rm" field.

Operation

CheckFPAdvSIMDEnabled64();
bits(datasize DIV 2) operand1 = Vpart[n,part];
bits(datasize DIV 2) operand2 = Vpart[m,part];
bits(datasize) operand3 = V[d];
bits(datasize) result;
bits(esize DIV 2) element1;
bits(esize DIV 2) element2;
for e = 0 to elements-1
element1 = Elem[operand1, e, esize DIV 2];
otherwise element1 = FPNeg(element1);
if sub_op then element1 = FPNeg(element1);
result = FPMulAddH(Elem[operand3, e, esize], element1, element2, FPCR);
V[d] = result;

Internal version only: isa v30.25, v29.05, AdvSIMD v27.01, pseudocode v85-xml-00bet8_rc3b32 ; Build timestamp: 2018-09-13 13:20 2018-06-16 09:45

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FMLS (by element)

Floating-point fused Multiply-Subtract from accumulator (by element). This instruction multiplies the vector elements in the first source
SIMD&FP register by the specified value in the second source SIMD&FP register, and subtracts the results from the vector elements of the
destination SIMD&FP register. All the values in this instruction are floating-point values.
This instruction can generate a floating-point exception. Depending on the settings in FPCR, the exception results in either a flag being set in
FPSCR or a synchronous exception being generated. For more information, see Floating-point exception traps.
Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an
ttempt to execute the instruction might be trapped.

It has encodings from 4 classes: Scalar, half-precision, Scalar, single-precision and double-precision, Vector, half-precision and Vector, single-
precision and double-precision

Scalar, half-precision

(ARMv8.2)

31  30  29  28  27  26  25  24  23  22  21  20  19  18  17  16  15  14  13  12  11  10  9  8  7  6  5  4  3  2  1  0
0  1  0  1  1  1  1  1  1  0  0  L  M  Rm  0  1  0  1  H  0  Rn  Rd

Scalar, half-precision

FMLS <Hd>, <Hn>, <Vm>.H[index]

if !HaveFP16Ext() then UNDEFINED;

integer idxdsize = if H == '1' then 128 else 64;
integer index;
index = if !HaveFP16Ext() then UnallocatedEncoding();
integer idxdsize = if H == '1' then 128 else 64;
integer index;
index = UInt(H:L:M);

integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rm);

integer esize = 16;
integer datasize = esize;
integer elements = 1;
boolean sub_op = (o2 == '1');

Scalar, single-precision and double-precision

31  30  29  28  27  26  25  24  23  22  21  20  19  18  17  16  15  14  13  12  11  10  9  8  7  6  5  4  3  2  1  0
0  1  0  1  1  1  1  1  1  1  sz  L  M  Rm  0  1  0  1  H  0  Rn  Rd

o2
Scalar, single-precision and double-precision

\[ \text{FMLS } \langle V \rangle \langle d \rangle, \langle V \rangle \langle n \rangle, \langle V \rangle . \langle T \rangle . [\langle \text{index} \rangle] \]

\begin{verbatim}
integer idxdsize = if H == '1' then 128 else 64;
integer index;
bit Rmhi = M;
case sz:L of
  when '0x' index = UInt(H:L);
  when '10' index = UInt(H);
  when '11' UNDEFINED;
integer d = when '11' UnallocatedEncoding();
integer n = UInt(Rn);
integer m = UInt(Rmhi:Rm);
integer esize = 32 «< UInt(sz);
integer datasize = esize;
integer elements = 1;
boolean sub_op = (o2 == '1');
\end{verbatim}

Vector, half-precision

(ARMv8.2)

\begin{table}[h]
\centering
\begin{tabular}{cccccccccccccccccccccccccccc}
\hline
0 & Q & 0 & 0 & 1 & 1 & 1 & 1 & 0 & 0 & L & M & Rm & 0 & 1 & 0 & 1 & H & 0 & Rn & Rd
\end{tabular}
\caption{Half-precision register layout.}
\end{table}

Vector, half-precision

\[ \text{FMLS } \langle Vd \rangle . \langle T \rangle, \langle Vn \rangle . \langle T \rangle, \langle Vm \rangle . H[\langle \text{index} \rangle] \]

\begin{verbatim}
if !HaveFP16Ext() then UNDEFINED;
integer idxdsize = if H == '1' then 128 else 64;
integer index;
index = () then UnallocatedEncoding();
integer idxdsize = if H == '1' then 128 else 64;
integer index;
index = UInt(H:L:M);
integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rm);
integer esize = 16;
integer datasize = if Q == '1' then 128 else 64;
integer elements = datasize DIV esize;
boolean sub_op = (o2 == '1');
\end{verbatim}

Vector, single-precision and double-precision

\[ \text{FMLS } \langle V \rangle \langle d \rangle, \langle V \rangle \langle n \rangle, \langle V \rangle \langle T \rangle . [\langle \text{index} \rangle] \]

\begin{table}[h]
\centering
\begin{tabular}{cccccccccccccccccccccccccccc}
\hline
0 & Q & 0 & 0 & 1 & 1 & 1 & 1 & 1 & L & M & Rm & 0 & 1 & 0 & 1 & H & 0 & Rn & Rd
\end{tabular}
\caption{Single-precision and double-precision register layout.}
\end{table}
Vector, single-precision and double-precision

FMLS \( <\text{Vd}>. <\text{T}>, <\text{Vn}>. <\text{T}>, <\text{Vm}>. <\text{T}>[<\text{index}>] \)

```plaintext
def integer idxdsiz = if H == '1' then 128 else 64;
def integer index;
def bit Rmhi = M;
case sz:L of
  when '0x' index = UInt(H:L);
  when '10' index = UInt(H);
  when '11' UNDEFINED;

def integer d = when '11' UnallocatedEncoding(A);

def integer d = UInt(Rd);
def integer n = UInt(Rn);
def integer m = UInt(Rmhi:Rm);
if sz:Q == '10' then ReservedValue(Rmhi:Rm);
if sz:Q == '10' then UNDEFINED;

def integer esize = 32 << UInt(sz);
def integer datasiz = if Q == '1' then 128 else 64;
def integer elements = datasize DIV esize;
def boolean sub_op = (o2 == '1');
```

Assembler Symbols

- `<Hd>` Is the 16-bit name of the SIMD&FP destination register, encoded in the "Rd" field.
- `<Hn>` Is the 16-bit name of the first SIMD&FP source register, encoded in the "Rn" field.
- `<V>` Is a width specifier, encoded in "sz":
  ```plaintext
  sz  <V>
  0  S
  1  D
  ```
- `<d>` Is the number of the SIMD&FP destination register, encoded in the "Rd" field.
- `<n>` Is the number of the first SIMD&FP source register, encoded in the "Rn" field.
- `<Vd>` Is the name of the SIMD&FP destination register, encoded in the "Rd" field.
- `<T>` For the vector, half-precision variant: is an arrangement specifier, encoded in “Q”:
  ```plaintext
  Q  <T>
  0  4H
  1  8H
  ```
  For the vector, single-precision and double-precision variant: is an arrangement specifier, encoded in “Q:sz”:
  ```plaintext
  Q  sz  <T>
  0  0  2S
  0  1  RESERVED
  1  0  4S
  1  1  2D
  ```
- `<Vn>` Is the name of the first SIMD&FP source register, encoded in the "Rn" field.
- `<Vm>` For the half-precision variant: is the name of the second SIMD&FP source register, in the range V0 to V15, encoded in the "Rm" field.
  For the single-precision and double-precision variant: is the name of the second SIMD&FP source register, encoded in the "M:Rm" fields.
- `<Ts>` Is an element size specifier, encoded in “sz”:
  ```plaintext
  sz  <Ts>
  0  S
  1  D
  ```
- `<index>` For the half-precision variant: is the element index, in the range 0 to 7, encoded in the "H:L:M" fields.
For the single-precision and double-precision variant: is the element index, encoded in “sz:L:H”:

<table>
<thead>
<tr>
<th>sz</th>
<th>L</th>
<th>&lt;index&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>x</td>
<td>H:L</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>H</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

**Operation**

```c
CheckFPAdvSIMDEnabled64();
bits(datasize) operand1 = \text{V}[n];
bits(idxdsize) operand2 = \text{V}[m];
bits(datasize) operand3 = \text{V}[d];
bits(datasize) result;
bits(esize) element1;
bits(esize) element2 = \text{Elem}[operand2, index, esize];

for e = 0 to elements-1
    element1 = \text{Elem}[operand1, e, esize];
    if sub_op then element1 = FPNeg(element1);
    \text{Elem}[result, e, esize] = FPMulAdd(\text{Elem}[operand3, e, esize], element1, element2, FPCR);
\text{V}[d] = result;
```


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FMLS (vector)

Floating-point fused Multiply-Subtract from accumulator (vector). This instruction multiplies corresponding floating-point values in the vectors in the two source SIMD&FP registers, negates the product, adds the result to the corresponding vector element of the destination SIMD&FP register, and writes the result to the destination SIMD&FP register.

A floating-point exception can be generated by this instruction. Depending on the settings in FPCR, the exception results in either a flag being set in FPSR, or a synchronous exception being generated. For more information, see Floating-point exception traps.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

It has encodings from 2 classes: Half-precision and Single-precision and double-precision

**Half-precision**

(ARMv8.2)

<table>
<thead>
<tr>
<th>31</th>
<th>30</th>
<th>29</th>
<th>28</th>
<th>27</th>
<th>26</th>
<th>25</th>
<th>24</th>
<th>23</th>
<th>22</th>
<th>21</th>
<th>20</th>
<th>19</th>
<th>18</th>
<th>17</th>
<th>16</th>
<th>15</th>
<th>14</th>
<th>13</th>
<th>12</th>
<th>11</th>
<th>10</th>
<th>9</th>
<th>8</th>
<th>7</th>
<th>6</th>
<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Q</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>Rm</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>Rn</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>Rd</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Half-precision**

FMLS <Vd>.<T>, <Vn>.<T>, <Vm>.<T>

if !HaveFP16Ext() then UNDEFINED;

integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rm);
integer esize = 16;
integer datasize = if Q == '1' then 128 else 64;
integer elements = datasize DIV esize;

boolean sub_op = (a == '1');

**Single-precision and double-precision**

<table>
<thead>
<tr>
<th>31</th>
<th>30</th>
<th>29</th>
<th>28</th>
<th>27</th>
<th>26</th>
<th>25</th>
<th>24</th>
<th>23</th>
<th>22</th>
<th>21</th>
<th>20</th>
<th>19</th>
<th>18</th>
<th>17</th>
<th>16</th>
<th>15</th>
<th>14</th>
<th>13</th>
<th>12</th>
<th>11</th>
<th>10</th>
<th>9</th>
<th>8</th>
<th>7</th>
<th>6</th>
<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Q</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>Rm</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>Rn</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>Rd</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Single-precision and double-precision**

FMLS <Vd>.<T>, <Vn>.<T>, <Vm>.<T>

integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rm);
if sz:Q == '10' then UNDEFINED;
integer esize = 32 << if sz:Q == '10' then ReservedValue();
integer esize = 32 << UInt(sz);
integer datasize = if Q == '1' then 128 else 64;
integer elements = datasize DIV esize;

boolean sub_op = (op == '1');

**Assembler Symbols**

<Vd> Is the name of the SIMD&FP destination register, encoded in the "Rd" field.
For the half-precision variant: is an arrangement specifier, encoded in “Q”:

<table>
<thead>
<tr>
<th>Q</th>
<th>&lt;T&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>4H</td>
</tr>
<tr>
<td>1</td>
<td>8H</td>
</tr>
</tbody>
</table>

For the single-precision and double-precision variant: is an arrangement specifier, encoded in “sz:Q”:

<table>
<thead>
<tr>
<th>sz</th>
<th>Q</th>
<th>&lt;T&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>2S</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>4S</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>RESERVED</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>2D</td>
</tr>
</tbody>
</table>

<vn> Is the name of the first SIMD&FP source register, encoded in the "Rn" field.

<vm> Is the name of the second SIMD&FP source register, encoded in the "Rm" field.

**Operation**

```c
CheckFPAdvSIMDEnabled64();
bits(datasize) operand1 = V[n];
bits(datasize) operand2 = V[m];
bits(datasize) operand3 = V[d];
bits(datasize) result;
bits(esize) element1;
bits(esize) element2;
for e = 0 to elements-1
    element1 = Elem[operand1, e, esize];
    element2 = Elem[operand2, e, esize];
    if sub_op then element1 = FPNeg(element1);
    Elem[result, e, esize] = FPMulAdd(Elem[operand3, e, esize], element1, element2, FPCR);
V[d] = result;
```

Internal version only: isa v30.25 v29.05, AdvSIMD v27.01 v26.0, pseudocode v85-xml-00ber8_re3353; Build timestamp: 2018-09-13T132018.051600Z 0445

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FMLSL, FMLSL2 (by element)

Floating-point fused Multiply-Subtract Long from accumulator (by element). This instruction multiplies the negated vector elements in the first source SIMD&FP register by the specified value in the second source SIMD&FP register, and accumulates the product to the corresponding vector element of the destination SIMD&FP register. The instruction does not round the result of the multiply before the accumulation.

A floating-point exception can be generated by this instruction. Depending on the settings in FPCR, the exception results in either a flag being set in FPSR, or a synchronous exception being generated. For more information, see Floating-point exception traps.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

In ARMv8.2 and ARMv8.3, this is an OPTIONAL instruction. From ARMv8.4 it is mandatory for all implementations to support it.

ID_AA64ISAR0_EL1 indicates whether this instruction is supported.

It has encodings from 2 classes: FMLSL and FMLSL2

FMLSL

(ARMv8.2)

```
| 31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0 |
|-----------------------------------------------|-----|-----|
| 0  Q  0  1  1  1  1  1  0sz L  M  Rm  0  1  0  H  0  Rn  Rd |

SZ  S
```

FMLSL

FMLSL <Vd>.<Ta>, <Vn>.<Tb>, <Vm>.H[<index>]

```plaintext
if !HaveFP16MulNoRoundingToFP32Ext() then UNDEFINED;
integer d = 1 then UnallocatedEncoding();
integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt('0':Rm);    // Vm can only be in bottom 16 registers.
if sz == '1' then ReservedValue('0':Rm);    // Vm can only be in bottom 16 registers.
if sz == '1' then UNDEFINED;
integer index = UInt(H:L:M);
integer esize = 32;
integer datasize = if Q=='1' then 128 else 64;
integer elements = datasize DIV esize;
boolean sub_op = (S == '1');
integer part = 0;
```

FMLSL2

(ARMv8.2)

```
| 31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0 |
|-----------------------------------------------|-----|-----|
| 0  Q  1  1  1  1  1  1  0sz L  M  Rm  1  1  0  0  H  0  Rn  Rd |

SZ  S
```
FMLSL2

FMLSL <Vd>, <Ta>, <Vn>, <Tb>, <Vm>.H<index>

if !HaveFP16MulNoRoundingToFP32Ext() then UNDEFINED;
integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rm);  // Vm can only be in bottom 16 registers.
if sz == '1' then ReservedValue('0':Rm);  // Vm can only be in bottom 16 registers.
integer index = UInt(H:L:M);
integer esize = 32;
integer datasize = if Q=='1' then 128 else 64;
integer elements = datasize DIV esize;
boolean sub_op = (S == '1');
integer part = 1;

Assembler Symbols

<Vd>  Is the name of the SIMD&FP destination register, encoded in the "Rd" field.
<Ta>  Is an arrangement specifier, encoded in “Q”:

<table>
<thead>
<tr>
<th>Q</th>
<th>&lt;Ta&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>2S</td>
</tr>
<tr>
<td>1</td>
<td>4S</td>
</tr>
</tbody>
</table>

<Vn>  Is the name of the first SIMD&FP source register, encoded in the "Rn" field.
<Tb>  Is an arrangement specifier, encoded in “Q”:

<table>
<thead>
<tr>
<th>Q</th>
<th>&lt;Tb&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>2H</td>
</tr>
<tr>
<td>1</td>
<td>4H</td>
</tr>
</tbody>
</table>

<Vm>  Is the name of the second SIMD&FP source register, encoded in the "Rm" field.
<index>  Is the element index, encoded in the "H:L:M" fields.

Operation

CheckFPAdvSIMDEnabled64();
bits(datasize DIV 2) operand1 = Vpart[n,part];
bits(128) operand2 = V[m];
bits(datasize) operand3 = V[d];
bits(datasize) result;
bits(esize DIV 2) element1;
bits(esize DIV 2) element2 = Elem[operand2, index, esize DIV 2];
for e = 0 to elements-1
  element1 = Elem[operand1, e, esize DIV 2];
  if sub_op then element1 = FPNeg(element1);
  Elem[result, e, esize] = FPMulAddH(Elem[operand3, e, esize], element1, element2, FPCR);
V[d] = result;
FMLSL, FMLSL2 (vector)

Floating-point fused Multiply-Subtract Long from accumulator (vector). This instruction negates the values in the vector of one SIMD&FP register, multiplies these with the corresponding values in another vector, and accumulates the product to the corresponding vector element of the destination SIMD&FP register. The instruction does not round the result of the multiply before the accumulation.

A floating-point exception can be generated by this instruction. Depending on the settings in FPCR, the exception results in either a flag being set in FPSR, or a synchronous exception being generated. For more information, see Floating-point exception traps.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

In ARMv8.2 and ARMv8.3, this is an OPTIONAL instruction. From ARMv8.4 it is mandatory for all implementations to support it.

It has encodings from 2 classes: FMLSL and FMLSL2.

FMLSL
(ARMv8.2)

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0  | Q  | 0  | 0  | 1  | 1  | 1  | 0  | 1  | 0  | 0  | 1  | Rm | 1  | 1  | 1  | 0  | 1  | 1  | Rn | Rd |

S, sz

FMLSL2
(ARMv8.2)

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0  | Q  | 1  | 0  | 1  | 1  | 1  | 0  | 1  | 0  | 0  | 1  | Rm | 1  | 1  | 1  | 0  | 0  | 1  | 1  | Rn | Rd |

S, sz
FMLSL2

FMLSL2 <Vd>.<Ta>, <Vn>.<Tb>, <Vm>.<Tb>

if !HaveFP16MulNoRoundingToFP32Ext() then UNDEFINED;
integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rm);
if sz == '1' then ReservedValue(Rm);
integer esize = 32;
integer datasize = if Q == '1' then 128 else 64;
integer elements = datasize DIV esize;
boolean sub_op = (S == '1');
integer part = 1;

Operation

CheckFPAdvSIMDEnabled64();
b bits(datasize DIV 2) operand1 = Vpart[n,part];
b bits(datasize DIV 2) operand2 = Vpart[m,part];
b bits(datasize) operand3 = V[d];
b bits(datasize) result;
b bits(esize DIV 2) element1;
b bits(esize DIV 2) element2;
for e = 0 to elements-1
  element1 = Elem[operand1, e, esize DIV 2];
  element2 = Elem[operand2, e, esize DIV 2];
  if sub_op then element1 = FPNeg(element1);
  Elem[result,e,esize] = FPMulAddH(Elem[operand3, e, esize], element1, element2, FPCR);
V[d] = result;

Assembler Symbols

<Vd> Is the name of the SIMD&FP destination register, encoded in the "Rd" field.
<Ta> Is an arrangement specifier, encoded in “Q”:

<table>
<thead>
<tr>
<th>Q</th>
<th>&lt;Ta&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>2S</td>
</tr>
<tr>
<td>1</td>
<td>4S</td>
</tr>
</tbody>
</table>

<Vn> Is the name of the first SIMD&FP source register, encoded in the "Rn" field.
<Tb> Is an arrangement specifier, encoded in “Q”:

<table>
<thead>
<tr>
<th>Q</th>
<th>&lt;Tb&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>2H</td>
</tr>
<tr>
<td>1</td>
<td>4H</td>
</tr>
</tbody>
</table>

<Vm> Is the name of the second SIMD&FP source register, encoded in the "Rm" field.

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FMOV (vector, immediate)

Floating-point move immediate (vector). This instruction copies an immediate floating-point constant into every element of the SIMD&FP destination register.

Depending on the settings in the \texttt{CPACR\_EL1}, \texttt{CPTR\_EL2}, and \texttt{CPTR\_EL3} registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

It has encodings from 2 classes: \texttt{Half-precision} and \texttt{Single-precision and double-precision}

\textbf{Half-precision} (ARMv8.2)

\begin{verbatim}
if !HaveFP16Ext() then UNDEFINED;
integer rd = Rd then UnallocatedEncoding();
integer rd = UInt(Rd);
integer datasize = if Q == '1' then 128 else 64;
bits(datasize) imm;
imm8 = a:b:c:d:e:f:g:h;
imm16 = imm8<7>:NOT(imm8<6>):Replicate(imm8<6>,2):imm8<5:0>:Zeros(6);
imm = Replicate(imm16, datasize DIV 16);
\end{verbatim}

\textbf{Single-precision and double-precision}
Single-precision (op == 0)

\[
\text{FMOV} \ <Vd>,<T>, \ #\langle\text{imm}\rangle
\]

Double-precision (Q == 1 && op == 1)

\[
\text{FMOV} \ <Vd>.2D, \ #\langle\text{imm}\rangle
\]

```plaintext
global int rd = UInt(Rd);

global int datasize = if Q == '1' then 128 else 64;
global bits(datasize) imm;
global bits(64) imm64;

global ImmediateOp operation;
global case cmode:op of
    when '0xx00' operation = ImmediateOp_MOVI;
    when '0xx01' operation = ImmediateOp_MVNI;
    when '0xx10' operation = ImmediateOp_ORR;
    when '0xx11' operation = ImmediateOp_BIC;
    when '10x00' operation = ImmediateOp_MOVI;
    when '10x01' operation = ImmediateOp_MVNI;
    when '10x10' operation = ImmediateOp_ORR;
    when '10x11' operation = ImmediateOp_BIC;
    when '110x0' operation = ImmediateOp_MOVI;
    when '110x1' operation = ImmediateOp_MVNI;
    when '1110x' operation = ImmediateOp_MOVI;
    when '11110' operation = ImmediateOp_MOVI;
    when '11111' // FMOV Dn,#imm is in main FP instruction set
        if Q == '0' then UNDEFINED;
        operation = ImmediateOp_MOVI;
        operation = UnallocatedEncoding();

imm64 = AdvSIMDExpandImm(op, cmode, a:b:c:d:e:f:g:h);
imm = Replicate(imm64, datasize DIV 64);
```

**Assembler Symbols**

\(<Vd>\)  Is the name of the SIMD&FP destination register, encoded in the "Rd" field.

\(<T>\)  For the half-precision variant: is an arrangement specifier, encoded in “Q”:

<table>
<thead>
<tr>
<th>Q</th>
<th>(&lt;T&gt;)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>4H</td>
</tr>
<tr>
<td>1</td>
<td>8H</td>
</tr>
</tbody>
</table>

For the single-precision variant: is an arrangement specifier, encoded in “Q”:

<table>
<thead>
<tr>
<th>Q</th>
<th>(&lt;T&gt;)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>2S</td>
</tr>
<tr>
<td>1</td>
<td>4S</td>
</tr>
</tbody>
</table>

\(<\text{imm}>\)  Is a signed floating-point constant with 3-bit exponent and normalized 4 bits of precision, encoded in "a:b:c:d:e:f:g:h". For details of the range of constants available and the encoding of \(<\text{imm}>\), see *Modified immediate constants in A64 floating-point instructions*.

**Operation**

```plaintext
CheckFPAdvSIMDEnabled64();
V[rd] = imm;
```

---

(0)d  htmldiff from-  (0)
FMOV (register)

Floating-point Move register without conversion. This instruction copies the floating-point value in the SIMD&FP source register to the SIMD&FP destination register.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

<table>
<thead>
<tr>
<th>opc</th>
<th>Rd</th>
<th>Rn</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 0 0 1 1 1 0</td>
<td>type</td>
<td>1 0 0 0 0 0 0 0 1 0 0 0 0</td>
</tr>
</tbody>
</table>

Half-precision (type == 11)
(ARMv8.2)

FMOV <Hd>, <Hn>

Single-precision (type == 00)

FMOV <Sd>, <Sn>

Double-precision (type == 01)

FMOV <Dd>, <Dn>

integer d = UInt(Rd);
integer n = UInt(Rn);

integer datasize;
case type of
    when '00' datasize = 32;
    when '01' datasize = 64;
    when '10' UNDEFINED;
    when '11' if when '10' UnallocatedEncoding() then
        datasize = 16;
    else
        UnallocatedEncoding() then
data        datasize = 16;
    else
        UNDEFINED();

FPUnaryOp fpop;
case opc of
    when '00' fpop = FPUnaryOp_MOV;
    when '01' fpop = FPUnaryOp_ABS;
    when '10' fpop = FPUnaryOp_NEG;
    when '11' fpop = FPUnaryOp_SQRt;

Assembler Symbols

<Dd> Is the 64-bit name of the SIMD&FP destination register, encoded in the "Rd" field.

<Dn> Is the 64-bit name of the SIMD&FP source register, encoded in the "Rn" field.

<Hd> Is the 16-bit name of the SIMD&FP destination register, encoded in the "Rd" field.

<Hn> Is the 16-bit name of the SIMD&FP source register, encoded in the "Rn" field.

<Sd> Is the 32-bit name of the SIMD&FP destination register, encoded in the "Rd" field.

<Sn> Is the 32-bit name of the SIMD&FP source register, encoded in the "Rn" field.
Operation

```c
CheckFPAdvSIMEnabled64();

bits(datasize) result;
bitez(datasize) operand = V[n];

case fpop of
    when FPUaryOp_MOV    result = operand;
    when FPUaryOp_ABS    result = FPAbs(operand);
    when FPUaryOp_NEG    result = FPNeg(operand);
    when FPUaryOp_SQRT   result = FPSqrt(operand, FPCR);

V[d] = result;
```

Internal version only: isa v30.25, AdvSIMD v27.01, pseudocode v85-xml-00bet8_rc3333; Build timestamp: 2018-09-13T13:2018-06-16T09:04:45

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FMOV (general)

Floating-point Move to or from general-purpose register without conversion. This instruction transfers the contents of a SIMD&FP register to a general-purpose register, or the contents of a general-purpose register to a SIMD&FP register.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

```
+------------------++------------------+
|  sf | 0  | 0  | 1  | 1  | 1  | 0  | type | 1  | 0  | x | 1  | 1  | x | 0  | 0  | 0  | 0  | 0  | Rn | Rd |
|-----|----+----+----+----+----+----+------|----+----+---+----+---+---+----+----+----+----+----+----|
| rmode | opcode |
```
Half-precision to 32-bit (sf == 0 && type == 11 && rmode == 00 && opcode == 110)
(ARMv8.2)

FMOV <Wd>, <Hn>

Half-precision to 64-bit (sf == 1 && type == 11 && rmode == 00 && opcode == 110)
(ARMv8.2)

FMOV <Xd>, <Hn>

32-bit to half-precision (sf == 0 && type == 11 && rmode == 00 && opcode == 111)
(ARMv8.2)

FMOV <Hd>, <Wn>

32-bit to single-precision (sf == 0 && type == 00 && rmode == 00 && opcode == 111)

FMOV <Sd>, <Wn>

Single-precision to 32-bit (sf == 0 && type == 00 && rmode == 00 && opcode == 110)

FMOV <Wd>, <Sn>

64-bit to half-precision (sf == 1 && type == 11 && rmode == 00 && opcode == 111)
(ARMv8.2)

FMOV <Hd>, <Xn>

64-bit to double-precision (sf == 1 && type == 01 && rmode == 00 && opcode == 111)

FMOV <Dd>, <Xn>

64-bit to top half of 128-bit (sf == 1 && type == 10 && rmode == 01 && opcode == 111)

FMOV <Vd>.D[1], <Xn>

Double-precision to 64-bit (sf == 1 && type == 01 && rmode == 00 && opcode == 110)

FMOV <Xd>, <Dn>

Top half of 128-bit to 64-bit (sf == 1 && type == 10 && rmode == 01 && opcode == 110)

FMOV <Xd>, <Vn>.D[1]
integer d = UInt(Rd);
integer n = UInt(Rn);

integer intsize = if sf == '1' then 64 else 32;
integer fitsize;
FPConvOp op;
FPRounding rounding;
boolean unsigned;
integer part;

case type of
    when '00'
        fitsize = 32;
    when '01'
        fitsize = 64;
    when '10'
        if opcode<2:1>:rmode != '11 01' then UNDEFINED;
        fitsize = 128;
    when '11'
        if HaveFP16Ext() then
            fitsize = 16;
        else
            UNDEFINED;
    when '11'
        if HaveFP16Ext() then
            fitsize = 16;
        else
            UNDEFINED;
    case opcode<2:1>:rmode of
        when '00 xx'        // FCVT[NPMZ][US]
            rounding = FPRounding_TIEAWAY;
            unsigned = (opcode<0> == '1');
            op = FPConvOp_CVT_FtoI;
        when '01 00'        // [US]CVTF
            rounding = FPRoundingZERO;
            unsigned = (opcode<0> == '1');
            op = FPConvOp_CVT_ItoF;
        when '10 00'        // FCVTA[US]
            rounding = FPRounding_TIEAWAY;
            unsigned = (opcode<0> == '1');
            op = FPConvOp_CVT_FtoI;
        when '11 00'        // FMOV
            if fitsize != 16 && fitsize != intsize then UNDEFINED;
            op = if opcode<0> == '1' then
                FPConvOp_MOV_ItoF else FPConvOp_MOV_FtoI;
            part = 0;
        when '11 01'        // FMOV D[1]
            if intsize != 64 || fitsize != 128 then UNDEFINED;
            op = if opcode<0> == '1' then
                FPConvOp_MOV_ItoF else FPConvOp_MOV_FtoI;
            part = 1;
        when '11 11'        // FJCVTZS
            if !HaveFJCVTZSExt() then UNDEFINED;
            rounding = FPRoundingZERO;
            unsigned = (opcode<0> == '1');
            op = FPConvOp_CVT_FtoI_JS;
    otherwise
        UNallocatedEncoding();
    otherwise
        UNDEFINED();

Assembler Symbols

<Dd> Is the 64-bit name of the SIMD&FP destination register, encoded in the "Rd" field.
Is the 16-bit name of the SIMD&FP destination register, encoded in the "Rd" field.

Is the 32-bit name of the SIMD&FP destination register, encoded in the "Rd" field.

Is the 32-bit name of the general-purpose source register, encoded in the "Rn" field.

Is the name of the SIMD&FP destination register, encoded in the "Rd" field.

Is the 64-bit name of the general-purpose source register, encoded in the "Rn" field.

Is the 32-bit name of the general-purpose destination register, encoded in the "Rd" field.

Is the 64-bit name of the SIMD&FP source register, encoded in the "Rn" field.

Is the 64-bit name of the general-purpose destination register, encoded in the "Rd" field.

Is the name of the SIMD&FP source register, encoded in the "Rn" field.

Is the 16-bit name of the SIMD&FP source register, encoded in the "Rn" field.

Is the 64-bit name of the SIMD&FP source register, encoded in the "Rn" field.

Is the 64-bit name of the SIMD&FP source register, encoded in the "Rn" field.

Is the 64-bit name of the SIMD&FP source register, encoded in the "Rn" field.

Operation

```c
CheckFPAdvSIMDEnabled64();

bits(fltsize) fltval;
bits(intsize) intval;

case op of
  when FPConvOp_CVT_FtoI
    fltval = V[n];
    intval = FPToFixed(fltval, 0, unsigned, FPCR, rounding);
    X[d] = intval;
  when FPConvOp_CVT_ItoF
    intval = X[n];
    fltval = FixedToFP(intval, 0, unsigned, FPCR, rounding);
    V[d] = fltval;
  when FPConvOp_MOV_FtoI
    fltval = Vpart[n,part];
    intval = ZeroExtend(fltval, intsize);
    X[d] = intval;
  when FPConvOp_MOV_ItoF
    intval = X[n];
    fltval = intval<fltsize-1:0>;
    Vpart[d,part] = fltval;
  when FPConvOp_CVT_FtoI_JS
    fltval = V[n];
    intval = FPToFixedJS(fltval, FPCR, TRUE);
    X[d] = ZeroExtend(intval<31:0>, 64);
```

Internal version only: isa v30.25, AdvSIMD v27.01, pseudocode v85-xml-00bet8_rc3b3c ; Build timestamp: 2018-09-13T13:2018-08-16T09:04:44

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FMOV (scalar, immediate)

Floating-point move immediate (scalar). This instruction copies a floating-point immediate constant into the SIMD&FP destination register. Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9  | 8  | 7  | 6  | 5  | 4  | 3  | 2  | 1  | 0  |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0  | 0  | 1  | 1  | 1  | 1  | 0  | 1  | 1  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 1  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  |

**Half-precision (type == 11)**
(ARMv8.2)

\[ \text{FMOV } <Hd>, \#<imm> \]

**Single-precision (type == 00)**

\[ \text{FMOV } <Sd>, \#<imm> \]

**Double-precision (type == 01)**

\[ \text{FMOV } <Dd>, \#<imm> \]

```
integer d = UInt(Rd);
integer datasize;
case type of
    when '00' datasize = 32;
    when '01' datasize = 64;
    when '10' UNDEFINED;
    when '11'
        if when '10' UnallocatedEncoding();
        if HaveFP16Ext() then
data size = 16;
        else
            UnallocatedEncoding() then
data size = 16;
        else
            UNDEFINED;
        ();
bits(datasize) imm = VFPExpandImm(imm8);
```

**Assembler Symbols**

- `<Dd>` Is the 64-bit name of the SIMD&FP destination register, encoded in the "Rd" field.
- `<Hd>` Is the 16-bit name of the SIMD&FP destination register, encoded in the "Rd" field.
- `<Sd>` Is the 32-bit name of the SIMD&FP destination register, encoded in the "Rd" field.
- `<imm>` Is a signed floating-point constant with 3-bit exponent and normalized 4 bits of precision, encoded in the "imm8" field. For details of the range of constants available and the encoding of `<imm>`, see [Modified immediate constants in A64 floating-point instructions](#).

**Operation**

```
CheckFPAdvSIMDEnabled64();
V[d] = imm;
```
FMOV (scalar, immediate)
FMSUB

Floating-point Fused Multiply-Subtract (scalar). This instruction multiplies the values of the first two SIMD&FP source registers, negates the product, adds that to the value of the third SIMD&FP source register, and writes the result to the SIMD&FP destination register.

A floating-point exception can be generated by this instruction. Depending on the settings in FPCR, the exception results in either a flag being set in FPSR, or a synchronous exception being generated. For more information, see Floating-point exception traps.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

FMSUB

Half-precision (type == 11) (ARMv8.2)

FMSUB <Hd>, <Hn>, <Hm>, <Ha>

Single-precision (type == 00)

FMSUB <Sd>, <Sn>, <Sm>, <Sa>

Double-precision (type == 01)

FMSUB <Dd>, <Dn>, <Dm>, <Da>

integer d = UInt(Rd);
integer a = UInt(Ra);
integer n = UInt(Rn);
integer m = UInt(Rm);

integer datasize;
case type of
when '00' datasize = 32;
when '01' datasize = 64;
when '10' UNDEFINED;
when '11' if when '00' UnallocatedEncoding();
when '11' if HaveFP16Ext() then
    datasize = 16;
else UnallocatedEncoding() then
    datasize = 16;
else
    UNDEFINED;
end

boolean opa_neg = (o1 == '1');
boolean opl_neg = (o0 != o1);

Assembler Symbols

<Dd> Is the 64-bit name of the SIMD&FP destination register, encoded in the "Rd" field.
<Dn> Is the 64-bit name of the first SIMD&FP source register holding the multiplicand, encoded in the "Rn" field.
<Dm> Is the 64-bit name of the second SIMD&FP source register holding the multiplier, encoded in the "Rm" field.
<Da> Is the 64-bit name of the third SIMD&FP source register holding the minuend, encoded in the "Ra" field.
<Hd> Is the 16-bit name of the SIMD&FP destination register, encoded in the "Rd" field.
Is the 16-bit name of the first SIMD&FP source register holding the multiplicand, encoded in the "Rn" field.

Is the 16-bit name of the second SIMD&FP source register holding the multiplier, encoded in the "Rm" field.

Is the 16-bit name of the third SIMD&FP source register holding the minuend, encoded in the "Ra" field.

Is the 32-bit name of the SIMD&FP destination register, encoded in the "Rd" field.

Is the 32-bit name of the first SIMD&FP source register holding the multiplicand, encoded in the "Rn" field.

Is the 32-bit name of the second SIMD&FP source register holding the multiplier, encoded in the "Rm" field.

Is the 32-bit name of the third SIMD&FP source register holding the minuend, encoded in the "Ra" field.

**Operation**

```c
CheckFPAdvSIMDEnabled64();
bits(datasize) result;
bits(datasize) operanda = V[a];
bits(datasize) operand1 = V[n];
bits(datasize) operand2 = V[m];

if opa_neg then operanda = FPNeg(operanda);
if op1_neg then operand1 = FPNeg(operand1);
result = FPMulAdd(operanda, operand1, operand2, FPCR);
V[d] = result;
```

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**FMUL (by element)**

Floating-point Multiply (by element). This instruction multiplies the vector elements in the first source SIMD&FP register by the specified value in the second source SIMD&FP register, places the results in a vector, and writes the vector to the destination SIMD&FP register. All the values in this instruction are floating-point values.

This instruction can generate a floating-point exception. Depending on the settings in FPCR, the exception results in either a flag being set in FPSR or a synchronous exception being generated. For more information, see Floating-point exception traps.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

It has encodings from 4 classes: Scalar, half-precision, Scalar, single-precision and double-precision, Vector, half-precision and Vector, single-precision and double-precision.

### Scalar, half-precision

**(ARMv8.2)**

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0  | 1  | 0  | 1  | 1  | 1  | 1  | 1  | 0  | 0  | L  | M  | Rm | 1  | 0  | 0  | 1  | H  | 0  | Rn | Rd |
| U  |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |

#### Scalar, half-precision

\[
\text{FMUL} <\text{Hd}>, <\text{Hn}>, <\text{Vm}>, \text{H}[<\text{index}>] \]

if !HaveFP16Ext() then UNDEFINED;

integer idxdsize = if H == 'I' then 128 else 64;
integer index;
index = if then UnallocatedEncoding();

integer idxdsize = if H == 'I' then 128 else 64;
integer index;
index = UInt(H:L:M);

integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rm);

integer esize = 16;
integer datasize = esize;
integer elements = 1;
boolean mulx_op = (U == '1');

### Scalar, single-precision and double-precision

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0  | 1  | 0  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | sz | L  | M  | Rm | 1  | 0  | 0  | 1  | H  | 0  | Rn | Rd |
| U  |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
Scalar, single-precision and double-precision

```
FMUL <V><d>, <V><n>, <Vm><Ts>[<index>]
```

```csharp
integer idxdsize = if H == '1' then 128 else 64;
integer index;
bit Rmhi = M;
case sz:L of
  when '0x' index = UInt(H:L);
  when '10' index = UInt(H);
  when '11' UNDEFINED;
integer d = when '11' UnallocatedEncoding();
integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rmhi:Rm);
integer esize = 32 << UInt(sz);
integer datasize = esize;
integer elements = 1;
boolean mulx_op = (U == '1');
```

Vector, half-precision

(ARMv8.2)

<table>
<thead>
<tr>
<th>31</th>
<th>30</th>
<th>29</th>
<th>28</th>
<th>27</th>
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<th>5</th>
<th>4</th>
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<th>2</th>
<th>1</th>
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</tr>
</thead>
<tbody>
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<td>M</td>
<td>Rm</td>
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</tr>
</tbody>
</table>

Vector, half-precision

```
FMUL <Vd>..<T>, <Vn>..<T>, <Vm>.H[<index>]
```

```
if !HaveFP16Ext() then UNDEFINED;
integer idxdsize = if H == '1' then 128 else 64;
integer index;
index -1() then UnallocatedEncoding();
integer idxdsize = if H == '1' then 128 else 64;
integer index;
index = UInt(H:L:M);
integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rm);
integer esize = 16;
integer datasize = if Q == '1' then 128 else 64;
integer elements = datasize DIV esize;
boolean mulx_op = (U == '1');
```

Vector, single-precision and double-precision

<table>
<thead>
<tr>
<th>31</th>
<th>30</th>
<th>29</th>
<th>28</th>
<th>27</th>
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<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Q</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>sz</td>
<td>L</td>
<td>M</td>
<td>Rm</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>H</td>
<td>0</td>
<td>Rn</td>
<td>Rd</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>U</td>
<td></td>
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</tr>
</tbody>
</table>

FMUL (by element)
Vector, single-precision and double-precision

FMUL $<V_d>, <T>, <V_n>, <T>, <V_m>, <T_s>[<index>]

```plaintext
define integer idxdsz = if H == '1' then 128 else 64;
define integer index;
define bit Rmhi = M;
case sz:L of
  when '0x' index = UInt(H:L);
  when '10' index = UInt(H);
  when '11' UNDEFINED;
#define integer d = when '11' UnallocatedEncoding(Rd);
define integer d = UInt(Rd);
define integer n = UInt(Rn);
define integer m = UInt(Rmhi:Rm);
define if sz:Q == '10' then ReservedValue(Rmhi:Rm);
#define if sz:Q == '10' then UNDEFINED;
define integer esize = 32 << UInt(sz);
define integer datasize = if Q == '1' then 128 else 64;
define integer elements = datasize DIV esize;
define boolean mulx_op = (U == '1');
```

Assembler Symbols

- `<Hd>`: Is the 16-bit name of the SIMD&FP destination register, encoded in the "Rd" field.
- `<Hn>`: Is the 16-bit name of the first SIMD&FP source register, encoded in the "Rn" field.
- `<V>`: Is a width specifier, encoded in “sz”:
  - sz  <V>
    - 0  S
    - 1  D
- `<d>`: Is the number of the SIMD&FP destination register, encoded in the "Rd" field.
- `<n>`: Is the number of the first SIMD&FP source register, encoded in the "Rn" field.
- `<V_d>`: Is the name of the SIMD&FP destination register, encoded in the "Rd" field.
- `<T>`: For the vector, half-precision variant: is an arrangement specifier, encoded in “Q”:
  - Q  <T>
    - 0  4H
    - 1  8H
  For the vector, single-precision and double-precision variant: is an arrangement specifier, encoded in “Q:sz”:
  - Q sz  <T>
    - 0  0  2S
    - 0  1  RESERVED
    - 1  0  4S
    - 1  1  2D
- `<V_n>`: Is the name of the first SIMD&FP source register, encoded in the "Rn" field.
- `<V_m>`: For the half-precision variant: is the name of the second SIMD&FP source register, in the range V0 to V15, encoded in the "Rm" field.
  For the single-precision and double-precision variant: is the name of the second SIMD&FP source register, encoded in the "M:Rm" fields.
- `<T_s>`: Is an element size specifier, encoded in “sz”:
  - sz  <T_s>
    - 0  S
    - 1  D
- `<index>`: For the half-precision variant: is the element index, in the range 0 to 7, encoded in the "H:L:M" fields.
For the single-precision and double-precision variant: is the element index, encoded in “sz:L:H”:

<table>
<thead>
<tr>
<th>sz</th>
<th>L</th>
<th>&lt;index&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>x</td>
<td>H:L</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>H</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

**Operation**

```c
CheckFPAdvSIMDEnabled64();
bits(datasize) operand1 = V[n];
bits(idxdsize) operand2 = V[m];
bits(datasize) result;
bits(esize) element1;
bits(esize) element2 = Elem[operand2, index, esize];

for e = 0 to elements-1
    element1 = Elem[operand1, e, esize];
    if mulx_op then
        Elem[result, e, esize] = FPMulX(element1, element2, FPCR);
    else
        Elem[result, e, esize] = FPMul(element1, element2, FPCR);

V[d] = result;
```
FMUL (vector)

Floating-point Multiply (vector). This instruction multiplies corresponding floating-point values in the vectors in the two source SIMD&FP registers, places the result in a vector, and writes the vector to the destination SIMD&FP register.

This instruction can generate a floating-point exception. Depending on the settings in FPCR, the exception results in either a flag being set in FPSR, or a synchronous exception being generated. For more information, see Floating-point exception traps.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

It has encodings from 2 classes: Half-precision and Single-precision and double-precision

### Half-precision (ARMv8.2)

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0  | 1  | 0  | 1  | 1  | 0  | 0  | 1  | 0  | Rm | 0  | 0  | 0  | 1  | 1  | 1  | Rn | Rd |

### Single-precision and double-precision

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0  | 1  | 0  | 1  | 1  | 0  | 0  | sz | 1  | Rm | 1  | 1  | 0  | 1  | 1  | 1  | Rn | Rd |

**Assembler Symbols**

- `<Vd>` is the name of the SIMD&FP destination register, encoded in the “Rd” field.
- `<T>` For the half-precision variant: is an arrangement specifier, encoded in “Q”:
  - `<T> 0 4H`
  - `<T> 1 8H`

- For the single-precision and double-precision variant: is an arrangement specifier, encoded in “sz:Q”:
<table>
<thead>
<tr>
<th>sz</th>
<th>Q</th>
<th>&lt;I&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>2S</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>4S</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>RESERVED</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>2D</td>
</tr>
</tbody>
</table>

<\text{Vn}> Is the name of the first SIMD&FP source register, encoded in the "Rn" field.

<\text{Vm}> Is the name of the second SIMD&FP source register, encoded in the "Rm" field.

**Operation**

```c
CheckFPAdvSIMDEnabled64();

bits(datasize) operand1 = V[n];
bits(datasize) operand2 = V[m];
bits(datasize) result;
bits(esize) element1;
bits(esize) element2;

for e = 0 to elements-1
    element1 = Elem[operand1, e, esize];
    element2 = Elem[operand2, e, esize];
    Elem[result, e, esize] = FPMul(element1, element2, FPCR);

V[d] = result;
```

Internal version only: isa v30.25, AdvSIMD v27.01, pseudocode v85-xml-00bet8_rc3; Build timestamp: 2018-06-16T09:04

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**FMUL (scalar)**

Floating-point Multiply (scalar). This instruction multiplies the floating-point values of the two source SIMD&FP registers, and writes the result to the destination SIMD&FP register.

This instruction can generate a floating-point exception. Depending on the settings in **FPCR**, the exception results in either a flag being set in **FPSR**, or a synchronous exception being generated. For more information, see *Floating-point exception traps*.

Depending on the settings in the **CPACR_EL1**, **CPTR_EL2**, and **CPTR_EL3** registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9  | 8  | 7  | 6  | 5  | 4  | 3  | 2  | 1  | 0  |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0  | 0  | 1  | 1  | 1  | 0  | 0  | 0  | 0  | 0  | 0  | 1  | 0  | Rm | Rd | Rn | type | 1  | Rm  | 0  | 0  | 0  | 0  | 1  | 0  | Rd |

**Half-precision (type == 11)**

(ARMv8.2)

FMUL <Hd>, <Hn>, <Hm>

**Single-precision (type == 00)**

FMUL <Sd>, <Sn>, <Sm>

**Double-precision (type == 01)**

FMUL <Dd>, <Dn>, <Dm>

```plaintext
integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rm);

integer datasize;
case type of
    when '00' datasize = 32;
    when '01' datasize = 64;
    when '10' UNDEFINED;
    when '11' if when '10' UnallocatedEncoding() then
        datasize = 16;
    else
        UnallocatedEncoding() then
        datasize = 16;
    else
        UNDEFINED;
end;

boolean negated = (op == '1');
```

**Assembler Symbols**

- `<Dd>` is the 64-bit name of the SIMD&FP destination register, encoded in the "Rd" field.
- `<Dn>` is the 64-bit name of the first SIMD&FP source register, encoded in the "Rn" field.
- `<Dm>` is the 64-bit name of the second SIMD&FP source register, encoded in the "Rm" field.
- `<Hd>` is the 16-bit name of the SIMD&FP destination register, encoded in the "Rd" field.
- `<Hn>` is the 16-bit name of the first SIMD&FP source register, encoded in the "Rn" field.
- `<Hm>` is the 16-bit name of the second SIMD&FP source register, encoded in the "Rm" field.
<Sd> Is the 32-bit name of the SIMD&FP destination register, encoded in the "Rd" field.
<Sn> Is the 32-bit name of the first SIMD&FP source register, encoded in the "Rn" field.
<Sm> Is the 32-bit name of the second SIMD&FP source register, encoded in the "Rm" field.

Operation

```c
CheckFPAdvSIMDEnabled64();
bits(datasize) result;
bits(datasize) operand1 = V[n];
bits(datasize) operand2 = V[m];

result = FPMul(operand1, operand2, FPCR);

if negated then result = FPNeg(result);

V[d] = result;
```


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(old) htmldiff from- (new)
**FMULX (by element)**

Floating-point Multiply extended (by element). This instruction multiplies the floating-point values in the vector elements in the first source SIMD&FP register by the specified floating-point value in the second source SIMD&FP register, places the results in a vector, and writes the vector to the destination SIMD&FP register.

If one value is zero and the other value is infinite, the result is 2.0. In this case, the result is negative if only one of the values is negative, otherwise the result is positive.

This instruction can generate a floating-point exception. Depending on the settings in **FPCR**, the exception results in either a flag being set in **FPSR** or a synchronous exception being generated. For more information, see [Floating-point exception traps](#).

Depending on the settings in the **CPACR_EL1**, **CPTR_EL2**, and **CPTR_EL3** registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

It has encodings from 4 classes: Scalar, half-precision, Scalar, single-precision and double-precision, Vector, half-precision and Vector, single-precision and double-precision.

### Scalar, half-precision

**(ARMv8.2)**

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 0 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | L | M | Rm | 1 | 0 | 0 | 1 | H | 0 | Rn | Rd |
| U |

**FMULX** `<Hd>, <Hn>, <Vm>.H[index]`

```plaintext
if !HaveFP16Ext() then UNDEFINED;

integer idxdsize = if H == '1' then 128 else 64;
integer index;
index = if H == '1' then UnallocatedEncoding();

integer idxdsize = if H == '1' then 128 else 64;
integer index;
index = UInt(H:L:M);

integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rm);

integer esize = 16;
integer datasize = esize;
integer elements = 1;
boolean mulx_op = (U == '1');
```

### Scalar, single-precision and double-precision

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | sz | L | M | Rm | 1 | 0 | 0 | 1 | H | 0 | Rn | Rd |
| U |
Scalar, single-precision and double-precision

\[
\text{FMULX} <V\langle d\rangle, <V\langle n\rangle, <Vm>.<Ts>[\langle index\rangle]>
\]

\begin{verbatim}
integer idxdsize = if H == '1' then 128 else 64;
integer index;
bit Rmhi = M;
case sz:L of
  when '0x' index = UInt(H:L);
  when '10' index = UInt(H);
  when '11' UNDEFINED;
integer d = when '11' UnallocatedEncoding();
integer n = UInt(Rn);
integer m = UInt(Rmhi:Rm);
integer esize = 32 << UInt(sz);
integer datasize = esize;
integer elements = 1;
boolean mulx_op = (U == '1');
\end{verbatim}

Vector, half-precision
(ARMv8.2)

\[
\begin{array}{cccccccccccccccccccccccccccc}
0 & Q & 1 & 0 & 1 & 1 & 1 & 1 & 0 & 0 & L & M & Rm & 1 & 0 & 0 & 1 & H & 0 & Rn & Rd \\
\end{array}
\]

\[
\begin{array}{cccccccccccccccccccccccccccc}
0 & Q & 1 & 0 & 1 & 1 & 1 & 1 & 1 & sz & L & M & Rm & 1 & 0 & 0 & 1 & H & 0 & Rn & Rd \\
\end{array}
\]

Vector, half-precision

\[
\text{FMULX} <Vd>.<T>, <Vn>.<T>, <Vm>.H[<index>]
\]

\begin{verbatim}
if !HaveFP16Ext() then UNDEFINED;
integer idxdsize = if H == '1' then 128 else 64;
integer index;
index = () then UnallocatedEncoding();
integer idxdsize = if H == '1' then 128 else 64;
integer index = UInt(H:L:M);
integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rmhi:Rm);
integer esize = 16;
integer datasize = if Q == '1' then 128 else 64;
integer elements = datasize DIV esize;
boolean mulx_op = (U == '1');
\end{verbatim}

Vector, single-precision and double-precision
Vector, single-precision and double-precision

FMULX <Vd>.<T>, <Vn>.<T>, <Vm>.<Ts>[<index>]

integer idxdsizesize = if \( H == '1' \) then 128 else 64;
integer index;
bit Rmhi = M;

\begin{align*}
\text{case sz1:} & \text{of} \\
& \text{when '0x' index} = \text{UInt}(H:L)
\end{align*}

integer d = when '11' UNDEFINED;
integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rmhi:Rm);

if sz:Q == '10' then ReservedValue(Rmhi:Rm);
if sz:Q == '10' then UNDEFINED;

integer esize = 32 <<UInt(sz);
integer datasize = if Q == '1' then 128 else 64;
integer elements = datasize \div esize;
boolean mulx_op = (U == '1');

Assembler Symbols

<\text{Hd}> Is the 16-bit name of the SIMD&FP destination register, encoded in the "Rd" field.
<\text{Hn}> Is the 16-bit name of the first SIMD&FP source register, encoded in the "Rn" field.
<\text{V}> Is a width specifier, encoded in "sz":

\begin{tabular}{|c|c|}
\hline
sz & V \\
\hline
0 & S \\
1 & D \\
\hline
\end{tabular}

<d> Is the number of the SIMD&FP destination register, encoded in the "Rd" field.
<n> Is the number of the first SIMD&FP source register, encoded in the "Rn" field.
<Vd> Is the name of the SIMD&FP destination register, encoded in the "Rd" field.
<T> For the vector, half-precision variant: is an arrangement specifier, encoded in “Q”:

\begin{tabular}{|c|c|}
\hline
Q & T \\
\hline
0 & 4H \\
1 & 8H \\
\hline
\end{tabular}

For the vector, single-precision and double-precision variant: is an arrangement specifier, encoded in “Q:sz”:

\begin{tabular}{|c|c|c|}
\hline
Q & sz & T \\
\hline
0 & 0 & 2S \\
0 & 1 & RESERVED \\
1 & 0 & 4S \\
1 & 1 & 2D \\
\hline
\end{tabular}

<Vn> Is the name of the first SIMD&FP source register, encoded in the "Rn" field.
<Vm> For the half-precision variant: is the name of the second SIMD&FP source register, in the range V0 to V15, encoded in the "Rm" field.

For the single-precision and double-precision variant: is the name of the second SIMD&FP source register, encoded in the "M:Rm" fields.

<Ts> Is an element size specifier, encoded in “sz”:

\begin{tabular}{|c|c|}
\hline
sz & Ts \\
\hline
0 & S \\
1 & D \\
\hline
\end{tabular}

<index> For the half-precision variant: is the element index, in the range 0 to 7, encoded in the "H:L:M" fields.
For the single-precision and double-precision variant: is the element index, encoded in “sz:L:H”:

<table>
<thead>
<tr>
<th>sz</th>
<th>L</th>
<th>&lt;index&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>x</td>
<td>H:L</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>H</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

Operation

```c
CheckFPAdvSIMDEnabled64();
bits(datasize) operand1 = V[n];
bits(idxsize) operand2 = V[m];
bits(datasize) result;
bits(esize) element1;
bits(esize) element2 = Elem[operand2, index, esize];

for e = 0 to elements-1
    element1 = Elem[operand1, e, esize];
    if mulx_op then
        Elem[result, e, esize] = FPMulX(element1, element2, FPCR);
    else
        Elem[result, e, esize] = FPMul(element1, element2, FPCR);

V[d] = result;
```
FMULX

Floating-point Multiply extended. This instruction multiplies corresponding floating-point values in the vectors of the two source SIMD&FP registers, places the resulting floating-point values in a vector, and writes the vector to the destination SIMD&FP register.

If one value is zero and the other value is infinite, the result is 2.0. In this case, the result is negative if only one of the values is negative, otherwise the result is positive.

This instruction can generate a floating-point exception. Depending on the settings in FPCR, the exception results in either a flag being set in FPSR, or a synchronous exception being generated. For more information, see Floating-point exception traps.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

It has encodings from 4 classes: Scalar half precision, Scalar single-precision and double-precision, Vector half precision, and Vector single-precision and double-precision

Scalar half precision

(ARMv8.2)

| 31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0 | Rm | 0 0 0 1 1 1 1 0 | 0 1 0 | Rd | 0 0 0 1 1 1 |

Scalar half precision

FMULX <Hd>, <Hn>, <Hm>

if !HaveFP16Ext() then UNDEFINED;

integer d = 0; then unallocatedEncoding(1);

integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rm);
integer esize = 16;
integer datasize = esize;
integer elements = 1;

Scalar single-precision and double-precision

| 31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0 | Rm | 1 1 0 1 1 1 1 0 | sz 1 | Rd | 1 1 0 1 1 1 |

Scalar single-precision and double-precision

FMULX <V><d>, <V><n>, <V><m>

integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rm);
integer esize = 32 << UInt(sz);
integer datasize = esize;
integer elements = 1;

Vector half precision

(ARMv8.2)

| 31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0 | Rm | 0 0 0 1 1 1 1 0 | 0 1 0 | Rd | 0 0 0 1 1 1 |
Vector half precision

```plaintext
FMULX <Vd>.<T>, <Vn>.<T>, <Vm>.<T>
```

```plaintext
if !HaveFP16Ext() then UNDEFINED;
integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rm);
integer esize = 16;
integer datasize = if Q == '1' then 128 else 64;
integer elements = datasize DIV esize;
```

Vector single-precision and double-precision

```plaintext
integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rm);
if sz:Q == '10' then UNDEFINED;
integer esize = 32 << if sz:Q == '10' then ReservedValue() else UInt(sz);
integer datasize = if Q == '1' then 128 else 64;
integer elements = datasize DIV esize;
```

Assembler Symbols

- `<Hd>` is the 16-bit name of the SIMD&FP destination register, encoded in the "Rd" field.
- `<Hn>` is the 16-bit name of the first SIMD&FP source register, encoded in the "Rn" field.
- `<Hm>` is the 16-bit name of the second SIMD&FP source register, encoded in the "Rm" field.
- `<V>` is a width specifier, encoded in "sz":
  - `sz`<V>
  - `0 S 1 D`
- `<d>` is the number of the SIMD&FP destination register, in the "Rd" field.
- `<n>` is the number of the first SIMD&FP source register, encoded in the "Rn" field.
- `<m>` is the number of the second SIMD&FP source register, encoded in the "Rm" field.
- `<Vd>` is the name of the SIMD&FP destination register, encoded in the "Rd" field.
- `<T>` For the vector half precision variant: is an arrangement specifier, encoded in "Q":
  - `Q <T>
  - `0 4H 1 8H`
  - For the vector single-precision and double-precision variant: is an arrangement specifier, encoded in "sz:Q":
  - `sz Q <T>
  - `0 0 2S
  - `0 1 4S
  - `1 0 RESERVED
  - `1 1 2D`
- `<Vn>` is the name of the first SIMD&FP source register, encoded in the "Rn" field.
- `<Vm>` is the name of the second SIMD&FP source register, encoded in the "Rm" field.
Operation

```c
CheckFPAdvSIMDEnabled64();

bits(datasize) operand1 = V[n];
bits(datasize) operand2 = V[m];
bits(datasize) result;
bits(eseize) element1;
bits(eseize) element2;

for e = 0 to elements-1
    element1 = Elem[operand1, e, esize];
    element2 = Elem[operand2, e, esize];
    Elem[result, e, esize] = FPMulX(element1, element2, FPCR);
V[d] = result;
```

Internal version only: isa v30.25,v29.05, AdvSIMD v27.01,v26.0, pseudocode v85-xml-00bet8_rc355; Build timestamp: 2018-09-13T13:2018-06-16T02 04:45

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FNEG (vector)

Floating-point Negate (vector). This instruction negates the value of each vector element in the source SIMD&FP register, writes the result to a vector, and writes the vector to the destination SIMD&FP register.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

It has encodings from 2 classes: Half-precision and Single-precision and double-precision

Half-precision

(ARMv8.2)

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0  | Q | 1 | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | Rn | Rd |

U

Single-precision and double-precision

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0  | Q | 1 | 0 | 1 | 1 | 1 | 0 | 1 | sz | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | Rn | Rd |

Assembler Symbols

<Vd> Is the name of the SIMD&FP destination register, encoded in the "Rd" field.
<T> For the half-precision variant: is an arrangement specifier, encoded in “Q”:

<table>
<thead>
<tr>
<th>Q</th>
<th>&lt;T&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>4H</td>
</tr>
<tr>
<td>1</td>
<td>8H</td>
</tr>
</tbody>
</table>
For the single-precision and double-precision variant: is an arrangement specifier, encoded in “sz:Q”:

<table>
<thead>
<tr>
<th>sz</th>
<th>Q</th>
<th>&lt;T&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>2S</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>4S</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>RESERVED</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>2D</td>
</tr>
</tbody>
</table>

<Vn> Is the name of the SIMD&FP source register, encoded in the "Rn" field.

Operation

```c
CheckFPAdvSIMDEnabled64();

bits(datasize) operand = V[n];
bits(datasize) result;
bits(esize) element;

for e = 0 to elements-1
  element = Elem[operand, e, esize];
  if neg then
    element = FPNeg(element);
  else
    element = FPAbs(element);
  Elem[result, e, esize] = element;

V[d] = result;
```

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FNEG (scalar)

Floating-point Negate (scalar). This instruction negates the value in the SIMD&FP source register and writes the result to the SIMD&FP destination register.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

```
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9  | 8  | 7  | 6  | 5  | 4  | 3  | 2  | 1  | 0  |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0  | 0  | 1  | 1  | 1  | 0  | 1   | 0   | 0   | 0   | 1   | 0   | 0   | 0   | 0   | Rn  | Rd  |

opc
```

Half-precision (type == 11)  
(ARMv8.2)

FNEG <Hd>, <Hn>

Single-precision (type == 00)

FNEG <Sd>, <Sn>

Double-precision (type == 01)

FNEG <Dd>, <Dn>

```plaintext
going d = UInt(Rd);
going n = UInt(Rn);

integer datasize;
case type of
  when '00' datasize = 32;
  when '01' datasize = 64;
  when '10' UNDEFINED;
  when '11' if when '10' UnallocatedEncoding();
     when '11' if HaveFP16Ext() then
       datasize = 16;
     else
       UnallocatedEncoding();
     else
       UNDEFINED();
FPUnaryOp fpop;
case opc of
  when '00' fpop = FPUnaryOp_MOV;
  when '01' fpop = FPUnaryOp_ABS;
  when '10' fpop = FPUnaryOp_NEG;
  when '11' fpop = FPUnaryOp_SQRT;
```

Assembler Symbols

- `<Dd>` Is the 64-bit name of the SIMD&FP destination register, encoded in the "Rd" field.
- `<Dn>` Is the 64-bit name of the SIMD&FP source register, encoded in the "Rn" field.
- `<Hd>` Is the 16-bit name of the SIMD&FP destination register, encoded in the "Rd" field.
- `<Hn>` Is the 16-bit name of the SIMD&FP source register, encoded in the "Rn" field.
- `<Sd>` Is the 32-bit name of the SIMD&FP destination register, encoded in the "Rd" field.
- `<Sn>` Is the 32-bit name of the SIMD&FP source register, encoded in the "Rn" field.
Operation

```
CheckFPAdvSIMDEnabled64();

bits(datasize) result;
bits(datasize) operand = V[n];

case fpop of
  when FPU unary MOV  result = operand;
  when FPU unary ABS  result = FPAbs(operand);
  when FPU unary NEG  result = FPNeg(operand);
  when FPU unary SQRT result = FPSqrt(operand, FPCR);
V[d] = result;
```

Internal version only: isa v30.25 v29.05, AdvSIMD v27.01 v26.0, pseudocode v85-xml-00bet8_rc333v35.3; Build timestamp: 2018-09-13T13 2018-06-16T09:04:45

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FNMAcD

Floating-point Negated fused Multiply-Add (scalar). This instruction multiplies the values of the first two SIMD&FP source registers, negates the product, subtracts the value of the third SIMD&FP source register, and writes the result to the destination SIMD&FP register.

This instruction can generate a floating-point exception. Depending on the settings in FPCR, the exception results in either a flag being set in FPSR, or a synchronous exception being generated. For more information, see Floating-point exception traps.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
|    |    | 0  | 0  | 1  | 1  | 1  | 1  | 1  | 0  |    | 0  | 1  | 1  | 1  | 1  | 0  |    |    |    |    |    |    |    |    |    |    |    |    |    |    |

Half-precision (type == 11)

(ARMv8.2)

FNMAcD <Hd>, <Hn>, <Hm>, <Ha>

Single-precision (type == 00)

FNMAcD <Sd>, <Sn>, <Sm>, <Sa>

Double-precision (type == 01)

FNMAcD <Dd>, <Dn>, <Dm>, <Da>

integer d = UInt(Rd);
integer a = UInt(Ra);
integer n = UInt(Rn);
integer m = UInt(Rm);

integer datasize;

case type of
    when '00' datasize = 32;
    when '01' datasize = 64;
    when '10' UNDEFINED;
    when '11' if when '00' UnallocatedEncoding() then
        datasize = 16;
    else
        UnallocatedEncoding() then
            datasize = 16;
    else
        UNDEFINED;
end;

boolean opa_neg = (o1 == '1');
boolean opl_neg = (o0 != o1);

Assembler Symbols

<Dr> Is the 64-bit name of the SIMD&FP destination register, encoded in the "Rd" field.
<Dr> Is the 64-bit name of the first SIMD&FP source register holding the multiplicand, encoded in the "Rn" field.
<Dr> Is the 64-bit name of the second SIMD&FP source register holding the multiplier, encoded in the "Rm" field.
<Dr> Is the 64-bit name of the third SIMD&FP source register holding the addend, encoded in the "Ra" field.
<Dr> Is the 16-bit name of the SIMD&FP destination register, encoded in the "Rd" field.
Is the 16-bit name of the first SIMD&FP source register holding the multiplicand, encoded in the "Rn" field.

Is the 16-bit name of the second SIMD&FP source register holding the multiplier, encoded in the "Rm" field.

Is the 16-bit name of the third SIMD&FP source register holding the addend, encoded in the "Ra" field.

Is the 32-bit name of the SIMD&FP destination register, encoded in the "Rd" field.

Is the 32-bit name of the first SIMD&FP source register holding the multiplicand, encoded in the "Rn" field.

Is the 32-bit name of the second SIMD&FP source register holding the multiplier, encoded in the "Rm" field.

Is the 32-bit name of the third SIMD&FP source register holding the addend, encoded in the "Ra" field.

**Operation**

```c
CheckFPAdvSIMDEnabled64();

bits(datasize) result;
bits(datasize) operanda = V[a];
bits(datasize) operand1 = V[n];
bits(datasize) operand2 = V[m];

if opa_neg then operanda = FPNeg(operanda);
if op1_neg then operand1 = FPNeg(operand1);
result = FPMulAdd(operanda, operand1, operand2, FPCR);

V[d] = result;
```

Internal version only: isa v30.25 v29.05 AdvSIMD v27.01 v26.0 pseudocode v85-xml-008e8_rc3b353 ; Build timestamp: 2018-09-13T13:2018-06-16T09:45

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FNMSUB

Floating-point Negated fused Multiply-Subtract (scalar). This instruction multiplies the values of the first two SIMD&FP source registers, subtracts the value of the third SIMD&FP source register, and writes the result to the destination SIMD&FP register.

A floating-point exception can be generated by this instruction. Depending on the settings in FPCR, the exception results in either a flag being set in FPSR, or a synchronous exception being generated. For more information, see Floating-point exception traps.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

Half-precision (type == 11)
(ARMv8.2)

```
FNMSUB <Hd>, <Hn>, <Hm>, <Ha>
```

Single-precision (type == 00)

```
FNMSUB <Sd>, <Sn>, <Sm>, <Sa>
```

Double-precision (type == 01)

```
FNMSUB <Dd>, <Dn>, <Dm>, <Da>
```

```java
integer d = UInt(Rd);
integer a = UInt(Ra);
integer n = UInt(Rn);
integer m = UInt(Rm);

integer datasize;
case type of
    when '00' datasize = 32;
    when '01' datasize = 64;
    when '10' UNDEFINED;
    when '11'
        if when '10' UnallocatedEncoding();
        when '11'
            if HaveFP16Ext() then
                datasize = 16;
            else
                UnallocatedEncoding() then
                    datasize = 16;
                else
                    UNDEFINED;
        else
            UnallocatedEncoding();

boolean opa_neg = (o1 == '1');
boolean opl_neg = (o0 != o1);
```
Is the 16-bit name of the first SIMD&FP source register holding the multiplicand, encoded in the "Rn" field.

Is the 16-bit name of the second SIMD&FP source register holding the multiplier, encoded in the "Rm" field.

Is the 16-bit name of the third SIMD&FP source register holding the minuend, encoded in the "Ra" field.

Is the 32-bit name of the SIMD&FP destination register, encoded in the "Rd" field.

Is the 32-bit name of the first SIMD&FP source register holding the multiplicand, encoded in the "Rn" field.

Is the 32-bit name of the second SIMD&FP source register holding the multiplier, encoded in the "Rm" field.

Is the 32-bit name of the third SIMD&FP source register holding the minuend, encoded in the "Ra" field.

Operation

```c
CheckFPAdvSIMDEnabled64();

bits(datasize) result;
bits(datasize) operanda = V[a];
bits(datasize) operand1 = V[n];
bits(datasize) operand2 = V[m];

if opa_neg then operanda = FPNeg(operanda);
if op1_neg then operand1 = FPNeg(operand1);
result = FPMulAdd(operanda, operand1, operand2, FPCR);
V[d] = result;
```

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FNMUL (scalar)

Floating-point Multiply-Negate (scalar). This instruction multiplies the floating-point values of the two source SIMD&FP registers, and writes the negation of the result to the destination SIMD&FP register.

This instruction can generate a floating-point exception. Depending on the settings in FPCR, the exception results in either a flag being set in FPSR, or a synchronous exception being generated. For more information, see Floating-point exception traps.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

Half-precision (type == 11)  
(ARMv8.2)

FNMUL <Hd>, <Hn>, <Hm>

Single-precision (type == 00)

FNMUL <Sd>, <Sn>, <Sm>

Double-precision (type == 01)

FNMUL <Dd>, <Dn>, <Dm>

integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rm);

integer datasize;
case type of
  when '00' datasize = 32;
  when '01' datasize = 64;
  when '10' UNDEFINED;
  when '11'
    if when '10' UnallocatedEncoding() then
      datasize = 16;
    else
      if HaveFP16Ext() then
        datasize = 16;
      else
        UnallocatedEncoding() then
          datasize = 16;
        else
          UNDEFINED;
  end

boolean negated = (op == '1');
Is the 32-bit name of the SIMD&FP destination register, encoded in the "Rd" field.

Is the 32-bit name of the first SIMD&FP source register, encoded in the "Rn" field.

Is the 32-bit name of the second SIMD&FP source register, encoded in the "Rm" field.

**Operation**

```c
CheckFPAdvSIMDEnabled64();
bits(datasize) result;
bits(datasize) operand1 = V[n];
bits(datasize) operand2 = V[m];

result = FPMul(operand1, operand2, FPCR);
if negated then result = FPNeg(result);
V[d] = result;
```

Internal version only: isa v36.25, v29.05, AdvSIMD v27.01, v26.0, pseudocode v85.xml-00bet8_rc3.b5 ; Build timestamp: 2018-09-13T13:2018-06-16T09:04:45

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Floating-point Reciprocal Estimate. This instruction finds an approximate reciprocal estimate for each vector element in the source SIMD&FP register, places the result in a vector, and writes the vector to the destination SIMD&FP register.

This instruction can generate a floating-point exception. Depending on the settings in FPCR, the exception results in either a flag being set in FPSR or a synchronous exception being generated. For more information, see Floating-point exception traps.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

It has encodings from 4 classes: Scalar half precision, Scalar single-precision and double-precision, Vector half precision and Vector single-precision and double-precision

**Scalar half precision**

(ARMv8.2)

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9  | 8  | 7  | 6  | 5  | 4  | 3  | 2  | 1  | 0  |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0  | 1  | 0  | 1  | 1  | 1  | 1  | 0  | 1  | 1  | 1  | 1  | 0  | 0  | 1  | 1  | 1  | 0  | 1  | 1  | 0  | Rn | Rd |

**Scalar single-precision and double-precision**

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9  | 8  | 7  | 6  | 5  | 4  | 3  | 2  | 1  | 0  |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0  | 1  | 0  | 1  | 1  | 1  | 1  | 0  | 1  | 1  | 0  | 0  | 0  | 0  | 1  | 1  | 1  | 0  | 1  | 1  | 0  | Rn | Rd |

**Vector half precision**

(ARMv8.2)

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9  | 8  | 7  | 6  | 5  | 4  | 3  | 2  | 1  | 0  |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0  | 0  | 0  | 1  | 1  | 1  | 1  | 0  | 1  | 1  | 1  | 1  | 0  | 0  | 1  | 1  | 1  | 0  | 1  | 1  | 0  | Rn | Rd |
Vector half precision

\[ \text{FRECPE } <\text{Vd}>.<?\text{T}>>, <\text{Vn}>.<?\text{T}> \]

if \(!\text{HaveFP16Ext}()\) then UNDEFINED;
integer d = UInt(Rd);
integer n = UInt(Rn);
integer esize = 16;
integer datasize = if Q == '1' then 128 else 64;
integer elements = datasize DIV esize;

Vector single-precision and double-precision

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9  | 8  | 7  | 6  | 5  | 4  | 3  | 2  | 1  | 0  |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0  | Q  | 0  | 1  | 1  | 1  | 0  | 1  | sz | 1  | 0  | 0  | 0  | 0  | 1  | 1  | 0  | 1  | 1  | 0  |

Rn     Rd

Vector single-precision and double-precision

\[ \text{FRECPE } <\text{Vd}>.<?\text{T}>>, <\text{Vn}>.<?\text{T}> \]

integer d = UInt(Rd);
integer n = UInt(Rn);
if sz:Q == '10' then UNDEFINED;
integer esize = 32 << if sz:Q == '10' then ReservedValue() else UInt(sz);
integer datasize = if Q == '1' then 128 else 64;
integer elements = datasize DIV esize;

Assembler Symbols

\(<\text{Hd}>\) Is the 16-bit name of the SIMD&FP destination register, encoded in the "Rd" field.
\(<\text{Hn}>\) Is the 16-bit name of the SIMD&FP source register, encoded in the "Rn" field.
\(<\text{V}>\) Is a width specifier, encoded in "sz":

<table>
<thead>
<tr>
<th>sz</th>
<th>&lt;V&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>S</td>
</tr>
<tr>
<td>1</td>
<td>D</td>
</tr>
</tbody>
</table>

\(<\text{d}>\) Is the number of the SIMD&FP destination register, encoded in the "Rd" field.
\(<\text{n}>\) Is the number of the SIMD&FP source register, encoded in the "Rn" field.
\(<\text{Vd}>\) Is the name of the SIMD&FP destination register, encoded in the "Rd" field.
\(<\text{T}>\) For the vector half precision variant: is an arrangement specifier, encoded in “Q”:

<table>
<thead>
<tr>
<th>Q</th>
<th>&lt;T&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>4H</td>
</tr>
<tr>
<td>1</td>
<td>8H</td>
</tr>
</tbody>
</table>

For the vector single-precision and double-precision variant: is an arrangement specifier, encoded in “sz:Q”:

<table>
<thead>
<tr>
<th>sz</th>
<th>Q</th>
<th>&lt;T&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>2S</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>4S</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>RESERVED</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>2D</td>
</tr>
</tbody>
</table>

\(<\text{Vn}>\) Is the name of the SIMD&FP source register, encoded in the "Rn" field.
Operation

```c
CheckFPAdvSIMDEnabled64();
bits(datasize) operand = V[n];
bits(datasize) result;
bits(esize) element;

for e = 0 to elements-1
    element = Elem[operand, e, esize];
    Elem[result, e, esize] = FPREcipEstimate(element, FPCR);

V[d] = result;
```
FRECPS

Floating-point Reciprocal Step. This instruction multiplies the corresponding floating-point values in the vectors of the two source SIMD&FP registers, subtracts each of the products from 2.0, places the resulting floating-point values in a vector, and writes the vector to the destination SIMD&FP register.

This instruction can generate a floating-point exception. Depending on the settings in FPCR, the exception results in either a flag being set in FPSR, or a synchronous exception being generated. For more information, see Floating-point exception traps.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

It has encodings from 4 classes: Scalar half precision, Scalar single-precision and double-precision, Vector half precision, and Vector single-precision and double-precision.

Scalar half precision (ARMv8.2)

```
FRECPS <Hd>, <Hn>, <Hm>
```

```c
if !HaveFP16Ext() then UNDEFINED;
integer d =(UInt(Rd));
integer n = UInt(Rn);
integer m = UInt(Rm);
integer esize = 16;
integer datasize = esize;
integer elements = 1;
```

Scalar single-precision and double-precision

```
FRECPS <V><d>, <V><n>, <V><m>
```

```c
integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rm);
integer esize = 32 << UInt(sz);
integer datasize = esize;
integer elements = 1;
```

Vector half precision (ARMv8.2)

```
0 Q 0 0 1 1 0 0 1 0 0 0 1 1 1 1 Rm 0 0 1 1 1 1 Rn Rd
```
Vector half precision

FRECPS \(<V_d>\cdot<T>, <V_n>\cdot<T>, <V_m>\cdot<T>\)

if !HaveFP16Ext() then UNDEFINED;
integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rm);
integer esize = 16;
integer datasize = if Q == '1' then 128 else 64;
integer elements = datasize DIV esize;

Vector single-precision and double-precision

FRECPS \(<V_d>\cdot<T>, <V_n>\cdot<T>, <V_m>\cdot<T>\)

integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rm);
if sz:Q == '10' then UNDEFINED;
integer esize = 32 << if sz:Q == '10' then ReservedValue() else UInt(sz);
integer datasize = if Q == '1' then 128 else 64;
integer elements = datasize DIV esize;

Assembler Symbols

\(<H_d>\) Is the 16-bit name of the SIMD&FP destination register, encoded in the "Rd" field.
\(<H_n>\) Is the 16-bit name of the first SIMD&FP source register, encoded in the "Rn" field.
\(<H_m>\) Is the 16-bit name of the second SIMD&FP source register, encoded in the "Rm" field.
\(<V>\) Is a width specifier, encoded in "sz":

<table>
<thead>
<tr>
<th>sz</th>
<th>&lt;V&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>S</td>
</tr>
<tr>
<td>1</td>
<td>D</td>
</tr>
</tbody>
</table>

\(<d>\) Is the number of the SIMD&FP destination register, in the "Rd" field.
\(<n>\) Is the number of the first SIMD&FP source register, encoded in the "Rn" field.
\(<m>\) Is the number of the second SIMD&FP source register, encoded in the "Rm" field.
\(<V_d>\) Is the name of the SIMD&FP destination register, encoded in the "Rd" field.
\(<T>\) For the vector half precision variant: is an arrangement specifier, encoded in “Q”:

<table>
<thead>
<tr>
<th>Q</th>
<th>&lt;T&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>4H</td>
</tr>
<tr>
<td>1</td>
<td>8H</td>
</tr>
</tbody>
</table>

For the vector single-precision and double-precision variant: is an arrangement specifier, encoded in “sz:Q”:

<table>
<thead>
<tr>
<th>sz</th>
<th>Q</th>
<th>&lt;T&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>2S</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>4S</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>RESERVED</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>2D</td>
</tr>
</tbody>
</table>

\(<V_n>\) Is the name of the first SIMD&FP source register, encoded in the "Rn" field.
\(<V_m>\) Is the name of the second SIMD&FP source register, encoded in the "Rm" field.
Operation

```c
CheckFPAdvSIMDEnabled64();
bits(datasize) operand1 = V[n];
bits(datasize) operand2 = V[m];
bits(datasize) result;
bits(esize) element1;
bits(esize) element2;

for e = 0 to elements-1
    element1 = Elem[operand1, e, esize];
    element2 = Elem[operand2, e, esize];
    Elem[result, e, esize] = FPRecipStepFused(element1, element2);

V[d] = result;
```

Internal version only: isa v36.25, v35.3, AdvSIMD v27.01, pseudocode v85-xml-00be8_3052, Build timestamp: 2018-09-13T13:2018-06-16T09:45:45

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FRECPX

Floating-point Reciprocal exponent (scalar). This instruction finds an approximate reciprocal exponent for each vector element in the source SIMD&FP register, places the result in a vector, and writes the vector to the destination SIMD&FP register. This instruction can generate a floating-point exception. Depending on the settings in FPCR, the exception results in either a flag being set in FPSR or a synchronous exception being generated. For more information, see Floating-point exception traps. Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

It has encodings from 2 classes: Half-precision and Single-precision and double-precision

**Half-precision**

(ARMv8.2)

<table>
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<tr>
<th>31</th>
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<th>6</th>
<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
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<td>0</td>
<td>Rn</td>
<td>Rd</td>
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</tbody>
</table>

**Half-precision**

FRECPX `<Hd>, <Hn>`

```plaintext
if !HaveFP16Ext() then UNDEFINED;
integer d = 1; then UnallocatedEncoding();
integer d = UInt(Rd);
integer n = UInt(Rn);

integer esize = 16;
integer datasize = esize;
integer elements = 1;
```

**Single-precision and double-precision**

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<thead>
<tr>
<th>31</th>
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<th>26</th>
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<th>11</th>
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<th>8</th>
<th>7</th>
<th>6</th>
<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
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<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>Rn</td>
<td>Rd</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Single-precision and double-precision**

FRECPX `<V><d>, <V><n>`

```plaintext
integer d = UInt(Rd);
integer n = UInt(Rn);

integer esize = 32 << UInt(sz);
integer datasize = esize;
integer elements = 1;
```

**Assembler Symbols**

`<Hd>` Is the 16-bit name of the SIMD&FP destination register, encoded in the "Rd" field.

`<Hn>` Is the 16-bit name of the SIMD&FP source register, encoded in the "Rn" field.

`<V>` Is a width specifier, encoded in "sz":

<table>
<thead>
<tr>
<th><code>sz</code></th>
<th><code>&lt;V&gt;</code></th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>S</td>
</tr>
<tr>
<td>1</td>
<td>D</td>
</tr>
</tbody>
</table>

`<d>` Is the number of the SIMD&FP destination register, encoded in the "Rd" field.
Is the number of the SIMD&FP source register, encoded in the "Rn" field.

**Operation**

```c
CheckFPAdvSIMDEnabled64();
bits(datasize) operand = V[n];
bits(datasize) result;
bits(esize) element;

for e = 0 to elements-1
    element = Elem[operand, e, esize];
    Elem[result, e, esize] = FPRcpx(element, FPCR);
V[d] = result;
```


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FRINT32X (vector)

Floating-point Round to 32-bit Integer, using current rounding mode (vector). This instruction rounds a vector of floating-point values in the SIMD&FP source register to integral floating-point values that fit into a 32-bit integer size using the rounding mode that is determined by the FPCR, and writes the result to the SIMD&FP destination register.

A zero input returns a zero result with the same sign. When one of the result values is not numerically equal to the corresponding input value, an Inexact exception is raised. When an input is infinite, NaN or out-of-range, the instruction returns for the corresponding result value the most negative integer representable in the destination size, and an Invalid Operation floating-point exception is raised.

A floating-point exception can be generated by this instruction. Depending on the settings in FPCR, the exception results in either a flag being set in FPSR, or a synchronous exception being generated. For more information, see Floating-point exception traps.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

Vector single-precision and double-precision
(ARMv8.5)

### Assembler Symbols

- `<Vd>`: Is the name of the SIMD&FP destination register, encoded in the "Rd" field.
- `<Vn>`: Is the name of the SIMD&FP source register, encoded in the "Rn" field.
- `<T>`: Is an arrangement specifier, encoded in “sz:Q”:

<table>
<thead>
<tr>
<th>sz</th>
<th>Q</th>
<th>&lt;T&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>2S</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>4S</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>RESERVED</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>2D</td>
</tr>
</tbody>
</table>

### Operation

```assembly
CheckFPAdvSIMDEnabled64();
bits(datasize) operand = V[n];
bits(datasize) result;
bits(esize) element;

for e = 0 to elements-1
    element = Elem[operand, e, esize];
    Elem[result, e, esize] = FPRoundIntN(element, FPCR, rounding, intsize);

V[d] = result;
```
FRINT32X (scalar)

Floating-point Round to 32-bit Integer, using current rounding mode (scalar). This instruction rounds a floating-point value in the SIMD&FP source register to an integral floating-point value that fits into a 32-bit integer size using the rounding mode that is determined by the FPCR, and writes the result to the SIMD&FP destination register.

A zero input returns a zero result with the same sign. When the result value is not numerically equal to the input value, an Inexact exception is raised. When the input is infinite, NaN or out-of-range, the instruction returns \{for the corresponding result value\} the most negative integer representable in the destination size, and an Invalid Operation floating-point exception is raised.

A floating-point exception can be generated by this instruction. Depending on the settings in FPCR, the exception results in either a flag being set in FPSR, or a synchronous exception being generated. For more information, see Floating-point exception traps.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

Floating-point
(ARMv8.5)

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9  | 8  | 7  | 6  | 5  | 4  | 3  | 2  | 1  | 0  |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0  | 0  | 0  | 1  | 1  | 1  | 0  | 0  | 0  | 0  | x  | 1  | 0  | 1  | 0  | 0  | 0  | 1  | 1  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | Rn  | Rd  |

**type**  **op**

**Single-precision (type == 00)**

FRINT32X <Sd>, <Sn>

**Double-precision (type == 01)**

FRINT32X <Dd>, <Dn>

```plaintext
if !HaveFrintExt() then UNDEFINED;
integer d = UInt(Rd);
integer n = UInt(Rn);

integer datasize;
case type of
  when '00' datasize = 32;
  when '01' datasize = 64;
  when '1x' UNDEFINED;

integer intsize = if op<1> == '0' then 32 else 64;

FPRounding rounding = if op<0> == '0' then FPRounding_ZERO else FPRoundingMode(FPCR);
```

**Assembler Symbols**

- **<Dd>** Is the 64-bit name of the SIMD&FP destination register, encoded in the "Rd" field.
- **<Dn>** Is the 64-bit name of the SIMD&FP source register, encoded in the "Rn" field.
- **<Sd>** Is the 32-bit name of the SIMD&FP destination register, encoded in the "Rd" field.
- **<Sn>** Is the 32-bit name of the SIMD&FP source register, encoded in the "Rn" field.
CheckFPAdvSIMDEnabled64();

bits(datasize) result;
bits(datasize) operand = V[n];

result = FPRoundIntN(operand, FPCR, rounding, intsize);

V[d] = result;
FRINT32Z (vector)

Floating-point Round to 32-bit Integer toward Zero (vector). This instruction rounds a vector of floating-point values in the SIMD&FP source register to integral floating-point values that fit into a 32-bit integer size using the Round towards Zero rounding mode, and writes the result to the SIMD&FP destination register.

A zero input returns a zero result with the same sign. When one of the result values is not numerically equal to the corresponding input value, an Inexact exception is raised. When an input is infinite, NaN or out-of-range, the instruction returns for the corresponding result value the most negative integer representable in the destination size, and an Invalid Operation floating-point exception is raised.

A floating-point exception can be generated by this instruction. Depending on the settings in FPCR, the exception results in either a flag being set in FPSR, or a synchronous exception being generated. For more information, see Floating-point exception traps.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

Vector single-precision and double-precision

(ARMv8.5)

```
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9  | 8  | 7  | 6  | 5  | 4  | 3  | 2  | 1  | 0  |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0  | Q  | 0  | 1  | 1  | 1  | 0  | 0  | 0  | 0  | 1  | 1  | 1  | 1  | 0  | 1  | 0  |   |   |   |   |   |   |   |   |   |   |   |   |   |
```

U op Rn Rd

Assembler Symbols

<Vd> Is the name of the SIMD&FP destination register, encoded in the "Rd" field.

<T> Is an arrangement specifier, encoded in “sz:Q”:

<table>
<thead>
<tr>
<th>sz</th>
<th>Q</th>
<th>&lt;T&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>2S</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>4S</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>RESERVED</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>2D</td>
</tr>
</tbody>
</table>

<Vn> Is the name of the SIMD&FP source register, encoded in the "Rn" field.

Operation

```
CheckFPAdvSIMDEnabled64();
bits(datasize) operand = V[n];
bits(datasize) result;
bits(esize) element;

for e = 0 to elements-1
    element = Elem[operand, e, esize];
    Elem[result, e, esize] = FPRoundIntN(element, FPCR, rounding, intsize);

V[d] = result;
```
FRINT32Z (scalar)

Floating-point Round to 32-bit Integer toward Zero (scalar). This instruction rounds a floating-point value in the SIMD&FP source register to an integral floating-point value that fits into a 32-bit integer size using the Round towards Zero rounding mode, and writes the result to the SIMD&FP destination register.

A zero input returns a zero result with the same sign. When the result value is not numerically equal to the {corresponding} input value, an Inexact exception is raised. When the input is infinite, NaN or out-of-range, the instruction returns {for the corresponding result value} the most negative integer representable in the destination size, and an Invalid Operation floating-point exception is raised.

A floating-point exception can be generated by this instruction. Depending on the settings in FPCR, the exception results in either a flag being set in FPSR, or a synchronous exception being generated. For more information, see Floating-point exception traps.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

Floating-point
(ARMv8.5)

<table>
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<table>
<thead>
<tr>
<th>type</th>
<th>op</th>
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<tbody>
<tr>
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</tbody>
</table>

Single-precision (type == 00)

FRINT32Z <Sd>, <Sn>

Double-precision (type == 01)

FRINT32Z <Dd>, <Dn>

if !HaveFrintExt() then UNDEFINED;
integer d = UInt(Rd);
integer n = UInt(Rn);

integer datasize;
case type of
    when '00' datasize = 32;
    when '01' datasize = 64;
    when '1x' UNDEFINED;

integer intsize = if op<1> == '0' then 32 else 64;
FPRounding rounding = if op<0> == '0' then FPRounding_ZERO else FPRoundingMode(FPCR);

Assembler Symbols

<Dd> Is the 64-bit name of the SIMD&FP destination register, encoded in the "Rd" field.
<Dn> Is the 64-bit name of the SIMD&FP source register, encoded in the "Rn" field.
<Sd> Is the 32-bit name of the SIMD&FP destination register, encoded in the "Rd" field.
<Sn> Is the 32-bit name of the SIMD&FP source register, encoded in the "Rn" field.
Operation

```c
CheckFPAdvSIMDEnabled64();

bits(datasize) result;
bits(datasize) operand = V[n];

result = FPRoundIntN(operand, FPCR, rounding, intsize);
V[d] = result;
```
FRINT64X (vector)

Floating-point Round to 64-bit Integer, using current rounding mode (vector). This instruction rounds a vector of floating-point values in the SIMD&FP source register to integral floating-point values that fit into a 64-bit integer size using the rounding mode that is determined by the FPCR, and writes the result to the SIMD&FP destination register.

A zero input returns a zero result with the same sign. When one of the result values is not numerically equal to the corresponding input value, an Inexact exception is raised. When an input is infinite, NaN or out-of-range, the instruction returns for the corresponding result value the most negative integer representable in the destination size, and an Invalid Operation floating-point exception is raised.

A floating-point exception can be generated by this instruction. Depending on the settings in FPCR, the exception results in either a flag being set in FPSR, or a synchronous exception being generated. For more information, see Floating-point exception traps.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

Vector single-precision and double-precision (ARMv8.5)

```
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0  | 0  | 1  | 0  | 1  | 1  | 0  | 0  | 0  | 0  | 1  | 1  | 1  | 1  | 1  | 0  | 0  | 0  | 1  | 1  | 1  | 0  | Rn |   |   |
| U  |   |   |   |   |   |   |   |   |   | op |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
```

Vector single-precision and double-precision

```
FRINT64X <Vd>,<T>, <Vn>,<T>

if !HaveFrintExt() then UNDEFINED;
integer d = UInt(Rd);
ninteger n = UInt(Rn);

if sz:Q == '10' then UNDEFINED;
integer esize = 32 << UInt(sz);
integer elements = datasize DIV esize;
integer intsize = if op == '0' then 32 else 64;
FPRounding rounding = if U == '0' then FPRounding ZERO else FPRoundingMode(FPCR);
```

Assembler Symbols

- `<Vd>` Is the name of the SIMD&FP destination register, encoded in the "Rd" field.
- `<T>` Is an arrangement specifier, encoded in “sz:Q”:
  
  | sz | Q | <T>         
  |----|----|-------------|
  | 0  | 0  | 2S          
  | 0  | 1  | 4S          
  | 1  | 0  | RESERVED    
  | 1  | 1  | 2D          

- `<Vn>` Is the name of the SIMD&FP source register, encoded in the "Rn" field.

Operation

```
CheckFPAdvSIMDEnabled64();
bits(datasize) operand = V[n];
bits(datasize) result;
bits(esize) element;
for e = 0 to elements-1
    element = Elem[operand, e, esize];
    Elem[result, e, esize] = FPRoundIntN(element, FPCR, rounding, intsize);
V[d] = result;
```
FRINT64X (scalar)

Floating-point Round to 64-bit Integer, using current rounding mode (scalar). This instruction rounds a floating-point value in the SIMD&FP source register to an integral floating-point value that fits into a 64-bit integer size using the rounding mode that is determined by the FPCR, and writes the result to the SIMD&FP destination register.

A zero input returns a zero result with the same sign. When the result value is not numerically equal to the input value, an Inexact exception is raised. When the input is infinite, NaN or out-of-range, the instruction returns {for the corresponding result value} the most negative integer representable in the destination size, and an Invalid Operation floating-point exception is raised.

A floating-point exception can be generated by this instruction. Depending on the settings in FPCR, the exception results in either a flag being set in FPSR, or a synchronous exception being generated. For more information, see Floating-point exception traps.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

Floating-point
(ARMv8.5)

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9  | 8  | 7  | 6  | 5  | 4  | 3  | 2  | 1  | 0  |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0  | 0  | 0  | 0  | 1  | 1  | 1  | 1  | 1  | 0  | 0  | x  | 1  | 0  | 1  | 0  | 0  | 1  | 1  | 1  | 0  | 0  | 0  | Rn |

<table>
<thead>
<tr>
<th>type</th>
<th>op</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Single-precision (type == 00)

FRINT64X <Sd>, <Sn>

Double-precision (type == 01)

FRINT64X <Dd>, <Dn>

if !HaveFrintExt() then UNDEFINED;
integer d = UInt(Rd);
integer n = UInt(Rn);

integer datasize;
case type of
    when '00' datasize = 32;
    when '01' datasize = 64;
    when '1x' UNDEFINED;

integer intsize = if op<1> == '0' then 32 else 64;

FPRounding rounding = if op<0> == '0' then FPRounding_ZERO else FPRoundingMode(FPCR);

Assembler Symbols

<Dd> Is the 64-bit name of the SIMD&FP destination register, encoded in the "Rd" field.
<Dn> Is the 64-bit name of the SIMD&FP source register, encoded in the "Rn" field.
<Sd> Is the 32-bit name of the SIMD&FP destination register, encoded in the "Rd" field.
<Sn> Is the 32-bit name of the SIMD&FP source register, encoded in the "Rn" field.
Operation

```c
CheckFPAdvSIMDEnabled64();

bits(datasize) result;
bits(datasize) operand = V[n];

result = FPRoundIntN(operand, FPCR, rounding, intsize);
V[d] = result;
```

Internal version only: isa v30.25, AdvSIMD v27.01, pseudocode v85-xml-00bet8_rc3 ; Build timestamp: 2018-09-13T13:04

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FRINT64Z (vector)

Floating-point Round to 64-bit Integer toward Zero (vector). This instruction rounds a vector of floating-point values in the SIMD&FP source register to integral floating-point values that fit into a 64-bit integer size using the Round towards Zero rounding mode, and writes the result to the SIMD&FP destination register.

A zero input returns a zero result with the same sign. When one of the result values is not numerically equal to the corresponding input value, an Inexact exception is raised. When an input is infinite, NaN or out-of-range, the instruction returns for the corresponding result value the most negative integer representable in the destination size, and an Invalid Operation floating-point exception is raised.

A floating-point exception can be generated by this instruction. Depending on the settings in FPCR, the exception results in either a flag being set in FPSR, or a synchronous exception being generated. For more information, see Floating-point exception traps.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

Vector single-precision and double-precision

(ARMv8.5)

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0  | Q  | 0  | 1  | 1  | 0  | 0  | sz | 1  | 0  | 0  | 0  | 1  | 1  | 1  | 1  | 1  | 0  | Rn | Rd |
| U  | op |

Vector single-precision and double-precision

FRINT64Z <Vd>.<T>, <Vn>.<T>

if !HaveFrintExt() then UNDEFINED;
integer d = UInt(Rd);
integer n = UInt(Rn);
if sz:Q == '10' then UNDEFINED;
integer esize = 32 << UInt(sz);
integer datasize = if Q == '1' then 128 else 64;
integer elements = datasize DIV esize;
integer intsize = if op == '0' then FPRounding ZERO else FPRoundingMode(FPCR);

Assembler Symbols

<Vd> Is the name of the SIMD&FP destination register, encoded in the "Rd" field.
<T> Is an arrangement specifier, encoded in “sz:Q”:

<table>
<thead>
<tr>
<th>sz</th>
<th>Q</th>
<th>&lt;T&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>2S</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>4S</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>RESERVED</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>2D</td>
</tr>
</tbody>
</table>

<Vn> Is the name of the SIMD&FP source register, encoded in the "Rn" field.

Operation

CheckFPAdvSIMDEnabled64();

bits(datasize) operand = V[n];
bits(datasize) result;
bits(esize) element;

for e = 0 to elements-1
    element = Elem[operand, e, esize];
    Elem[result, e, esize] = FPRoundIntN(element, FPCR, rounding, intsize);

V[d] = result;
FRINT64Z (scalar)

Floating-point Round to 64-bit Integer toward Zero (scalar). This instruction rounds a floating-point value in the SIMD&FP source register to an integral floating-point value that fits into a 64-bit integer size using the Round towards Zero rounding mode, and writes the result to the SIMD&FP destination register.

A zero input returns a zero result with the same sign. When the result value is not numerically equal to the {corresponding} input value, an Inexact exception is raised. When the input is infinite, NaN or out-of-range, the instruction returns {for the corresponding result value} the most negative integer representable in the destination size, and an Invalid Operation floating-point exception is raised.

A floating-point exception can be generated by this instruction. Depending on the settings in FPCR, the exception results in either a flag being set in FPSR, or a synchronous exception being generated. For more information, see Floating-point exception traps.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

Floating-point
(ARMv8.5)

<p>| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0  | 0  | 0  | 1  | 1  | 1  | 1  | 0  | 0  | x  | 1  | 0  | 1  | 0  | 0  | 1  | 0  | 1  | 0  | 0  | 0  | 0  | Rn |
|    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
|    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |</p>
<table>
<thead>
<tr>
<th>type</th>
<th>op</th>
</tr>
</thead>
</table>

Single-precision (type == 00)

FRINT64Z <Sd>, <Sn>

Double-precision (type == 01)

FRINT64Z <Dd>, <Dn>

if !HaveFrintExt() then UNDEFINED;
integer d = UInt(Rd);
integer n = UInt(Rn);

integer datasize;
case type of
    when '00' datasize = 32;
    when '01' datasize = 64;
    when '1x' UNDEFINED;

integer intsize = if op<1> == '0' then 32 else 64;

FPRounding rounding = if op<0> == '0' then FPRounding_ZERO else FPRoundingMode(FPCR);

Assembler Symbols

<Dr> Is the 64-bit name of the SIMD&FP destination register, encoded in the "Rd" field.
<Dr> Is the 64-bit name of the SIMD&FP source register, encoded in the "Rn" field.
<Sr> Is the 32-bit name of the SIMD&FP destination register, encoded in the "Rd" field.
<Sr> Is the 32-bit name of the SIMD&FP source register, encoded in the "Rn" field.
Operation

```c
CheckFPAdvSIMDEnabled64();

bits(datasize) result;
bits(datasize) operand = V[n];

result = FPRoundIntN(operand, FPCR, rounding, intsize);

V[d] = result;
```
FRINTA (vector)

Floating-point Round to Integral, to nearest with ties to Away (vector). This instruction rounds a vector of floating-point values in the SIMD&FP source register to integral floating-point values of the same size using the Round to Nearest with Ties to Away rounding mode, and writes the result to the SIMD&FP destination register.

A zero input gives a zero result with the same sign, an infinite input gives an infinite result with the same sign, and a NaN is propagated as for normal arithmetic.

A floating-point exception can be generated by this instruction. Depending on the settings in FPCR, the exception results in either a flag being set in FPSR, or a synchronous exception being generated. For more information, see Floating-point exception traps.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

It has encodings from 2 classes: Half-precision and Single-precision and double-precision

Half-precision

(ARMv8.2)

| 31  | 30  | 29  | 28  | 27  | 26  | 25  | 24  | 23  | 22  | 21  | 20  | 19  | 18  | 17  | 16  | 15  | 14  | 13  | 12  | 11  | 10  |  9  |  8  |  7  |  6  |  5  |  4  |  3  |  2  |  1  |  0 |
|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| 0   | Q   | 1   | 0   | 1   | 1   | 1   | 0   | 1   | 1   | 1   | 0   | 0   | 1   | 1   | 0   | 0   | 0   | 1   | 0   | 0   | 1   | 0   | Rn  |   | Rd  |
| U   | o2  | o1  |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |

Half-precision

FRINTA <Vd>.<T>, <Vn>.<T>

if !HaveFP16Ext() then UNDEFINED;

ingter d = 1 then UnallocatedEncoding();

integer d = UInt(Rd);
ingter n = UInt(Rn);

integer esize = 16;
ingter datasize = if Q == '1' then 128 else 64;
ingter elements = datasize DIV esize;

boolean exact = FALSE;
FPRounding rounding;
case U:o1:o2 of
  when '0xx' rounding = FPDecodeRounding(o1:o2);
  when '100' rounding = FPRounding_TIEAWAY;
  when '101' UnallocatedEncoding();
  when '110' UnallocatedEncoding();
  when '111' UNDEFINED;
  ()
    when '110' rounding = FPRoundingMode(FPCR); exact = TRUE;
    when '111' rounding = FPRoundingMode(FPCR);

Single-precision and double-precision

| 31  | 30  | 29  | 28  | 27  | 26  | 25  | 24  | 23  | 22  | 21  | 20  | 19  | 18  | 17  | 16  | 15  | 14  | 13  | 12  | 11  | 10  |  9  |  8  |  7  |  6  |  5  |  4  |  3  |  2  |  1  |  0 |
|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| 0   | Q   | 1   | 0   | 1   | 1   | 1   | 0   | 0   | 0   | 0   | 1   | 1   | 0   | 0   | 0   | 1   | 0   | Rn  |   | Rd  |
| U   | o2  | o1  |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
### Single-precision and double-precision

\[
\text{FRINTA} \quad \langle \text{Vd} \rangle . \langle \text{T} \rangle, \quad \langle \text{Vn} \rangle . \langle \text{T} \rangle
\]

integer \( d = \text{UInt}(\text{Rd}) \);
integer \( n = \text{UInt}(\text{Rn}) \);

\[
\text{if sz:Q == '10' then UNDEFINED};
\]
integer \( e\text{size} = 32 \times \text{UInt}(\text{sz}); \)
integer \( \text{datasize} = \text{if Q == '1' then 128 else 64}; \)
integer \( \text{elements} = \text{datasize DIV esize}; \)

boolean \( \text{exact} = \text{FALSE}; \)
\( \text{FPRounding} \)
\( \text{rounding}; \)
\( \text{case U:o1:o2 of} \)
\( \text{when '0xx' rounding} = \text{FPDecodeRounding}(o1:o2); \)
\( \text{when '100' rounding} = \text{FPRounding TIEAWAY}; \)
\( \text{when '101' UNDEFINED}; \)
\( \text{when '110' rounding} = \text{FPRoundingMode}(\text{FPCR}); \text{ exact} = \text{TRUE}; \)
\( \text{when '111' rounding} = \text{FPRoundingMode}(\text{FPCR}); \)

---

### Assembler Symbols

\text{<Vd>}
\text{Is the name of the SIMD&FP destination register, encoded in the "Rd" field.}

\text{<T>}
\text{For the half-precision variant: is an arrangement specifier, encoded in "Q".}

\[
\begin{array}{c|c}
\text{Q} & \langle \text{T} \rangle \\
\hline
0 & 4H \\
1 & 8H \\
\end{array}
\]

For the single-precision and double-precision variant: is an arrangement specifier, encoded in “sz:Q”:

\[
\begin{array}{c|c|c}
\text{sz} & \text{Q} & \langle \text{T} \rangle \\
0 & 0 & 2S \\
0 & 1 & 4S \\
1 & 0 & \text{RESERVED} \\
1 & 1 & 2D \\
\end{array}
\]

\text{<Vn>}
\text{Is the name of the SIMD&FP source register, encoded in the "Rn" field.}

---

### Operation

\text{CheckFPAdvSIMDEnabled64();}
\text{bits(datasize) operand} = \( \text{V}[n] \);
\text{bits(datasize) result;}
\text{bits(esize) element;}

\[
\text{for e = 0 to elements-1}
\]
\[
\text{element} = \text{Elem}[\text{operand}, e, \text{esize}];
\]
\[
\text{Elem}[\text{result}, e, \text{esize}] = \text{FPRoundInt}(\text{element}, \text{FPCR}, \text{rounding}, \text{exact});
\]
\[
\text{V}[d] = \text{result};
\]
FRINTA (scalar)

Floating-point Round to Integral, to nearest with ties to Away (scalar). This instruction rounds a floating-point value in the SIMD&FP source register to an integral floating-point value of the same size using the Round to Nearest with Ties to Away rounding mode, and writes the result to the SIMD&FP destination register.

A zero input gives a zero result with the same sign, an infinite input gives an infinite result with the same sign, and a NaN is propagated as for normal arithmetic.

A floating-point exception can be generated by this instruction. Depending on the settings in FPCR, the exception results in either a flag being set in FPSR, or a synchronous exception being generated. For more information, see Floating-point exception traps.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

```
31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
0 0 0 1 1 1 0 | type | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | Rn | Rd |
```

rmode

Half-precision (type == 11)  
(ARMv8.2)

```
FRINTA <Hd>, <Hn>
```

Single-precision (type == 00)

```
FRINTA <Sd>, <Sn>
```

Double-precision (type == 01)

```
FRINTA <Dd>, <Dn>
```

```plaintext
integer d = UInt(Rd);
integer n = UInt(Rn);

integer datasize;
case type of
  when '00' datasize = 32;
  when '01' datasize = 64;
  when '10' UNDEFINED;
  when '11' if when '10' UnallocatedEncoding();
    datasize = 16;
  else
    UNDEFINED;

boolean exact = FALSE;
else UnallocatedEncoding();

boolean exact = FALSE;
FPRounding rounding;
case rmode of
  when '0xx' rounding = FPDecodeRounding(rmode<1:0>);
  when '100' rounding = FPRounding_TIEAWAY;
  when '101' UnallocatedEncoding;
  when '110' UNDEFINED;
    when '110' rounding = FPRoundingMode(FPCR); exact = TRUE;
  when '111' rounding = FPRoundingMode(FPCR);
```
Assembler Symbols

<Dd> Is the 64-bit name of the SIMD&FP destination register, encoded in the "Rd" field.
<Dn> Is the 64-bit name of the SIMD&FP source register, encoded in the "Rn" field.
<Hd> Is the 16-bit name of the SIMD&FP destination register, encoded in the "Rd" field.
<Hn> Is the 16-bit name of the SIMD&FP source register, encoded in the "Rn" field.
<Sd> Is the 32-bit name of the SIMD&FP destination register, encoded in the "Rd" field.
<Sn> Is the 32-bit name of the SIMD&FP source register, encoded in the "Rn" field.

Operation

```c
CheckFPAdvSIMDEnabled64();

bits(datasize) result;
bits(datasize) operand = V[n];

result = FPRoundInt(operand, FPCR, rounding, exact);
V[d] = result;
```

Copyright © 2010-2018 ARM Limited or its affiliates. All rights reserved. This document is Non-Confidential. (old) htmldiff from-(new)
FRINTI (vector)

Floating-point Round to Integral, using current rounding mode (vector). This instruction rounds a vector of floating-point values in the SIMD&FP source register to integral floating-point values of the same size using the rounding mode that is determined by the FPCR, and writes the result to the SIMD&FP destination register.

A zero input gives a zero result with the same sign, an infinite input gives an infinite result with the same sign, and a NaN is propagated as for normal arithmetic.

A floating-point exception can be generated by this instruction. Depending on the settings in FPCR, the exception results in either a flag being set in FPSR, or a synchronous exception being generated. For more information, see Floating-point exception traps.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

It has encodings from 2 classes: Half-precision and Single-precision and double-precision.

### Half-precision (ARMv8.2)

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9  | 8  | 7  | 6  | 5  | 4  | 3  | 2  | 1  | 0  |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0  | Q  | 1  | 0  | 1  | 1  | 1  | 1  | 0  | 1  | 1  | 1  | 1  | 0  | 0  | 1  | 1  | 0  | 0  | 1  | 1  | 0  | Rn | Rd |

| U | o2 | o1 |

### Half-precision

```plaintext
FRINTI <Vd>.<T>, <Vn>.<T>

if !HaveFP16Ext() then UNDEFINED;

type integer d = if !HaveFP16Ext() then UnallocatedEncoding();

integer d = UInt(Rd);
integer n = UInt(Rn);

integer esize = 16;
integer datasize = if Q == '1' then 128 else 64;
integer elements = datasize DIV esize;

boolean exact = FALSE;
FPRounding rounding;

case U:o1:o2 of
when '0xx' rounding = FPDecodeRounding(o1:o2);
when '100' rounding = FPRounding_TIEAWAY;
when '101' UnallocatedEncoding();
when '110' UNDEFINED();
when '111' rounding = FPRoundingMode(FPCR); exact = TRUE;
when '111' rounding = FPRoundingMode(FPCR);
```
Single-precision and double-precision

FRINTI <Vd>.<T>, <Vn>.<T>

integer d = UInt(Rd);
integer n = UInt(Rn);

if sz:Q == '10' then UNDEFINED;
integer esize = 32 << UInt(sz);
integer datasize = if Q == '1' then 128 else 64;
integer elements = datasize DIV esize;

boolean exact = FALSE;
FPRounding rounding;
case U:o1:o2 of
  when '0xx' rounding = FPDecodeRounding(o1:o2);
  when '100' rounding = FPRounding_TIEAWAY;
  when '101' UnallocatedEncoding;
  when '101' UNDEFINED;
  when '110' rounding = FPRoundingMode(FPCR); exact = TRUE;
  when '111' rounding = FPRoundingMode(FPCR);

Assembler Symbols

<Vd> Is the name of the SIMD&FP destination register, encoded in the "Rd" field.
<T> For the half-precision variant: is an arrangement specifier, encoded in "Q":

<table>
<thead>
<tr>
<th>Q</th>
<th>&lt;T&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>4H</td>
</tr>
<tr>
<td>1</td>
<td>8H</td>
</tr>
</tbody>
</table>

For the single-precision and double-precision variant: is an arrangement specifier, encoded in “sz:Q”:

<table>
<thead>
<tr>
<th>sz</th>
<th>Q</th>
<th>&lt;T&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>2S</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>4S</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>RESERVED</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>2D</td>
</tr>
</tbody>
</table>

<Vn> Is the name of the SIMD&FP source register, encoded in the "Rn" field.

Operation

CheckFPAdvSIMDEnabled64();
bits(datasize) operand = V[n];
bits(datasize) result;
bits(esize) element;

for e = 0 to elements-1
  element = Elem[operand, e, esize];
  Elem[result, e, esize] = FPRoundInt(element, FPCR, rounding, exact);

V[d] = result;

Internal version only: isa v30.25 v29.05 AdvSIMD v27.01 v26.0 pseudocode v85.xml-00898_rc3255 ; Build timestamp: 2018-09-13T12:59:45-04:00

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FRINTI (scalar)

Floating-point Round to Integral, using current rounding mode (scalar). This instruction rounds a floating-point value in the SIMD&FP source register to an integral floating-point value of the same size using the rounding mode that is determined by the FPCR, and writes the result to the SIMD&FP destination register.

A zero input gives a zero result with the same sign, an infinite input gives an infinite result with the same sign, and a NaN is propagated as for normal arithmetic.

A floating-point exception can be generated by this instruction. Depending on the settings in FPCR, the exception results in either a flag being set in FPSR, or a synchronous exception being generated. For more information, see Floating-point exception traps.

Depending on the settings in the CPCR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

Half-precision (type == 11)
(ARMv8.2)

FRINTI <Hd>, <Hn>

Single-precision (type == 00)

FRINTI <Sd>, <Sn>

Double-precision (type == 01)

FRINTI <Dd>, <Dn>

integer d = UInt(Rd);
integer n = UInt(Rn);

integer datasize;
case type of
  when '00' datasize = 32;
  when '01' datasize = 64;
  when '10' UNDEFINED;
  when '11' if when '110' UnallocatedEncoding();
  when '111' if HaveFP16Ext() then
datasize = 16;
else
  UNDEFINED;

boolean exact = FALSE; else
UnallocatedEncoding();

boolean exact = FALSE;
FPRounding rounding;
case rmode of
  when '0xx' rounding = FPDecodeRounding(rmode<1:0>);
  when '100' rounding = FPRounding_TIEAWAY;
  when '111' UnallocatedEncoding();
  when '110' UNDEFINED;
  when '111' rounding = FPRoundingMode(FPCR); exact = TRUE;
  when '111' rounding = FPRoundingMode(FPCR);
Assembler Symbols

&lt;Dd&gt; Is the 64-bit name of the SIMD&FP destination register, encoded in the "Rd" field.
&lt;Dn&gt; Is the 64-bit name of the SIMD&FP source register, encoded in the "Rn" field.
&lt;Hd&gt; Is the 16-bit name of the SIMD&FP destination register, encoded in the "Rd" field.
&lt;Hn&gt; Is the 16-bit name of the SIMD&FP source register, encoded in the "Rn" field.
&lt;Sd&gt; Is the 32-bit name of the SIMD&FP destination register, encoded in the "Rd" field.
&lt;Sn&gt; Is the 32-bit name of the SIMD&FP source register, encoded in the "Rn" field.

Operation

```c
CheckFPAdvSIMDEnabled64();

bits(datasize) result;
bits(datasize) operand = V[n];
result = FPRoundInt(operand, FPCR, rounding, exact);
V[d] = result;
```

Internal version only: isa v30.25, AdvSIMD v27.01, pseudocode v85-xml-00bet8_rc3531; Build timestamp: 2018-09-13 13:45
Copyright © 2010-2018 ARM Limited or its affiliates. All rights reserved. This document is Non-Confidential.
FRINTM (vector)

Floating-point Round to Integral, toward Minus infinity (vector). This instruction rounds a vector of floating-point values in the SIMD&FP source register to integral floating-point values of the same size using the Round towards Minus Infinity rounding mode, and writes the result to the SIMD&FP destination register.

A zero input gives a zero result with the same sign, an infinite input gives an infinite result with the same sign, and a NaN is propagated as for normal arithmetic.

A floating-point exception can be generated by this instruction. Depending on the settings in FPCR, the exception results in either a flag being set in FPSR, or a synchronous exception being generated. For more information, see Floating-point exception traps.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

It has encodings from 2 classes: Half-precision and Single-precision and double-precision.

**Half-precision (ARMv8.2)**

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0  | Q  | 0  | 1  | 1  | 1  | 0  | 0  | 1  | 1  | 1  | 0  | 0  | 1  | 1  | 0  | 0  | 1  | 1  | 0  | Rn | Rd |
| U  | o2 | o1 |

**Single-precision and double-precision**

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0  | Q  | 0  | 1  | 1  | 1  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 1  | 1  | 0  | 0  | 1  | 1  | 0  | Rn | Rd |
| U  | o2 | o1 |
Single-precision and double-precision

\[ \text{FRINTM } \langle Vd \rangle \langle T \rangle, \langle Vn \rangle \langle T \rangle \]

integer \( d = \text{UInt}(Rd) \);
integer \( n = \text{UInt}(Rn) \);

if \( \text{sz:Q} == '10' \) then \text{UNDEFINED};
integer \( \text{esize} = 32 \times \text{UInt}(\text{sz}) \);
integer \( \text{datasize} = \text{if} \ \text{Q} == '1' \ \text{then} \ 128 \ \text{else} \ 64 \);
integer \( \text{elements} = \text{datasize} \div \text{esize} \);

boolean \( \text{exact} = \text{FALSE}; \)
\( \text{FPRounding} \ \text{rounding}; \)
case U:01:02 of
  when '0xx' \( \text{rounding} = \text{FPDecodeRounding}(o1:o2) \);
  when '100' \( \text{rounding} = \text{FPRounding TIEAWAY} \);
  when '101' \( \text{UnallocatedEncoding} \);
  when '101' \( \text{UNDEFINED} \);
  when '110' \( \text{rounding} = \text{FPRoundingMode}(\text{FPCR}); \ \text{exact} = \text{TRUE}; \)
  when '111' \( \text{rounding} = \text{FPRoundingMode}(\text{FPCR}); \)

Assembler Symbols

\(<Vd>\) Is the name of the SIMD&FP destination register, encoded in the "Rd" field.

\(<T>\) For the half-precision variant: is an arrangement specifier, encoded in "Q":

<table>
<thead>
<tr>
<th>Q</th>
<th>&lt;T&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>\text{4H}</td>
</tr>
<tr>
<td>1</td>
<td>\text{8H}</td>
</tr>
</tbody>
</table>

For the single-precision and double-precision variant: is an arrangement specifier, encoded in “sz:Q”:

<table>
<thead>
<tr>
<th>sz</th>
<th>Q</th>
<th>&lt;T&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>\text{2}S</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>\text{4}S</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>\text{RESERVED}</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>\text{2D}</td>
</tr>
</tbody>
</table>

\(<Vn>\) Is the name of the SIMD&FP source register, encoded in the "Rn" field.

Operation

\(\text{CheckFPAdvSIMDEnabled64}()\);
\(\text{bits}(<\text{datasize}) \ \text{operand} = V[n];\)
\(\text{bits}(<\text{datasize}) \ \text{result};\)
\(\text{bits}(<\text{esize}) \ \text{element};\)

for \( e = 0 \) to elements-1
  \( \text{element} = \text{Elem}[\text{operand}, e, \text{esize}]; \)
  \( \text{Elem}[\text{result}, e, \text{esize}] = \text{FPRoundInt}(\text{element}, \text{FPCR}, \text{rounding}, \text{exact}); \)

\( V[d] = \text{result}; \)
FRINTM (scalar)

Floating-point Round to Integral, toward Minus infinity (scalar). This instruction rounds a floating-point value in the SIMD&FP source register to an integral floating-point value of the same size using the Round towards Minus Infinity rounding mode, and writes the result to the SIMD&FP destination register.

A zero input gives a zero result with the same sign, an infinite input gives an infinite result with the same sign, and a NaN is propagated as for normal arithmetic.

A floating-point exception can be generated by this instruction. Depending on the settings in FPCR, the exception results in either a flag being set in FPSR, or a synchronous exception being generated. For more information, see Floating-point exception traps.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9  | 8  | 7  | 6  | 5  | 4  | 3  | 2  | 1  | 0  |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0  | 0  | 1  | 1  | 1  | 1  | 0  | type| 1  | 0  | 0  | 1  | 0  | 1  | 0  | 1  | 0  | 0  | 0  | 0  | 0  | Rn | Rd |

rmode

Half-precision (type == 11)
(ARMv8.2)

FRINTM <Hd>, <Hn>

Single-precision (type == 00)

FRINTM <Sd>, <Sn>

Double-precision (type == 01)

FRINTM <Dd>, <Dn>

```plaintext
integer d = UInt(Rd);
integer n = UInt(Rn);

integer datasize;

<table>
<thead>
<tr>
<th>datasize</th>
</tr>
</thead>
<tbody>
<tr>
<td>32</td>
</tr>
<tr>
<td>64</td>
</tr>
<tr>
<td>UNDEFINED</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>case type of</th>
</tr>
</thead>
<tbody>
<tr>
<td>'00' datasize = 32;</td>
</tr>
<tr>
<td>'01' datasize = 64;</td>
</tr>
<tr>
<td>'10' UNDEFINED;</td>
</tr>
<tr>
<td>'11' if '10' UnallocatedEncoding();</td>
</tr>
<tr>
<td>'11' if HaveFP16Ext() then</td>
</tr>
<tr>
<td>datasize = 16;</td>
</tr>
<tr>
<td>else</td>
</tr>
<tr>
<td>UNDEFINED;</td>
</tr>
</tbody>
</table>

boolean exact = FALSE; else UnallocatedEncoding();

boolean exact = FALSE;

FPRounding rounding;

<table>
<thead>
<tr>
<th>rounding</th>
</tr>
</thead>
<tbody>
<tr>
<td>FPRoundingTIEAWAY&lt;1:0&gt;</td>
</tr>
<tr>
<td>FPRoundingTIEAWAY&lt;1:0&gt;</td>
</tr>
<tr>
<td>UnallocatedEncoding();</td>
</tr>
<tr>
<td>UnallocatedEncoding();</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>case rmode of</th>
</tr>
</thead>
<tbody>
<tr>
<td>'0xx' rounding = FPRoundingTIEAWAY&lt;1:0&gt;;</td>
</tr>
<tr>
<td>'100' rounding = FPRoundingTIEAWAY&lt;1:0&gt;;</td>
</tr>
<tr>
<td>'101' UnallocatedEncoding();</td>
</tr>
<tr>
<td>'110' UnallocatedEncoding();</td>
</tr>
<tr>
<td>'111' rounding = FPRoundingTIEAWAY&lt;1:0&gt;;</td>
</tr>
<tr>
<td>'110' UnallocatedEncoding();</td>
</tr>
<tr>
<td>'111' rounding = FPRoundingTIEAWAY&lt;1:0&gt;;</td>
</tr>
</tbody>
</table>
```
Assembler Symbols

<DD> Is the 64-bit name of the SIMD&FP destination register, encoded in the "Rd" field.

<DN> Is the 64-bit name of the SIMD&FP source register, encoded in the "Rn" field.

<HD> Is the 16-bit name of the SIMD&FP destination register, encoded in the "Rd" field.

<Hn> Is the 16-bit name of the SIMD&FP source register, encoded in the "Rn" field.

<SD> Is the 32-bit name of the SIMD&FP destination register, encoded in the "Rd" field.

<SN> Is the 32-bit name of the SIMD&FP source register, encoded in the "Rn" field.

Operation

```c
CheckFPAdvSIMDEnabled64();

bits(datasize) result;
bits(datasize) operand = V[n];

result = FPRoundInt(operand, FPCR, rounding, exact);
V[d] = result;
```


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FRINTN (vector)

Floating-point Round to Integral, to nearest with ties to even (vector). This instruction rounds a vector of floating-point values in the SIMD&FP source register to integral floating-point values of the same size using the Round to Nearest rounding mode, and writes the result to the SIMD&FP destination register.

A zero input gives a zero result with the same sign, an infinite input gives an infinite result with the same sign, and a NaN is propagated as for normal arithmetic.

A floating-point exception can be generated by this instruction. Depending on the settings in $FPCR$, the exception results in either a flag being set in $FPSR$, or a synchronous exception being generated. For more information, see Floating-point exception traps.

Depending on the settings in the $CPACR_EL1$, $CPTR_EL2$, and $CPTR_EL3$ registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

It has encodings from 2 classes: Half-precision and Single-precision and double-precision

### Half-precision
(ARMv8.2)

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9  | 8  | 7  | 6  | 5  | 4  | 3  | 2  | 1  | 0  |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0  | Q  | 0  | 0  | 1  | 1  | 1  | 0  | 0  | 1  | 1  | 1  | 0  | 0  | 1  | 0  | 0  | 0  | 1  | 0  | 1  | 0  | Rn |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| U  |    | o2 |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |     |    |    |    |    |    |    |    |    |    |
| o1 |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |

Half-precision

FRINTN <$Vd>$,$<T>$, <$Vn>$,$<T>$

if !HaveFP16Ext() then UNDEFINED;

integer d = -1 then UnallocatedEncoding();
integer d = UInt(Rd);
integer n = UInt(Rn);

integer esize = 16;
integer datasize = if Q == '1' then 128 else 64;
integer elements = datasize DIV esize;

boolean exact = FALSE;
FPRounding rounding;
case U:o1:o2 of
  when '0xx' rounding = FPDecodeRounding(o1:o2);
  when '100' rounding = FPRounding_TIEAWAY;
  when '101' UnallocatedEncoding();
  when '110' UNDEFINED;
  when '111' rounding = FPRoundingMode(FPCR);

Single-precision and double-precision

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9  | 8  | 7  | 6  | 5  | 4  | 3  | 2  | 1  | 0  |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0  | Q  | 0  | 0  | 1  | 1  | 1  | 0  | 0  | 1  | 0  | 0  | 1  | 1  | 0  | 0  | 0  | 1  | 1  | 0  | 1  | 0  | Rn |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| U  |    | o2 |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |     |    |    |    |    |    |    |    |    |    |
| o1 |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
Single-precision and double-precision

FRINTN <Vd>,<T>, <Vn>,<T>

integer d = UInt(Rd);
integer n = UInt(Rn);

if sz:Q == '10' then UNDEFINED;
integer esize = 32;
integer datasize = if Q == '1' then 128 else 64;
integer elements = datasize DIV esize;

boolean exact = FALSE;
FPRounding rounding;
case U:o1:o2 of
  when '0xx' rounding = FPDecodeRounding(o1:o2);
  when '100' rounding = FPRounding_TIEAWAY;
  when '101' UnallocatedEncoding;
  when '110' rounding = FPRoundingMode(FPCR); exact = TRUE;
  when '111' rounding = FPRoundingMode(FPCR);

Assembler Symbols

<Vd> Is the name of the SIMD&FP destination register, encoded in the "Rd" field.
<T> For the half-precision variant: is an arrangement specifier, encoded in "Q":

<table>
<thead>
<tr>
<th>Q</th>
<th>&lt;T&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>4H</td>
</tr>
<tr>
<td>1</td>
<td>8H</td>
</tr>
</tbody>
</table>

For the single-precision and double-precision variant: is an arrangement specifier, encoded in “sz:Q”:

<table>
<thead>
<tr>
<th>sz</th>
<th>Q</th>
<th>&lt;T&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>2S</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>4S</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>RESERVED</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>2D</td>
</tr>
</tbody>
</table>

<Vn> Is the name of the SIMD&FP source register, encoded in the "Rn" field.

Operation

CheckFPAdvSIMDEnabled64();
bits(datasize) operand = V[n];
bits(datasize) result;
bits(esize) element;

for e = 0 to elements-1
  element = Elem[operand, e, esize];
  Elem[result, e, esize] = FPRoundInt(element, FPCR, rounding, exact);
V[d] = result;

Internal version only: isa v30.25 v29.05 AdvSIMD v27.01 v26.0 pseudocode v85-xml-00beta_re3_v35_2018-09-13T13:2018-06-16+04:04
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FRINTN (scalar)

Floating-point Round to Integral, to nearest with ties to even (scalar). This instruction rounds a floating-point value in the SIMD&FP source register to an integral floating-point value of the same size using the Round to Nearest rounding mode, and writes the result to the SIMD&FP destination register.

A zero input gives a zero result with the same sign, an infinite input gives an infinite result with the same sign, and a NaN is propagated as for normal arithmetic.

A floating-point exception can be generated by this instruction. Depending on the settings in FPCR, the exception results in either a flag being set in FPSR, or a synchronous exception being generated. For more information, see Floating-point exception traps.

Depending on the settings on the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
0 0 0 1 1 1 1 0 1 type 1 0 0 1 0 0 0 1 Rd Rd

Half-precision (type == 11)
(ARMv8.2)

FRINTN <Hd>, <Hn>

Single-precision (type == 00)

FRINTN <Sd>, <Sn>

Double-precision (type == 01)

FRINTN <Dd>, <Dn>

integer d = UInt(Rd);
integer n = UInt(Rn);

integer datasize;
-case type of
  -when '00' datasize = 32;
  -when '01' datasize = 64;
  -when '10' UNDEFINED;
  -when '11' if when '10'
    -UnallocatedEncoding();
  -else UNDEFINED;

Boolean exact = FALSE;

Boolean exact = FALSE;

FPRounding rounding;
-case rmode of
  -when '0xx' rounding = FPDecodeRounding(rmode<1:0>);
  -when '100' rounding = FPRounding_TIEAWAY;
  -when '111' UnallocatedEncoding();
  -when '101' UNDEFINED;

 Boolean exact = FALSE;
  -when '110' rounding = FPRoundingMode(FPCR); exact = TRUE;
  -when '111' rounding = FPRoundingMode(FPCR);
Assembler Symbols

<d> Is the 64-bit name of the SIMD&FP destination register, encoded in the "Rd" field.
<dn> Is the 64-bit name of the SIMD&FP source register, encoded in the "Rn" field.
<hd> Is the 16-bit name of the SIMD&FP destination register, encoded in the "Rd" field.
<hn> Is the 16-bit name of the SIMD&FP source register, encoded in the "Rn" field.
<s> Is the 32-bit name of the SIMD&FP destination register, encoded in the "Rd" field.
<sn> Is the 32-bit name of the SIMD&FP source register, encoded in the "Rn" field.

Operation

CheckFPAdvSIMDEnabled64();

bits(datasize) result;
bits(datasize) operand = V[n];

result = FPRoundInt(operand, FPCR, rounding, exact);

V[d] = result;

Internal version only: isa v30.25, AdvSIMD v27.01, pseudocode v85-xml-00bet8_rc3v358 ; Build timestamp: 2018-09-13T13:2018-06-16T09:45

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FRINTP (vector)

Floating-point Round to Integral, toward Plus infinity (vector). This instruction rounds a vector of floating-point values in the SIMD&FP source register to integral floating-point values of the same size using the Round towards Plus Infinity rounding mode, and writes the result to the SIMD&FP destination register.

A zero input gives a zero result with the same sign, an infinite input gives an infinite result with the same sign, and a NaN is propagated as for normal arithmetic.

A floating-point exception can be generated by this instruction. Depending on the settings in FPCR, the exception results in either a flag being set in FPSR, or a synchronous exception being generated. For more information, see Floating-point exception traps.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

It has encodings from 2 classes: Half-precision and Single-precision and double-precision

### Half-precision

**ARMv8.2**

<table>
<thead>
<tr>
<th>31</th>
<th>30</th>
<th>29</th>
<th>28</th>
<th>27</th>
<th>26</th>
<th>25</th>
<th>24</th>
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<th>18</th>
<th>17</th>
<th>16</th>
<th>15</th>
<th>14</th>
<th>13</th>
<th>12</th>
<th>11</th>
<th>10</th>
<th>9</th>
<th>8</th>
<th>7</th>
<th>6</th>
<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Q</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
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</tr>
<tr>
<td>Rn</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>U</td>
<td>o2</td>
<td>o1</td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

### Half-precision

FRINTP <Vd.<T>, <Vn>.<T>

```plaintext
if !HaveFP16Ext() then UNDEFINED;

integer d = s1 then UnallocatedEncoding();
integer d = UInt(Rd);
integer n = UInt(Rn);

integer esize = 16;
integer datasize = if Q == '1' then 128 else 64;
integer elements = datasize DIV esize;

boolean exact = FALSE;
FPRounding rounding;
case U:ol:oz of
    when '0xx' rounding = FPDecodeRounding(o1:o2);
    when '100' rounding = FPRounding_TIEAWAY;
    when '101' UnallocatedEncoding();
    when '110' UNDEFINED();
    when '111' rounding = FPRoundingMode(FPCR); exact = TRUE;
when '111' rounding = FPRoundingMode(FPCR);
```

### Single-precision and double-precision

<table>
<thead>
<tr>
<th>31</th>
<th>30</th>
<th>29</th>
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<th>27</th>
<th>26</th>
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<th>10</th>
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<th>8</th>
<th>7</th>
<th>6</th>
<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Q</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>sz</td>
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<td>Rn</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>U</td>
<td>o2</td>
<td>o1</td>
<td></td>
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</tr>
</tbody>
</table>
Single-precision and double-precision

FRINTP <Vd>.<T>, <Vn>.<T>

integer d = UInt(Rd);
integer n = UInt(Rn);

if sz:Q == '10' then UNDEFINED;
integer esize = 32 << UInt(sz);
integer datasize = if Q == '1' then 128 else 64;
integer elements = datasize DIV esize;

boolean exact = FALSE;
FPRounding rounding;
case U:o1:o2 of
  when '0xx' rounding = FPDecodeRounding(o1:o2);
  when '100' rounding = FPRounding_TIEAWAY;
  when '101' UnallocatedEncoding;
  when '110' rounding = FPRoundingMode(FPCR); exact = TRUE;
  when '111' rounding = FPRoundingMode(FPCR);

Assembler Symbols

<Vd> Is the name of the SIMD&FP destination register, encoded in the "Rd" field.
<T> For the half-precision variant: is an arrangement specifier, encoded in "Q":

<table>
<thead>
<tr>
<th>Q</th>
<th>&lt;T&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>4H</td>
</tr>
<tr>
<td>1</td>
<td>8H</td>
</tr>
</tbody>
</table>

For the single-precision and double-precision variant: is an arrangement specifier, encoded in “sz:Q”:

<table>
<thead>
<tr>
<th>sz</th>
<th>Q</th>
<th>&lt;T&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>2S</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>4S</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>RESERVED</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>2D</td>
</tr>
</tbody>
</table>

<Vn> Is the name of the SIMD&FP source register, encoded in the "Rn" field.

Operation

CheckFPAdvSIMDEnabled64();
bits(datasize) operand = V[n];
bits(datasize) result;
bits(esize) element;

for e = 0 to elements-1
  element = Elem[operand, e, esize];
  Elem[result, e, esize] = FPRoundInt(element, FPCR, rounding, exact);

V[d] = result;
FRINTP (scalar)

Floating-point Round to Integral, toward Plus infinity (scalar). This instruction rounds a floating-point value in the SIMD&FP source register to an integral floating-point value of the same size using the Round towards Plus Infinity rounding mode, and writes the result to the SIMD&FP destination register.

A zero input gives a zero result with the same sign, an infinite input gives an infinite result with the same sign, and a NaN is propagated as for normal arithmetic.

A floating-point exception can be generated by this instruction. Depending on the settings in FPCR, the exception results in either a flag being set in FPSR, or a synchronous exception being generated. For more information, see Floating-point exception traps.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9  | 8  | 7  | 6  | 5  | 4  | 3  | 2  | 1  | 0  |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0  | 0  | 0  | 1  | 1  | 1  | 1  | 0  | type | 1  | 0  | 0  | 1  | 0  | 0  | 1  | 1  | 0  | 0  | 0  | Rd |

rmode

Half-precision (type == 11)
(ARMv8.2)

FRINTP <Hd>, <Hn>

Single-precision (type == 00)

FRINTP <Sd>, <Sn>

Double-precision (type == 01)

FRINTP <Dd>, <Dn>

```plaintext
integer d = UInt(Rd);
integer n = UInt(Rn);

integer datasize;
case type of
    when '00' datasize = 32;
    when '01' datasize = 64;
    when '10' UNDEFINED;
    when '11' if when '10' UnallocatedEncoding();
    when '11' if HaveFP16Ext() then
datasize = 16;
else
    UNDEFINED;

boolean exact = FALSE;
else
    UnallocatedEncoding();

boolean exact = FALSE;
FPRounding rounding;
case rmode of
    when '0xx' rounding = FPDecodeRounding(rmode<1:0>);
    when '100' rounding = FPRounding_TIEAWAY;
    when '101' UnallocatedEncoding;
    when '110' rounding = FPRoundingMode(FPCR); exact = TRUE;
    when '111' rounding = FPRoundingMode(FPCR);
```

FRINTP (scalar)
Assembler Symbols

<DD> Is the 64-bit name of the SIMD&FP destination register, encoded in the "Rd" field.
<DN> Is the 64-bit name of the SIMD&FP source register, encoded in the "Rn" field.
<HD> Is the 16-bit name of the SIMD&FP destination register, encoded in the "Rd" field.
<HN> Is the 16-bit name of the SIMD&FP source register, encoded in the "Rn" field.
<SD> Is the 32-bit name of the SIMD&FP destination register, encoded in the "Rd" field.
<SN> Is the 32-bit name of the SIMD&FP source register, encoded in the "Rn" field.

Operation

CheckFPAdvSIMDEnabled64();

bits(datasize) result;
bits(datasize) operand = V[n];

result = FPRoundInt(operand, FPCR, rounding, exact);
V[d] = result;

Internal version only: isa v30.25 v29.05, AdvSIMD v27.01 v26.0, pseudocode v85-xml-00bte8_rc3e354 ; Build timestamp: 2018-09-13 2018-06-16 09:45

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FRINTX (vector)

Floating-point Round to Integral exact, using current rounding mode (vector). This instruction rounds a vector of floating-point values in the SIMD&FP source register to integral floating-point values of the same size using the rounding mode that is determined by the FPCR, and writes the result to the SIMD&FP destination register.

When an Inexact exception is raised when the result value is not numerically equal to the corresponding input value, an Inexact exception is raised. A zero input gives a zero result with the same sign, an infinite input gives an infinite result with the same sign, and a NaN is propagated as for normal arithmetic.

A floating-point exception can be generated by this instruction. Depending on the settings in FPCR, the exception results in either a flag being set in FPSR, or a synchronous exception being generated. For more information, see Floating-point exception traps.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

It has encodings from 2 classes: Half-precision and Single-precision and double-precision

**Half-precision**

(ARMv8.2)

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 |  9 |  8 |  7 |  6 |  5 |  4 |  3 |  2 |  1 |  0 |
| 0 | Q | 1 | 0 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 1 | 0 |   |   |   |   |   |   |   |   |
|   | U |   | o2 |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
|   |   | o1 |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |

**Single-precision and double-precision**

FRINTX <Vd>.<T>, <Vn>.<T>

if !HaveFP16Ext() then UNDEFINED;

integer d = -1; then UnallocatedEncoding();

integer d = UInt(Rd);
integer n = UInt(Rn);

integer esize = 16;
integer datasize = if Q == '1' then 128 else 64;
integer elements = datasize DIV esize;

boolean exact = FALSE;
FPRounding rounding;
case U:o1:o2 of

when '0xx' rounding = FPCFRounding(o1:o2);
when '100' rounding = FPRounding_TIEAWAY;
when '101' UnallocatedEncoding();
when '110' UnallocatedEncoding();
when '111' UNDEFINED;

when '110' rounding = FPRoundingMode(FPCR); exact = TRUE;
when '111' rounding = FPRoundingMode(FPCR);
Single-precision and double-precision

FRINTX <Vd>.<T>, <Vn>.<T>

integer d = UInt(Rd);
integer n = UInt(Rn);

if sz:Q == '10' then UNDEFINED;
integer esize = 32 << if sz:Q == '10' then ReservedValue();
integer datasize = if Q == '1' then 128 else 64;
integer elements = datasize DIV esize;

boolean exact = FALSE;
FPRounding rounding;
case U:o1:o2 of
  when '0xx' rounding = FPDecodeRounding(o1:o2);
  when '100' rounding = FPRounding_TIEAWAY;
  when '101' UnallocatedEncoding;
  when '110' rounding = FPRoundingMode(FPCR); exact = TRUE;
  when '111' rounding = FPRoundingMode(FPCR);

Assembler Symbols

<Vd> Is the name of the SIMD&FP destination register, encoded in the "Rd" field.
<T> For the half-precision variant: is an arrangement specifier, encoded in "Q":

<table>
<thead>
<tr>
<th>Q</th>
<th>&lt;T&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>4H</td>
</tr>
<tr>
<td>1</td>
<td>8H</td>
</tr>
</tbody>
</table>

For the single-precision and double-precision variant: is an arrangement specifier, encoded in "sz:Q":

<table>
<thead>
<tr>
<th>sz</th>
<th>Q</th>
<th>&lt;T&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>2S</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>4S</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>RESERVED</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>2D</td>
</tr>
</tbody>
</table>

<Vn> Is the name of the SIMD&FP source register, encoded in the "Rn" field.

Operation

CheckFPAdvSIMDEnabled64();
bits(datasize) operand = V[n];
bits(datasize) result;
bits(esize) element;

for e = 0 to elements-1
element = Elem[operand, e, esize];
   Elem[result, e, esize] = FPRoundInt(element, FPCR, rounding, exact);
V[d] = result;
FRINTX (scalar)

Floating-point Round to Integral exact, using current rounding mode (scalar). This instruction rounds a floating-point value in the SIMD&FP source register to an integral floating-point value of the same size using the rounding mode that is determined by the FPCR, and writes the result to the SIMD&FP destination register.

When an Inexact exception is raised when the result value is not numerically equal to the input value, an Inexact exception is raised. A zero input gives a zero result with the same sign, an infinite input gives an infinite result with the same sign, and a NaN is propagated as for normal arithmetic.

A floating-point exception can be generated by this instruction. Depending on the settings in FPCR, the exception results in either a flag being set in FPSR, or a synchronous exception being generated. For more information, see Floating-point exception traps.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

### Half-precision (type == 11)
(ARMv8.2)

```assembly
FRINTX <Hd>, <Hn>
```

### Single-precision (type == 00)

```assembly
FRINTX <Sd>, <Sn>
```

### Double-precision (type == 01)

```assembly
FRINTX <Dd>, <Dn>
```

```plaintext
type | Rd | Rd 
--- | --- | --- 
0   | 1   | 1 
1   | 1   | 1 
1   | 1   | 0 
1   | 0   | 0 
0   | 0   | 0 
Rn   
```

```plaintext
type | Rd | Rd 
--- | --- | --- 
0   | 1   | 1 
1   | 1   | 1 
1   | 1   | 0 
1   | 0   | 0 
0   | 0   | 0 
Rn   
```

integer d = UInt(Rd);
integer n = UInt(Rn);

integer datasize;

```plaintext
case type of 
  when '00' datasize = 32;
  when '01' datasize = 64;
  when '10' UNDEFINED;
  when '11' if when '10' UnallocatedEncoding();
  when '11' if HaveFP16Ext() then 
    datasize = 16;
  else 
    UNDEFINED;
```

boolean exact = FALSE; else UnallocatedEncoding();

```plaintext
boolean exact = FALSE;
FPRounding rounding;
```

```plaintext
case rmode of 
  when '0xx' rounding = FPDecodeRounding(rmode<1:0>);
  when '100' rounding = FPRounding_TIEAWAY;
  when '101' UNDEFINED;
  when '110' rounding = FPRoundingMode(FPCR);
  when '111' rounding = FPRoundingMode(FPCR);
```

integer datasize;
```plaintext
case type of 
  when '00' datasize = 32;
  when '01' datasize = 64;
  when '10' UNDEFINED;
  when '11' if when '10' UnallocatedEncoding();
  when '11' if HaveFP16Ext() then 
    datasize = 16;
  else 
    UNDEFINED;
```

boolean exact = FALSE; else UnallocatedEncoding();

boolean exact = FALSE;
FPRounding rounding;
```plaintext
case rmode of 
  when '0xx' rounding = FPDecodeRounding(rmode<1:0>);
  when '100' rounding = FPRounding_TIEAWAY;
  when '101' UNDEFINED;
  when '110' rounding = FPRoundingMode(FPCR);
  when '111' rounding = FPRoundingMode(FPCR);
```
Assembler Symbols

<DD> Is the 64-bit name of the SIMD&FP destination register, encoded in the "Rd" field.

<DN> Is the 64-bit name of the SIMD&FP source register, encoded in the "Rn" field.

<HD> Is the 16-bit name of the SIMD&FP destination register, encoded in the "Rd" field.

<HN> Is the 16-bit name of the SIMD&FP source register, encoded in the "Rn" field.

<SD> Is the 32-bit name of the SIMD&FP destination register, encoded in the "Rd" field.

<SN> Is the 32-bit name of the SIMD&FP source register, encoded in the "Rn" field.

Operation

CheckFPAdvSIMDEnabled64();

bits(datasize) result;
bits(datasize) operand = V[n];

result = FPRoundInt(operand, FPCR, rounding, exact);

V[d] = result;

Internal version only: isa v30.25, AdvSIMD v27.01, pseudocode v85-xml-00bet8_rc3v35a; Build timestamp: 2018-09-13T13:20:45

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FRINTZ (vector)

Floating-point Round to Integral, toward Zero (vector). This instruction rounds a vector of floating-point values in the SIMD&FP source register to integral floating-point values of the same size using the Round towards Zero rounding mode, and writes the result to the SIMD&FP destination register.

A zero input gives a zero result with the same sign, an infinite input gives an infinite result with the same sign, and a NaN is propagated as for normal arithmetic.

A floating-point exception can be generated by this instruction. Depending on the settings in FPCR, the exception results in either a flag being set in FPSR, or a synchronous exception being generated. For more information, see Floating-point exception traps.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

It has encodings from 2 classes: Half-precision and Single-precision and double-precision

### Half-precision

(ARMv8.2)

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0  | Q  | 0  | 0  | 1  | 1  | 1  | 1  | 0  | 1  | 1  | 1  | 1  | 1  | 0  | 0  | 1  | 1  | 0  | 0  | 1  | 1  | 0  | Rn | Rd |
| U  | o2 |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
|    | o1 |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |

#### Half-precision

FRINTZ <Vd>.<T>, <Vn>.<T>

if !HaveFP16Ext() then UNDEFINED;

integer d = 1; then UnallocatedEncoding();

integer d = UInt(Rd);
integer n = UInt(Rn);

integer esize = 16;
integer datasize = if Q == '1' then 128 else 64;
integer elements = datasize DIV esize;

boolean exact = FALSE;

FPRounding rounding;

case U:o1:o2 of
when '0xx' rounding = FPDecodeRounding(o1:o2);
when '100' rounding = FPRounding_TIEAWAY;
when '101' UnallocatedEncoding();
when '110' UNDEFINED();

when '111' rounding = FPRoundingMode(FPCR); exact = TRUE;
when '111' rounding = FPRoundingMode(FPCR);

### Single-precision and double-precision

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0  | Q  | 0  | 0  | 1  | 1  | 1  | 0  | 1  | 0  | 0  | 0  | 0  | 1  | 1  | 0  | 0  | 1  | 1  | 0  | Rn | Rd |
| U  | o2 |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
|    | o1 |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
Single-precision and double-precision

\[ \text{FRINTZ} \ <Vd>.<T>, \ <Vn>.<T> \]

\[
\begin{align*}
\text{integer} \ d &= \text{UInt}(\text{Rd}); \\
\text{integer} \ n &= \text{UInt}(\text{Rn}); \\
\text{if sz:Q} &= '10' \text{ then UNDEFINED;}
\end{align*}
\]

\[
\begin{align*}
\text{integer} \ \text{esize} &= 32 \text{ if sz:Q} \text{ == '10' then ReservedValue();} \\
\text{integer} \ \text{datasize} &= \text{if Q} == '1' \text{ then 128 else 64;}
\end{align*}
\]

\[
\begin{align*}
\text{integer} \ \text{elements} &= \text{datasize DIV esize;}
\end{align*}
\]

\[
\begin{align*}
\text{boolean} \ \text{exact} &= \text{FALSE;}
\end{align*}
\]

\[
\begin{align*}
\text{FPRounding} \ \text{rounding;} \\
\text{case U:o1:o2 of} \\
\quad \text{when '0xx' rounding} &= \text{FPDecodeRounding(o1:o2);} \\
\quad \text{when '100' rounding} &= \text{FPRounding TIEAWAY;} \\
\quad \text{when '101' \ UnallocatedEncoding} &= \text{}; \\
\quad \text{when '110' rounding} &= \text{FPRoundingMode(FPCR); exact} = \text{TRUE;} \\
\quad \text{when '111' rounding} &= \text{FPRoundingMode(FPCR);} \\
\end{align*}
\]

Assembler Symbols

\begin{itemize}
\item \(<Vd>\) \quad \text{Is the name of the SIMD&FP destination register, encoded in the "Rd" field.}
\item \(<T>\) \quad \text{For the half-precision variant: is an arrangement specifier, encoded in "Q".}
\end{itemize}

\[
\begin{array}{c|c}
\text{Q} & \text{T} \\
\hline
0 & 4H \\
1 & 8H \\
\end{array}
\]

\[
\begin{itemize}
\item \(<Vn>\) \quad \text{Is the name of the SIMD&FP source register, encoded in the "Rn" field.}
\end{itemize}

Operation

\[
\begin{align*}
\text{CheckFPAdvSIMDEnabled64();} \\
\text{bits(datasize) operand} &= \text{V}[n]; \\
\text{bits(datasize) result;} \\
\text{bits(esize) element;} \\
\text{for e = 0 to elements-1} \\
\text{element} &= \text{Elem}[\text{operand, e, esize}]; \\
\text{Elem}[\text{result, e, esize}] &= \text{FPRoundInt}(\text{element, FPCR, rounding, exact}); \\
\text{V}[d] &= \text{result;}
\end{align*}
\]
FRINTZ (scalar)

Floating-point Round to Integral, toward Zero (scalar). This instruction rounds a floating-point value in the SIMD&FP source register to an integral floating-point value of the same size using the Round towards Zero rounding mode, and writes the result to the SIMD&FP destination register.

A zero input gives a zero result with the same sign, an infinite input gives an infinite result with the same sign, and a NaN is propagated as for normal arithmetic.

A floating-point exception can be generated by this instruction. Depending on the settings in FPCR, the exception results in either a flag being set in FPSR, or a synchronous exception being generated. For more information, see Floating-point exception traps.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9  | 8  | 7  | 6  | 5  | 4  | 3  | 2  | 1  | 0  |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0  | 0  | 0  | 1  | 1  | 1  | 0  | type| 1  | 0  | 0  | 1  | 0  | 1  | 1  | 1  | 1  | 0  | 0  | 0  | 0  | Rd |

rmode

Half-precision (type == 11) (ARMv8.2)

FRINTZ <Hd>, <Hn>

Single-precision (type == 00)

FRINTZ <Sd>, <Sn>

Double-precision (type == 01)

FRINTZ <Dd>, <Dn>

integer d = UInt(Rd);
integer n = UInt(Rn);

integer datasize;
case type of
    when '00' datasize = 32;
    when '01' datasize = 64;
    when '10' UNDEFINED;
    when '11' if when '10'
        UnallocatedEncoding();
        datasize = 16;
        else
            UNDEFINED;
    boolean exact = FALSE;

    when '0xx' rounding = FPDecodeRounding(rmode<1:0>);
    when '100' rounding = FPRounding_TIEAWAY;
    when '111' UnallocatedEncoding();
    when '101' UNDEFINED;
        if HaveFP16Ext () then
            datasize = 16;
        else
            UNDEFINED;
        boolean exact = FALSE;

    FPRounding rounding;
case rmode of
    when '0xx' rounding = FPDecodeRounding(rmode<1:0>);
    when '100' rounding = FPRounding_TIEAWAY;
    when '111' UnallocatedEncoding();
    when '101' UNDEFINED;
        when '110' rounding = FPRoundingMode(FPCR); exact = TRUE;
        when '111' rounding = FPRoundingMode(FPCR);
Assembler Symbols

<Dd> Is the 64-bit name of the SIMD&FP destination register, encoded in the "Rd" field.
<Dn> Is the 64-bit name of the SIMD&FP source register, encoded in the "Rn" field.
<Hd> Is the 16-bit name of the SIMD&FP destination register, encoded in the "Rd" field.
<Hn> Is the 16-bit name of the SIMD&FP source register, encoded in the "Rn" field.
<Sd> Is the 32-bit name of the SIMD&FP destination register, encoded in the "Rd" field.
<Sn> Is the 32-bit name of the SIMD&FP source register, encoded in the "Rn" field.

Operation

```
CheckFPAdvSIMDEnabled64();

bits(datasize) result;
bits(datasize) operand = V[n];
result = FPRoundInt(operand, FPCR, rounding, exact);
V[d] = result;
```

Internal version only: isa v30.25, v29.05, v27.01, v26.0, pseudocode v85-xml-00bet8_rc3v35v; Build timestamp: 2018-09-13T13:20:45

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FRSRTE

Floating-point Reciprocal Square Root Estimate. This instruction calculates an approximate square root for each vector element in the source SIMD&FP register, places the result in a vector, and writes the vector to the destination SIMD&FP register.

This instruction can generate a floating-point exception. Depending on the settings in \textit{FPCR}, the exception results in either a flag being set in \textit{FPSR} or a synchronous exception being generated. For more information, see \textit{Floating-point exception traps}.

Depending on the settings in the \textit{CPACR_EL1}, \textit{CPTR_EL2}, and \textit{CPTR_EL3} registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

It has encodings from 4 classes: \textbf{Scalar half precision} , \textbf{Scalar single-precision and double-precision} , \textbf{Vector half precision} and \textbf{Vector single-precision and double-precision}

Scalar half precision
\textbf{(ARMv8.2)}

\begin{verbatim}
31  30  29  28  27  26  25  24  23  22  21  20  19  18  17  16  15  14  13  12  11  10  9  8  7  6  5  4  3  2  1  0
0  1  1  1  1  1  0  1  1  1  1  0  0  1  1  1  0  1  1  0  Rn  Rd
\end{verbatim}

Scalar half precision
\textbf{FRSRTE} <Hd>, <Hn>

\begin{verbatim}
if !HaveFP16Ext() then UNDEFINED;
integer d = i; then UnallocatedEncoding();
integer d = UInt(Rd);
integer n = UInt(Rn);
integer esize = 16;
integer datasize = esize;
integer elements = 1;
\end{verbatim}

Scalar single-precision and double-precision

\begin{verbatim}
31  30  29  28  27  26  25  24  23  22  21  20  19  18  17  16  15  14  13  12  11  10  9  8  7  6  5  4  3  2  1  0
0  1  1  1  1  1  0  1  sz 1  0  0  0  0  1  1  1  0  1  1  0  Rn  Rd
\end{verbatim}

Scalar single-precision and double-precision

\textbf{FRSRTE} <V><d>, <V><n>

\begin{verbatim}
integer d = UInt(Rd);
integer n = UInt(Rn);
integer esize = 32 << UInt(sz);
integer datasize = esize;
integer elements = 1;
\end{verbatim}

Vector half precision
\textbf{(ARMv8.2)}

\begin{verbatim}
31  30  29  28  27  26  25  24  23  22  21  20  19  18  17  16  15  14  13  12  11  10  9  8  7  6  5  4  3  2  1  0
0  Q 1  0  1  1  1  0  1  1  1  1  1  0  0  1  1  1  0  1  1  0  Rn  Rd
\end{verbatim}
Vector half precision

FRSQRTE <Vd>.<T>, <Vn>.<T>

if !HaveFP16Ext() then UNDEFINED;

integer d = UInt(Rd);
integer n = UInt(Rn);

integer esize = 16;
integer datasize = if Q == '1' then 128 else 64;
integer elements = datasize DIV esize;

Vector single-precision and double-precision

integersize = 32 << if sz:Q == '10' then ReservedValue();
integer esize = 32 << UInt(sz);
integer datasize = if Q == '1' then 128 else 64;
integer elements = datasize DIV esize;

Assembler Symbols

<Hd> Is the 16-bit name of the SIMD&FP destination register, encoded in the "Rd" field.

<In> Is the 16-bit name of the SIMD&FP source register, encoded in the "Rn" field.

<V> Is a width specifier, encoded in "sz":

<table>
<thead>
<tr>
<th>sz</th>
<th>&lt;V&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>S</td>
</tr>
<tr>
<td>1</td>
<td>D</td>
</tr>
</tbody>
</table>

<d> Is the number of the SIMD&FP destination register, encoded in the "Rd" field.

<n> Is the number of the SIMD&FP source register, encoded in the "Rn" field.

<Vd> Is the name of the SIMD&FP destination register, encoded in the "Rd" field.

For the vector half precision variant: is an arrangement specifier, encoded in “Q”:

<table>
<thead>
<tr>
<th>Q</th>
<th>&lt;T&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>4H</td>
</tr>
<tr>
<td>1</td>
<td>8H</td>
</tr>
</tbody>
</table>

For the vector single-precision and double-precision variant: is an arrangement specifier, encoded in “sz:Q”:

<table>
<thead>
<tr>
<th>sz</th>
<th>Q</th>
<th>&lt;T&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>2S</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>4S</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>RESERVED</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>2D</td>
</tr>
</tbody>
</table>

<Vn> Is the name of the SIMD&FP source register, encoded in the "Rn" field.
Operation

```c
CheckFPAdvSIMDEnabled64();

bits(datasize) operand = V[n];
bits(datasize) result;
bits(esize) element;

for e = 0 to elements-1
element = Elem[operand, e, esize];
    Elem[result, e, esize] = FPRSqrtEstimate(element, FPCR);

V[d] = result;
```

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FRSQRTS

Floating-point Reciprocal Square Root Step. This instruction multiplies corresponding floating-point values in the vectors of the two source SIMD&FP registers, subtracts each of the products from 3.0, divides these results by 2.0, places the results into a vector, and writes the vector to the destination SIMD&FP register.

This instruction can generate a floating-point exception. Depending on the settings in FPCR, the exception results in either a flag being set in FPSR, or a synchronous exception being generated. For more information, see Floating-point exception traps.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

It has encodings from 4 classes: Scalar half precision, Scalar single-precision and double-precision, Vector half precision and Vector single-precision and double-precision

Scalar half precision

(ARMv8.2)

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0  | 1  | 0  | 1  | 1  | 1  | 0  | 1  | 1  | 0  | Rm | 0  | 0  | 1  | 1  | 1  | 1  | Rn | 1  | 1  | 1  | 1  | 1  | Rd |

Scalar half precision

FRSQRTS <Hd>, <Hn>, <Hm>

if !HaveFP16Ext() then UNDEFINED;

integer d = 1; then UnallocatedEncoding();

integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rm);
integer esize = 16;
integer datasize = esize;
integer elements = 1;

Scalar single-precision and double-precision

(ARMv8.2)

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0  | 1  | 0  | 1  | 1  | 1  | 0  | 1  | sz | 1  | Rm | 1  | 1  | 1  | 1  | 1  | 1  | Rn | 1  | 1  | 1  | 1  | 1  | Rd |

Scalar single-precision and double-precision

FRSQRTS <V>d>, <V>n>, <V>m>

integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rm);
integer esize = 32 << UInt(sz);
integer datasize = esize;
integer elements = 1;

Vector half precision

(ARMv8.2)

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0  | Q  | 0  | 0  | 1  | 1  | 0  | 1  | 1  | 0  | Rm | 0  | 0  | 1  | 1  | 1  | 1  | Rn | 0  | 0  | 1  | 1  | 1  | Rd |
Vector half precision

FRSQRTS <Vd>.<T>, <Vn>.<T>, <Vm>.<T>

if !HaveFP16Ext() then UNDEFINED;

integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rm);
integer esize = 16;
integer datasize = if Q == '1' then 128 else 64;
integer elements = datasize DIV esize;

Vector single-precision and double-precision

FRSQRTS <Vd>.<T>, <Vn>.<T>, <Vm>.<T>

integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rm);
if sz:Q == '10' then UNDEFINED;
integer esize = 32 << if sz:Q == '10' then ReservedValue();
integer esize = 32 <<UInt(sz);
integer datasize = if Q == '1' then 128 else 64;
integer elements = datasize DIV esize;

Assembler Symbols

<Hd> Is the 16-bit name of the SIMD&FP destination register, encoded in the "Rd" field.

<Hn> Is the 16-bit name of the first SIMD&FP source register, encoded in the "Rn" field.

<Hm> Is the 16-bit name of the second SIMD&FP source register, encoded in the "Rm" field.

<V> Is a width specifier, encoded in “sz”:

<table>
<thead>
<tr>
<th>sz</th>
<th>&lt;V&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>S</td>
</tr>
<tr>
<td>1</td>
<td>D</td>
</tr>
</tbody>
</table>

<d> Is the number of the SIMD&FP destination register, in the "Rd" field.

<n> Is the number of the first SIMD&FP source register, encoded in the "Rn" field.

<m> Is the number of the second SIMD&FP source register, encoded in the "Rm" field.

<Vd> Is the name of the SIMD&FP destination register, encoded in the "Rd" field.

<T> For the vector half precision variant: is an arrangement specifier, encoded in “Q”:

<table>
<thead>
<tr>
<th>Q</th>
<th>&lt;T&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>4H</td>
</tr>
<tr>
<td>1</td>
<td>8H</td>
</tr>
</tbody>
</table>

For the vector single-precision and double-precision variant: is an arrangement specifier, encoded in “sz:Q”:

<table>
<thead>
<tr>
<th>sz</th>
<th>Q</th>
<th>&lt;T&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>2S</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>4S</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>RESERVED</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>2D</td>
</tr>
</tbody>
</table>

<Vn> Is the name of the first SIMD&FP source register, encoded in the "Rn" field.

<Vm> Is the name of the second SIMD&FP source register, encoded in the "Rm" field.
Operation

```c
CheckFPAdvSIMDEnabled64();
bits(datasize) operand1 = V[n];
bits(datasize) operand2 = V[m];
bits(datasize) result;
bits(esize) element1;
bits(esize) element2;

for e = 0 to elements-1
    element1 = Elem[operand1, e, esize];
    element2 = Elem[operand2, e, esize];
    Elem[result, e, esize] = FPRSQRTStepFused(element1, element2);
V[d] = result;
```
FSQRT (vector)

Floating-point Square Root (vector). This instruction calculates the square root for each vector element in the source SIMD&FP register, places
the result in a vector, and writes the vector to the destination SIMD&FP register.

This instruction can generate a floating-point exception. Depending on the settings in FPCR, the exception results in either a flag being set in
FPSR or a synchronous exception being generated. For more information, see Floating-point exception traps.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an
attempt to execute the instruction might be trapped.

It has encodings from 2 classes: Half-precision and Single-precision and double-precision

Half-precision (ARMv8.2)

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9  | 8  | 7  | 6  | 5  | 4  | 3  | 2  | 1  | 0  |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0  | Q | 1 | 0 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | Rn | Rd |

Half-precision

FSQRT <Vd>.<T>, <Vn>.<T>

if !HaveFP16Ext() then UNDEFINED;
integer d = UInt(Rd);
integer n = UInt(Rn);
integer esize = 16;
integer datasize = if Q == '1' then 128 else 64;
integer elements = datasize DIV esize;

Single-precision and double-precision

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9  | 8  | 7  | 6  | 5  | 4  | 3  | 2  | 1  | 0  |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0  | Q | 1 | 0 | 1 | 1 | 0 | 0 | 0 | sz | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | Rn | Rd |

Single-precision and double-precision

FSQRT <Vd>.<T>, <Vn>.<T>

integer d = UInt(Rd);
integer n = UInt(Rn);
if sz:Q == '10' then UNDEFINED;
integer esize = 32 << if sz:Q == '10' then ReservedValue();
integer esize = 32 << UInt(sz);
integer datasize = if Q == '1' then 128 else 64;
integer elements = datasize DIV esize;

Assembler Symbols

<Vd> Is the name of the SIMD&FP destination register, encoded in the "Rd" field.
<T> For the half-precision variant: is an arrangement specifier, encoded in “Q”:

<table>
<thead>
<tr>
<th>Q</th>
<th>&lt;T&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>4H</td>
</tr>
<tr>
<td>1</td>
<td>8H</td>
</tr>
</tbody>
</table>

For the single-precision and double-precision variant: is an arrangement specifier, encoded in “sz:Q”: 
<table>
<thead>
<tr>
<th>sz</th>
<th>Q</th>
<th>&lt;T&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>2S</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>4S</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>RESERVED</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>2D</td>
</tr>
</tbody>
</table>

<\text{Vn}> Is the name of the SIMD&FP source register, encoded in the "Rn" field.

**Operation**

```c
CheckFPAdvSIMDEnabled64();
bits(\text{datasize}) \text{ operand} = \text{V}[n];
bits(\text{datasize}) \text{ result};
bits(\text{esize}) \text{ element};

\text{for e = 0 to elements-1}
  \text{element = Elem[operand, e, esize];}
  \text{Elem[result, e, esize] = FPSqrt(element, FPCR);} \\
\text{V[d] = result;}
```

Internal version only: isa v30.25\^28.15, Adv\text{SIMD} v27.01\^26.0, pseudocode v85-xml-008ee8\_rc3c35e; Build timestamp: 2018-09-13T13:2018-06-16T04:44

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FSQRT (scalar)

Floating-point Square Root (scalar). This instruction calculates the square root of the value in the SIMD&FP source register and writes the result to the SIMD&FP destination register.

A floating-point exception can be generated by this instruction. Depending on the settings in FPCR, the exception results in either a flag being set in FPSR, or a synchronous exception being generated. For more information, see Floating-point exception traps.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

Half-precision (type == 11)
(ARMv8.2)

FSQRT <Hd>, <Hn>

Single-precision (type == 00)

FSQRT <Sd>, <Sn>

Double-precision (type == 01)

FSQRT <Dd>, <Dn>

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|-----|-----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0   | 0   | 0  | 1  | 1  | 1  | 0  | 1   | 0   | 0   | 0   | 1   | 1   | 1   | 0   | 0   | 0   | 0   | Rd |

opc

integer d = UInt(Rd);
integer n = UInt(Rn);

integer datasize;
case type of
    when '00' datasize = 32;
    when '01' datasize = 64;
    when '10' UNDEFINED;
    when '11' if when '10' UnallocatedEncoding();
        when '11' if HaveFP16Ext() then
datasize = 16;
        else UnallocatedEncoding() then
datasize = 16;
        else UNDEFINED();

FPUnaryOp fpop;
case opc of
    when '00' fpop = FPUnaryOp_MOV;
    when '01' fpop = FPUnaryOp_ABS;
    when '10' fpop = FPUnaryOp_NEG;
    when '11' fpop = FPUnaryOp_SQRT;

Assembler Symbols

<Dd> Is the 64-bit name of the SIMD&FP destination register, encoded in the "Rd" field.
<Dn> Is the 64-bit name of the SIMD&FP source register, encoded in the "Rn" field.
<Hd> Is the 16-bit name of the SIMD&FP destination register, encoded in the "Rd" field.
<Hn> Is the 16-bit name of the SIMD&FP source register, encoded in the "Rn" field.
Is the 32-bit name of the SIMD&FP destination register, encoded in the "Rd" field.

Is the 32-bit name of the SIMD&FP source register, encoded in the "Rn" field.

**Operation**

```c
CheckFPAdvSIMDEnabled64();

bits(datasize) result;
bits(datasize) operand = V[n];

case fpop of
    when FPUnaryOp_MOV          result = operand;
    when FPUnaryOp_ABS          result = FPAbs(operand);
    when FPUnaryOp_NEG          result = FPNeg(operand);
    when FPUnaryOp_SQRT         result = FPSqrt(operand, FPCR);

V[d] = result;
```

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FSUB (vector)

Floating-point Subtract (vector). This instruction subtracts the elements in the vector in the second source SIMD&FP register, from the corresponding elements in the vector in the first source SIMD&FP register, places each result into elements of a vector, and writes the vector to the destination SIMD&FP register.

This instruction can generate a floating-point exception. Depending on the settings in FPCR, the exception results in either a flag being set in FPSR, or a synchronous exception being generated. For more information, see Floating-point exception traps.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

It has encodings from 2 classes: Half-precision and Single-precision and double-precision

### Half-precision

(ARMv8.2)

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0  | Q  | 0  | 0  | 1  | 1  | 1  | 0  | 1  | 1  | 0  | Rm | 0  | 0  | 0  | 1  | 0  | 1  | Rn | Rd |
|    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
|    | U  |

### Single-precision and double-precision

FSUB <Vd>.<T>, <Vn>.<T>, <Vm>.<T>

if !HaveFP16Ext() then UNDEFINED;
integer d = U1() then UnallocatedEncoding(4);
integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rm);
integer esize = 16;
integer datasize = if Q == '1' then 128 else 64;
integer elements = datasize DIV esize;
boolean abs = (U == '1');

### Single-precision and double-precision

FSUB <Vd>.<T>, <Vn>.<T>, <Vm>.<T>

integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rm);
if sz:Q == '10' then UNDEFINED;
integer esize = 32 << if sz:Q == '10' then ReservedValue(1);
integer esize = 32 << UInt(sz);
integer datasize = if Q == '1' then 128 else 64;
integer elements = datasize DIV esize;
boolean abs = (U == '1');

### Assembler Symbols

<Vd> Is the name of the SIMD&FP destination register, encoded in the "Rd" field.
<T> For the half-precision variant: is an arrangement specifier, encoded in “Q”:
For the single-precision and double-precision variant: is an arrangement specifier, encoded in “sz:Q”:

<table>
<thead>
<tr>
<th>sz</th>
<th>Q</th>
<th>&lt;T&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>2S</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>4S</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>RESERVED</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>2D</td>
</tr>
</tbody>
</table>

<Vn> Is the name of the first SIMD&FP source register, encoded in the “Rn” field.

<Vm> Is the name of the second SIMD&FP source register, encoded in the “Rm” field.

Operation

```c
CheckFPAdvSIMDEnabled64();
bits(datasize) operand1 = V[n];
bits(datasize) operand2 = V[m];
bits(datasize) result;
bits(esize) element1;
bits(esize) element2;
bits(esize) diff;
for e = 0 to elements-1
    element1 = Elem[operand1, e, esize];
    element2 = Elem[operand2, e, esize];
    diff = FPSub(element1, element2, FPCR);
    Elem[result, e, esize] = if abs then FPAbs(diff) else diff;
V[d] = result;
```
FSUB (scalar)

Floating-point Subtract (scalar). This instruction subtracts the floating-point value of the second source SIMD&FP register from the floating-point value of the first source SIMD&FP register, and writes the result to the destination SIMD&FP register.

This instruction can generate a floating-point exception. Depending on the settings in FPCR, the exception results in either a flag being set in FPSR, or a synchronous exception being generated. For more information, see Floating-point exception traps.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

```
31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
0 0 0 1 1 1 0 | type | 1 | Rm | 0 0 1 | 1 | 1 0 | Rn | Rd
```

Half-precision (type == 11)
(ARMv8.2)

FSUB <Hd>, <Hn>, <Hm>

Single-precision (type == 00)

FSUB <Sd>, <Sn>, <Sm>

Double-precision (type == 01)

FSUB <Dd>, <Dn>, <Dm>

```
icenter integer d = UInt(Rd);
icenter integer n = UInt(Rn);
icenter integer m = UInt(Rm);

center integer datasize;
center case type of
  when '00' datasize = 32;
  when '01' datasize = 64;
  when '10' UNDEFINED;
  when '11' if when '10' UnallocatedEncoding() then datasize = 16;
   else UnallocatedEncoding() then datasize = 16;
   else UNDEFINED;
4:

boolean sub_op = (op == '1');
```

Assembler Symbols

- **<Dd>** Is the 64-bit name of the SIMD&FP destination register, encoded in the "Rd" field.
- **<Dn>** Is the 64-bit name of the first SIMD&FP source register, encoded in the "Rn" field.
- **<Dm>** Is the 64-bit name of the second SIMD&FP source register, encoded in the "Rm" field.
- **<Hd>** Is the 16-bit name of the SIMD&FP destination register, encoded in the "Rd" field.
- **<Hn>** Is the 16-bit name of the first SIMD&FP source register, encoded in the "Rn" field.
- **<Hm>** Is the 16-bit name of the second SIMD&FP source register, encoded in the "Rm" field.
<Sd> Is the 32-bit name of the SIMD&FP destination register, encoded in the "Rd" field.

<Sn> Is the 32-bit name of the first SIMD&FP source register, encoded in the "Rn" field.

<Sm> Is the 32-bit name of the second SIMD&FP source register, encoded in the "Rm" field.

**Operation**

```plaintext
CheckFPAdvSIMDEnabled64();
bits(datasize) result;
bits(datasize) operand1 = V[n];
bits(datasize) operand2 = V[m];

if sub_op then
    result = FPSub(operand1, operand2, FPCR);
else
    result = FPAdd(operand1, operand2, FPCR);

V[d] = result;
```

Internal version only: isa v30.25, AdvSIMD v27.01, pseudocode v85-xml-00bet8_rc3; Build timestamp: 2018-09-13T13:2018-06-16T09:04:45

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GMI

Tag Mask Insert inserts the tag in the first source register into the excluded set specified in the second source register, writing the new excluded set to the destination register.

Integer
(ARMv8.5)

|   | 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9  | 8  | 7  | 6  | 5  | 4  | 3  | 2  | 1  | 0  |
|---|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|    |
|Xm| 0  | 0  | 0  | 1  | 0  | 1  | 1  | 0  | 1  | 0  | 1  | 1  | 0  | 1  | 1  | 0  | 1  | 0  | 1  | 0  | 1  | 0  | 1  | 0  | 1  | 0  | 1  | 0  | 1  | 0  | 1  |   |
|Xn| 0  | 0  | 0  | 1  | 0  | 1  | 0  | 1  | 0  | 1  | 0  | 1  | 0  | 1  | 0  | 1  | 0  | 1  | 0  | 1  | 0  | 1  | 0  | 1  | 0  | 1  | 0  | 1  | 0  | 1  | 0  |   |
|Xd| 1  | 0  | 0  | 0  | 1  | 1  | 0  | 1  | 1  | 0  | 0  | 1  | 0  | 1  | 0  | 1  | 1  | 0  | 0  | 1  | 0  | 1  | 1  | 0  | 0  | 1  | 0  | 1  | 1  | 0  | 0  |   |

Assembler Symbols

<Xd> Is the 64-bit name of the general-purpose destination register, encoded in the "Xd" field.
<Xn|SP> Is the 64-bit name of the first source general-purpose register or stack pointer, encoded in the "Xn" field.
<Xm> Is the 64-bit name of the second general-purpose source register, encoded in the " Xm" field.

Operation

```plaintext
bits(64) address = if n == 31 then SP[] else X[n];
b_bits(64) mask = X[m];
b_bits(4) tag = AllocationTagFromAddress(address);
mask<UInt(tag)> = '1';
X[d] = mask;
```

Internal version only: isa v30.25, AdvSIMD v27.01, pseudocode v85-xml-00be8_rc3 ; Build timestamp: 2018-09-13T13:04
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HINT

Hint instruction is for the instruction set space that is reserved for architectural hint instructions.

Some encodings described here are not allocated in this revision of the architecture, and behave as NOPs. These encodings might be allocated to other hint functionality in future revisions of the architecture and therefore must not be used by software.

<table>
<thead>
<tr>
<th>CRm</th>
<th>op2</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

System

HINT #<imm>

```c
SystemHintOp op;

case CRm:op2 of
  when '0000 000' op = SystemHintOp_NOP;
  when '0000 001' op = SystemHintOp_YIELD;
  when '0000 010' op = SystemHintOp_WFE;
  when '0000 011' op = SystemHintOp_WFI;
  when '0000 100' op = SystemHintOp_SEV;
  when '0000 101' op = SystemHintOp_SEVL;
  when '0000 111'   SEE "XPACLRI";
  when '0001 xxx'   SEE "PACIA1716, PACIB1716, AUTIA1716, AUTIB1716";
  when '0010 000'   if !HaveRASExt() then EndOfInstruction();          // Instruction executes as NOP
               op = SystemHintOp_ESB;
  when '0010 001'   if !HaveStatisticalProfiling() then EndOfInstruction(); // Instruction executes as NOP
               op = SystemHintOp_PSB;
  when '0010 010'   if !HaveSelfHostedTrace() then EndOfInstruction();   // Instruction executes as NOP
               op = SystemHintOp_TSB;
  when '0010 100'   op = SystemHintOp_CSDB;
  when '0011 xxx'   SEE "PACIAZ, PACIAZP, PACIBZ, PACIBSP, AUTIAZ, AUTIASP, AUTIBZ, AUTIBSP";
  when '0100 xxx'   otherwise SystemHintOp_BTI;
  otherwise         BTypeCompatible = BTypeCompatible_BTI(op2<2:1>);
                    EndOfInstruction();                                 // Instruction executes as NOP
```

Assembler Symbols

<imm> Is a 7-bit unsigned immediate, in the range 0 to 127 encoded in the "CRm:op2" field.

The encodings that are allocated to architectural hint functionality are described in the "Hints" table in the "Index by Encoding".

For allocated encodings of "CRm:op2":

- A disassembler will disassemble the allocated instruction, rather than the HINT instruction.
- An assembler may support assembly of allocated encodings using HINT with the corresponding <imm> value, but it is not required to do so.
case op of
  when SystemHintOp_YIELD
    Yield();
  when SystemHintOp_WFE
    if IsEventRegisterSet() then
      ClearEventRegister();
    else
      if PSTATE.EL == EL0 then
        // Check for traps described by the OS which may be EL1 or EL2.
        AArch64.CheckForWFXTrap(EL1, TRUE);
      if EL2Enabled() && PSTATE.EL IN {EL0, EL1} && !IsInHost() then
        // Check for traps described by the Hypervisor.
        AArch64.CheckForWFXTrap(EL2, TRUE);
      if HaveEL(EL3) && PSTATE.EL != EL3 then
        // Check for traps described by the Secure Monitor.
        AArch64.CheckForWFXTrap(EL3, TRUE);
      WaitForEvent();
  when SystemHintOp_WFI
    if !InterruptPending() then
      if PSTATE.EL == EL0 then
        // Check for traps described by the OS which may be EL1 or EL2.
        AArch64.CheckForWFXTrap(EL1, FALSE);
      if EL2Enabled() && PSTATE.EL IN {EL0, EL1} && !IsInHost() then
        // Check for traps described by the Hypervisor.
        AArch64.CheckForWFXTrap(EL2, FALSE);
      if HaveEL(EL3) && PSTATE.EL != EL3 then
        // Check for traps described by the Secure Monitor.
        AArch64.CheckForWFXTrap(EL3, FALSE);
      WaitForInterrupt();
  when SystemHintOp_SEVSsendEvent();
  when SystemHintOp_SEVLSendEventLocal();
  when SystemHintOp_ESBSynchronizeErrors();
    AArch64.ESSOperation();
    if EL2Enabled() && PSTATE.EL IN {EL0, EL1} then AArch64.vESBOperation();
    TakeUnmaskedErrorInterrupts();
  when SystemHintOp_PSBProfilingSynchronizationBarrier();
  when SystemHintOp_TSB
    TraceSynchronizationBarrier();
  when SystemHintOp_CSDCConsumptionOfSpeculativeDataBarrier();
    when otherwise // do nothing SystemHintOp_BTI
      BTTypeNext = '00';
    otherwise // do nothing

Internal version only: isa v33.0.25.2025, AdvSIMD v27.0.1025, pseudocode v85-xml-00bet8_rc355 ; Build timestamp: 2018-09-13T13:04:45

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HLT

Halt instruction generates a Halt Instruction debug event. HLT instruction can generate a Halt Instruction debug event, which causes entry into Debug state.

![HLT instruction bit representation](image)

31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0

1 1 0 1 0 0 1 0 0 0 1 0 | imm16
| 0 0 0 0 0

System

HLT #<imm>

```assembly
if ESCR.HDE == '0' || !HaltingAllowed() then UndefinedFault();
if() then UndefinedFault(); HaveBTIExt() then
  BTypeCompatible = TRUE;
```

Assembler Symbols

<imm> Is a 16-bit unsigned immediate, in the range 0 to 65535, encoded in the "imm16" field.

Operation

```assembly
Halt(DebugHalt_HaltInstruction);
```


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Hypervisor Call causes an exception to EL2. Non-secure software executing at EL1 can use this instruction to call the hypervisor to request a service.

The HVC instruction is UNDEFINED:

- At EL0, and Secure EL1.
- When SCR_EL3.HCE is set to 0.

On executing an HVC instruction, the PE records the exception as a Hypervisor Call exception in ESR_ELx, using the EC value 0x16, and the value of the immediate argument.

31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0

| 1 1 | 0 1 0 | 1 0 0 | 0 0 0 | imm16 | 0 0 0 | 1 0 |

System

HVC #<imm>

bits(16) imm = imm16;

Assembler Symbols

<imm> Is a 16-bit unsigned immediate, in the range 0 to 65535, encoded in the "imm16" field.

Operation

if !HaveEL(EL2) || PSTATE.EL == EL0 || (PSTATE.EL == EL1 & & (!IsSecureEL2Enabled() & & IsSecure())) then
  UNDEFINED;

hvc_enable = if ())) then UnallocatedEncoding();

hvc_enable = if HaveEL(EL3) then SCR_EL3.HCE else NOT(HCR_EL2.HCD);
if hvc_enable == '0' then
  AArch64.UndefinedFault();
else
  AArch64.CallHypervisor(imm);

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INS (element)

Insert vector element from another vector element. This instruction copies the vector element of the source SIMD&FP register to the specified vector element of the destination SIMD&FP register. This instruction can insert data into individual elements within a SIMD&FP register without clearing the remaining bits to zero. Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

This instruction is used by the alias MOV (element).

Advanced SIMD

INS <Vd>.<Ts>[<index1>], <Vn>.<Ts>[<index2>]

integer d = UInt(Rd);
integer n = UInt(Rn);
integer size = LowestSetBit(imm5);
if size > 3 then UNDEFINED;
integer dst_index = if size > 3 then UnallocatedEncoding();
integer dst_index = UInt(imm5<4:size+1>);
integer src_index = UInt(imm4<3:size>);
integer idxdsize = if imm4<3> == '1' then 128 else 64;
// imm4<size-1:0> is IGNORED
integer esize = 8 << size;

Assembler Symbols

<Vd>      Is the name of the SIMD&FP destination register, encoded in the "Rd" field.
<Ts>     Is an element size specifier, encoded in “imm5”:

<index1>   Is the destination element index encoded in “imm5”:

<index2>   Is the source element index encoded in “imm5:imm4”:

Unspecified bits in “imm4” are ignored but should be set to zero by an assembler.
Operation

CheckFPAdvSIMDEnabled64();
bits(idxdsize) operand = \textit{V}[n];
bits(128) result;
result = \textit{V}[d];
\textit{Elem}[result, dst\_index, esize] = \textit{Elem}[operand, src\_index, esize];
\textit{V}[d] = result;

Operational information

If PSTATE.DIT is 1:

\begin{itemize}
  \item The execution time of this instruction is independent of:
    \begin{itemize}
      \item The values of the data supplied in any of its registers.
      \item The values of the NZCV flags.
    \end{itemize}
  \item The response of this instruction to asynchronous exceptions does not vary based on:
    \begin{itemize}
      \item The values of the data supplied in any of its registers.
      \item The values of the NZCV flags.
    \end{itemize}
\end{itemize}
**INS (general)**

Insert vector element from general-purpose register. This instruction copies the contents of the source general-purpose register to the specified vector element in the destination SIMD&FP register.

This instruction can insert data into individual elements within a SIMD&FP register without clearing the remaining bits to zero. Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

This instruction is used by the alias MOV (from general).

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9  | 8  | 7  | 6  | 5  | 4  | 3  | 2  | 1  | 0  |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0  | 1  | 0  | 0  | 1  | 1  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 1  | 1  | 1  | 1  | 1  | 0  | 0  | 0  | 1  | 1  | 1  | 0  | 0  | 0  | 0  | 0  | 0  |

**Advanced SIMD**

INS <Vd>.<Ts>[<index>], <R><n>

integer d = UInt(Rd);
integer n = UInt(Rn);
integer size = LowestSetBit(imm5);
if size > 3 then UNDEFINED;
integer index = if size > 3 then UnallocatedEncoding();
integer index = UInt(imm5<4:size+1>);
integer esize = 8 << size;
integer datasize = 128;

**Assembler Symbols**

<Vd> Is the name of the SIMD&FP destination register, encoded in the "Rd" field.

<Ts> Is an element size specifier, encoded in “imm5”:

<table>
<thead>
<tr>
<th>imm5</th>
<th>&lt;Ts&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>x0000</td>
<td>RESERVED</td>
</tr>
<tr>
<td>xxxx1</td>
<td>B</td>
</tr>
<tr>
<td>xxxx10</td>
<td>H</td>
</tr>
<tr>
<td>xx100</td>
<td>S</td>
</tr>
<tr>
<td>x1000</td>
<td>D</td>
</tr>
</tbody>
</table>

<index> Is the element index encoded in “imm5”:

<table>
<thead>
<tr>
<th>imm5</th>
<th>&lt;index&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>x0000</td>
<td>RESERVED</td>
</tr>
<tr>
<td>xxxx1</td>
<td>imm5&lt;4:1&gt;</td>
</tr>
<tr>
<td>xxxx10</td>
<td>imm5&lt;4:2&gt;</td>
</tr>
<tr>
<td>xx100</td>
<td>imm5&lt;4:3&gt;</td>
</tr>
<tr>
<td>x1000</td>
<td>imm5&lt;4&gt;</td>
</tr>
</tbody>
</table>

<R> Is the width specifier for the general-purpose source register, encoded in “imm5”:

<table>
<thead>
<tr>
<th>imm5</th>
<th>&lt;R&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>x0000</td>
<td>RESERVED</td>
</tr>
<tr>
<td>xxxx1</td>
<td>W</td>
</tr>
<tr>
<td>xxxx10</td>
<td>W</td>
</tr>
<tr>
<td>xx100</td>
<td>W</td>
</tr>
<tr>
<td>x1000</td>
<td>X</td>
</tr>
</tbody>
</table>

<n> Is the number [0-30] of the general-purpose source register or ZR (31), encoded in the "Rn" field.
Operation

```c
CheckFPAdvSIMDEnabled64();
bits(esize) element = X[n];
bits(datasize) result;

result = V[d];
Elem[result, index, esize] = element;
V[d] = result;
```

Operational information

If PSTATE.DIT is 1:

- The execution time of this instruction is independent of:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.

- The response of this instruction to asynchronous exceptions does not vary based on:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
IRG

Insert Random Tag inserts a random Logical Address Tag into the address in the first source register, and writes the result to the destination register. Any tags specified in the optional second source register or in GCR_EL1.Exclude are excluded from the selection of the random Logical Address Tag.

Integer

(ARMv8.5)

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 1  | 0  | 0  | 1  | 0  | 1  | 0  | 1  | 1  | 0  | 1  | 0  | 1  | 0  | 1  | 0  | 1  | 0  | 1  | 0  | 1  | 0  | 1  | 0  | 1  | 0  | 1  | 0  | 1  | 0  | 1  | 0  | 1  | 0  | 1  | 0  | 1  | 0  |

integer d = UInt(Xd);
integer n = UInt(Xn);
integer m = UInt(Xm);

Assembler Symbols

<Xd|SP> Is the 64-bit name of the destination general-purpose register or stack pointer, encoded in the "Xd" field.
<Xn|SP> Is the 64-bit name of the first source general-purpose register or stack pointer, encoded in the "Xn" field.
<Xm> Is the 64-bit name of the second general-purpose source register, encoded in the "Xm" field. Defaults to XZR if absent.

Operation

bits(64) operand = if n == 31 then SP[] else X[n];
bits(64) xm = X[m];
bits(16) exclude = xm<15:0> OR GCR_EL1.Exclude;
if AllocationTagAccessIsEnabled() then
  if GCR_EL1.RRND == '1' then
    RGSR_EL1 = bits(32) UNKNOWN;
    rtag = _ChooseRandomNonExcludedTag(exclude);
  else
    bits(4) start = RGSR_EL1.TAG;
    bits(4) offset = RandomTag();
    rtag = ChooseNonExcludedTag(start, offset, exclude);
  else
    rtag = '0000';
bits(64) result = AddressWithAllocationTag(operand, rtag);
if d == 31 then
  SP[] = result;
else
  X[d] = result;
ISB

Instruction Synchronization Barrier flushes the pipeline in the PE and is a context synchronization event. For more information, see Instruction Synchronization Barrier (ISB).

System

ISB {<option>|#(<imm>)}

MemBarrierOp op;
MBReqDomain domain;
MBReqTypes types;

case opc of
  when '00' op = MemBarrierOp_DSB;
  when '01' op = MemBarrierOp_DMB;
  when '10' op = MemBarrierOp_ISB;
otherwise
    if HaveSBExtUnallocatedEncoding() && CRm<3:0> == '0000' then
      op =();
    end
end

case CRm<3:2> of
  when '00' domain = MemBarrierOp_SB;
    else
      UNDEFINED;
end

case CRm<3:2> of
  when '00' domain = MBReqDomain_OuterShareable;
  when '01' domain = MBReqDomain_Nonshareable;
  when '10' domain = MBReqDomain_InnerShareable;
  when '11' domain = MBReqDomain_FullSystem;

case CRm<1:0> of
  when '01' types = MBReqTypes_Reads;
  when '10' types = MBReqTypes_Writes;
  when '11' types = MBReqTypes_All;
otherwise
  if CRm<3:2> == '01' then
    if CRm<3:2> == '00' then
      op = MemBarrierOp_PSSBB;
    elseif CRm<3:2> == '00' && opc == '00' then
      op = MemBarrierOp_SSBB;
    elseif CRm<3:2> == '01' then
      op = HaveSBExtMemBarrierOp_PSSBB() && CRm<3:2> == '00' && opc == '11' then
        op = MemBarrierOp_SS;
      else
        types = MBReqTypes_All;
        domain = MBReqDomain_FullSystem;
  end

Assembler Symbols

<option>
  Specifies an optional limitation on the barrier operation. Values are:

  SY
  Full system barrier operation, encoded as CRm = 0b1111. Can be omitted.

  All other encodings of CRm are reserved. The corresponding instructions execute as full system barrier operations, but must not be relied upon by software.

<imm>
  Is an optional 4-bit unsigned immediate, in the range 0 to 15, defaulting to 15 and encoded in the "CRm" field.
case op of
  when MemBarrierOp_DSBDATA_SynchronizationBarrier(domain, types);
  when MemBarrierOp_DMBDataMemoryBarrier(domain, types);
  when MemBarrierOp_ISBInstructionSynchronizationBarrier();
  when MemBarrierOp_SSBSpeculativeSynchronizationBarrierToVA();
  when MemBarrierOp_PSSBSpeculativeSynchronizationBarrierToPA();
  when MemBarrierOp_SBSpeculationBarrier();
LD1 (multiple structures)

Load multiple single-element structures to one, two, three, or four registers. This instruction loads multiple single-element structures from memory and writes the result to one, two, three, or four SIMD&FP registers.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

It has encodings from 2 classes: No offset and Post-index

No offset

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| Q  | 0  | 0  | 1  | 1  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | x  | x  | 1  | x  | size | Rn | Rr |

opcode

One register (opcode == 0111)

LD1 { <Vt>.<T> }, [<Xn|SP>]

Two registers (opcode == 1010)

LD1 { <Vt>.<T>, <Vt2>.<T> }, [<Xn|SP>]

Three registers (opcode == 0110)

LD1 { <Vt>.<T>, <Vt2>.<T>, <Vt3>.<T> }, [<Xn|SP>]

Four registers (opcode == 0010)

LD1 { <Vt>.<T>, <Vt2>.<T>, <Vt3>.<T>, <Vt4>.<T> }, [<Xn|SP>]

integer t = UInt(Rt);
integer n = UInt(Rn);
integer m = integer UNKNOWN;
boolean wback = FALSE;

Post-index

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| Q  | 0  | 0  | 1  | 1  | 0  | 0  | 1  | 1  | 0  | Rm | x  | x  | 1  | x  | size | Rn | Rr |

opcode
One register, immediate offset (Rm == 11111 && opcode == 0111)

LD1 { <Vt>.<T> }, [<Xn|SP>], <imm>

One register, register offset (Rm != 11111 && opcode == 0111)

LD1 { <Vt>.<T> }, [<Xn|SP>], <Xm>

Two registers, immediate offset (Rm == 11111 && opcode == 1010)

LD1 { <Vt>.<T>, <Vt2>.<T> }, [<Xn|SP>], <imm>

Two registers, register offset (Rm != 11111 && opcode == 1010)

LD1 { <Vt>.<T>, <Vt2>.<T> }, [<Xn|SP>], <Xm>

Three registers, immediate offset (Rm == 11111 && opcode == 0110)

LD1 { <Vt>.<T>, <Vt2>.<T>, <Vt3>.<T> }, [<Xn|SP>], <imm>

Three registers, register offset (Rm != 11111 && opcode == 0110)

LD1 { <Vt>.<T>, <Vt2>.<T>, <Vt3>.<T> }, [<Xn|SP>], <Xm>

Four registers, immediate offset (Rm == 11111 && opcode == 0010)

LD1 { <Vt>.<T>, <Vt2>.<T>, <Vt3>.<T>, <Vt4>.<T> }, [<Xn|SP>], <imm>

Four registers, register offset (Rm != 11111 && opcode == 0010)

LD1 { <Vt>.<T>, <Vt2>.<T>, <Vt3>.<T>, <Vt4>.<T> }, [<Xn|SP>], <Xm>

integer t = UInt(Rt);
integer n = UInt(Rn);
integer m = UInt(Rm);
boolean wback = TRUE;

Assembler Symbols

<Vt> Is the name of the first or only SIMD&FP register to be transferred, encoded in the "Rt" field.
<T> Is an arrangement specifier, encoded in “size:Q”:

<table>
<thead>
<tr>
<th>size</th>
<th>Q</th>
<th>&lt;T&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>0</td>
<td>8B</td>
</tr>
<tr>
<td>00</td>
<td>1</td>
<td>16B</td>
</tr>
<tr>
<td>01</td>
<td>0</td>
<td>4H</td>
</tr>
<tr>
<td>01</td>
<td>1</td>
<td>8H</td>
</tr>
<tr>
<td>10</td>
<td>0</td>
<td>2S</td>
</tr>
<tr>
<td>10</td>
<td>1</td>
<td>4S</td>
</tr>
<tr>
<td>11</td>
<td>0</td>
<td>1D</td>
</tr>
<tr>
<td>11</td>
<td>1</td>
<td>2D</td>
</tr>
</tbody>
</table>

<Vt2> Is the name of the second SIMD&FP register to be transferred, encoded as “Rt” plus 1 modulo 32.
<Vt3> Is the name of the third SIMD&FP register to be transferred, encoded as “Rt” plus 2 modulo 32.
<Vt4> Is the name of the fourth SIMD&FP register to be transferred, encoded as “Rt” plus 3 modulo 32.
<Xn|SP> Is the 64-bit name of the general-purpose base register or stack pointer, encoded in the "Rn" field.
<imm> For the one register, immediate offset variant: is the post-index immediate offset, encoded in “Q”:
For the two registers, immediate offset variant: is the post-index immediate offset, encoded in “Q”:

\[
\begin{array}{c|c}
Q & <\text{imm}> \\
\hline
0 & 0 \#8 \\
1 & 1 \#16 \\
\end{array}
\]

For the three registers, immediate offset variant: is the post-index immediate offset, encoded in “Q”:

\[
\begin{array}{c|c}
Q & <\text{imm}> \\
\hline
0 & 0 \#16 \\
1 & 1 \#32 \\
\end{array}
\]

For the four registers, immediate offset variant: is the post-index immediate offset, encoded in “Q”:

\[
\begin{array}{c|c}
Q & <\text{imm}> \\
\hline
0 & 0 \#24 \\
1 & 1 \#48 \\
\end{array}
\]

\[<\text{Xm}>\] Is the 64-bit name of the general-purpose post-index register, excluding XZR, encoded in the “Rm” field.

**Shared Decode**

```plaintext
MemOp memop = if L == '1' then MemOp_LOAD else MemOp_STORE;
integer datasize = if Q == '1' then 128 else 64;
integer esize = 8 << UInt(size);
integer elements = datasize DIV esize;

integer rpt; // number of iterations
integer selem; // structure elements

case opcode of
  when '0000' rpt = 1; selem = 4; // LD/ST4 (4 registers)
  when '0010' rpt = 4; selem = 1; // LD/ST1 (4 registers)
  when '0100' rpt = 1; selem = 3; // LD/ST3 (3 registers)
  when '0110' rpt = 3; selem = 1; // LD/ST1 (3 registers)
  when '0111' rpt = 1; selem = 1; // LD/ST1 (1 register)
  when '1000' rpt = 1; selem = 2; // LD/ST2 (2 registers)
  when '1010' rpt = 2; selem = 1; // LD/ST1 (2 registers)
otherwise UNDEFINED;

// 1D format only permitted with LD1 & ST1
if size:Q == '110' && selem != 1 then UNDEFINED; otherwise UnallocatedEncoding();
```

LD1 (multiple structures)
Operation

```c
CheckFPAdvSIMDEnabled64();

bits(64) address;
bits(64) offs;
bits(datasize) rval;
integer tt;
integer e, r, s, tt;
constant integer ebytes = esize DIV 8;

if n == 31 then HaveMTEExt() then
    SetNotTagCheckedInstruction(!wback && n == 31);

if n == 31 then
    CheckSPAlignment();
    address = SP[];
else
    address = X[n];

offs = Zeros();
for r = 0 to rpt-1
    for e = 0 to elements-1
        tt = (t + r) MOD 32;
        for s = 0 to selem-1
            rval = V[tt];
            if memop == MemOp_LOAD then
                Elem[rval, e, esize] = Mem[address + offs, ebytes, AccType_VEC];
            V[tt] = rval;
            else // memop == MemOp_STORE
                Mem[address + offs, ebytes, AccType_VEC] = Elem[rval, e, esize];
            offs = offs + ebytes;
            tt = (tt + 1) MOD 32;

if wback then
    if m != 31 then
        offs = X[m];
    if n == 31 then
        SP[] = address + offs;
    else
        X[n] = address + offs;
```

Operational information

If PSTATE.DIT is 1, the timing of this instruction is insensitive to the value of the data being loaded or stored.
LD1 (single structure)

Load one single-element structure to one lane of one register. This instruction loads a single-element structure from memory and writes the result to the specified lane of the SIMD&FP register without affecting the other bits of the register.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

It has encodings from 2 classes: No offset and Post-index.

No offset

8-bit (opcode == 000)

LD1 {<Vt>.B}[<index>], [<Xn|SP>]

16-bit (opcode == 010 && size == x0)

LD1 {<Vt>.H}[<index>], [<Xn|SP>]

32-bit (opcode == 100 && size == 00)

LD1 {<Vt>.S}[<index>], [<Xn|SP>]

64-bit (opcode == 100 && S == 0 && size == 01)

LD1 {<Vt>.D}[<index>], [<Xn|SP>]

integer t = UInt(Rt);
integer n = UInt(Rn);
integer m = integer UNKNOWN;
boolean wback = FALSE;

Post-index

integer t = UInt(Rt);
integer n = UInt(Rn);
integer m = integer UNKNOWN;
boolean wback = FALSE;
8-bit, immediate offset (Rm == 11111 && opcode == 000)

LD1 { <Vt>.B ][<index>], [<Xn|SP>], #1

8-bit, register offset (Rm != 11111 && opcode == 000)

LD1 { <Vt>.B ][<index>], [<Xn|SP>], <Xm>

16-bit, immediate offset (Rm == 11111 && opcode == 010 && size == x0)

LD1 { <Vt>.H ][<index>], [<Xn|SP>], #2

16-bit, register offset (Rm != 11111 && opcode == 010 && size == x0)

LD1 { <Vt>.H ][<index>], [<Xn|SP>], <Xm>

32-bit, immediate offset (Rm == 11111 && opcode == 100 && size == 00)

LD1 { <Vt>.S ][<index>], [<Xn|SP>], #4

32-bit, register offset (Rm != 11111 && opcode == 100 && size == 00)

LD1 { <Vt>.S ][<index>], [<Xn|SP>], <Xm>

64-bit, immediate offset (Rm == 11111 && opcode == 100 && S == 0 && size == 01)

LD1 { <Vt>.D ][<index>], [<Xn|SP>], #8

64-bit, register offset (Rm != 11111 && opcode == 100 && S == 0 && size == 01)

LD1 { <Vt>.D ][<index>], [<Xn|SP>], <Xm>

integer t = UInt(Rt);
integer n = UInt(Rn);
integer m = UInt(Rm);
boolean wback = TRUE;

Assembler Symbols

<Vt> Is the name of the first or only SIMD&FP register to be transferred, encoded in the "Rt" field.

<integer> For the 8-bit variant: is the element index, encoded in "Q:S:size".
For the 16-bit variant: is the element index, encoded in "Q:S:size<1>".
For the 32-bit variant: is the element index, encoded in "Q:S".
For the 64-bit variant: is the element index, encoded in "Q".

<Xn|SP> Is the 64-bit name of the general-purpose base register or stack pointer, encoded in the "Rn" field.

<Xm> Is the 64-bit name of the general-purpose post-index register, excluding XZR, encoded in the "Rm" field.
integer scale = \texttt{UInt}(\texttt{opcode}<2:1>);  
integer selem = \texttt{UInt}(\texttt{opcode}<0>:R) + 1;  
boolean replicate = FALSE;  
integer index;

\begin{verbatim}
case scale of
    when 3
        // load and replicate
        if \texttt{L} == '0' || \texttt{S} == '1' then UNDEFINED;
        scale = \texttt{UInt}(\texttt{size});  
        replicate = TRUE;
    when 0
        index = \texttt{UInt}(Q:S:size); // B[0-15]
    when 1
        if size<0> == '1' then UNDEFINED;
        index = \texttt{UInt}(Q:S:size<1>); // H[0-7]
    when 2
        if size<1> == '1' then UNDEFINED;
        if size<0> == '0' then
            index = \texttt{UInt}(Q:S); // S[0-3]
        else
            if S == '1' then \texttt{UnallocatedEncoding}(Q:S); // S[0-3]
            else
                if S == '1' then UNDEFINED;
        
        scale = 3;

MemOp memop = if \texttt{L} == '1' then \texttt{MemOp LOAD} else \texttt{MemOp STORE};
integer datasize = if \texttt{Q} == '1' then 128 else 64;
integer esize = 8 \ll scale;
\end{verbatim}
if HaveMTEExt() then
    SetNotTagCheckedInstruction(!wback && n == 31);

CheckFPAdvSIMDEnabled64();

bits(64) address;
bits(64) offs;
bits(128) rval;
bits(esize) element;
integer s;

const integer ebytes = esize DIV 8;

if n == 31 then
    CheckSPAlignment();
    address = SP[];
else
    address = X[n];

offs = Zeros();

if replicate then
    // load and replicate to all elements
    for s = 0 to selem-1
        element = Mem[address + offs, ebytes, AccType_VEC];
    // replicate to fill 128- or 64-bit register
    V[t] = Replicate(element, datasize DIV esize);
    offs = offs + ebytes;
    t = (t + 1) MOD 32;
else
    // load/store one element per register
    for s = 0 to selem-1
        rval = V[t];
        if memop == MemOp_LOAD then
            Elem[rval, index, esize] = Mem[address + offs, ebytes, AccType_VEC];
            V[t] = rval;
        else // memop == MemOp_STORE
            Mem[address + offs, ebytes, AccType_VEC] = Elem[rval, index, esize];
        offs = offs + ebytes;
        t = (t + 1) MOD 32;

if wback then
    if m != 31 then
        offs = X[m];
    if n == 31 then
        SP[] = address + offs;
    else
        X[n] = address + offs;

Operational information

If PSTATE.DIT is 1, the timing of this instruction is insensitive to the value of the data being loaded or stored.
LD1R

Load one single-element structure and Replicate to all lanes (of one register). This instruction loads a single-element structure from memory and replicates the structure to all the lanes of the SIMD&FP register.

Depending on the settings in the `CPACR_EL1`, `CPTR_EL2`, and `CPTR_EL3` registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

It has encodings from 2 classes: No offset and Post-index

### No offset

```
| 31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10  9  8  7  6  5  4  3  2  1  0 |
|-----------------------------|-------------|-------------|
| 0 | 0 | 0 | 1 | 1 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | size | Rn | Rt |
| L | R | opcode | S |
```

### Post-index

```
| 31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10  9  8  7  6  5  4  3  2  1  0 |
|-----------------------------|-------------|-------------|
| 0 | 0 | 0 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 0 | size | Rm | 1 | 1 | 0 | 0 | size | Rn | Rt |
| L | R | opcode | S |
```

### Immediate offset (Rm == 11111)

```
LD1R { <Vt>.<T> }, [<Xn|SP>], <imm>
```

### Register offset (Rm != 11111)

```
LD1R { <Vt>.<T> }, [<Xn|SP>], <Xm>
```

### Assembler Symbols

- `<V>` is the name of the first or only SIMD&FP register to be transferred, encoded in the "Rt" field.
- `<T>` is an arrangement specifier, encoded in "size:Q":

```
<table>
<thead>
<tr>
<th>size</th>
<th>Q</th>
<th>&lt;T&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>0</td>
<td>8B</td>
</tr>
<tr>
<td>00</td>
<td>1</td>
<td>16B</td>
</tr>
<tr>
<td>01</td>
<td>0</td>
<td>4H</td>
</tr>
<tr>
<td>01</td>
<td>1</td>
<td>8H</td>
</tr>
<tr>
<td>10</td>
<td>0</td>
<td>2S</td>
</tr>
<tr>
<td>10</td>
<td>1</td>
<td>4S</td>
</tr>
<tr>
<td>11</td>
<td>0</td>
<td>1D</td>
</tr>
<tr>
<td>11</td>
<td>1</td>
<td>2D</td>
</tr>
</tbody>
</table>
```

- `<Xn|SP>` is the 64-bit name of the general-purpose base register or stack pointer, encoded in the "Rn" field.

```
<imm> Is the post-index immediate offset, encoded in "size":

<table>
<thead>
<tr>
<th>size</th>
<th>&lt;imm&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>#1</td>
</tr>
<tr>
<td>01</td>
<td>#2</td>
</tr>
<tr>
<td>10</td>
<td>#4</td>
</tr>
<tr>
<td>11</td>
<td>#8</td>
</tr>
</tbody>
</table>

<Xm> Is the 64-bit name of the general-purpose post-index register, excluding XZR, encoded in the "Rm" field.

**Shared Decode**

```plaintext
integer scale = UInt(opcode<2:1>);
integer selem = UInt(opcode<0>:R) + 1;
boolean replicate = FALSE;
integer index;

case scale of
    when 3
        // load and replicate
        if L == '0' || S == '1' then UNDEFINED;
        scale = if L == '0' || S == '1' then UnallocatedEncoding();
        replicate = TRUE;
        when 0
            index = UInt(Q:S:size);         // B[0-15]
        when 1
            if size<0> == '1' then UNDEFINED;
            index = if size<0> == '1' then UnallocatedEncoding();
            index = UInt(Q:S:size<1>);      // H[0-7]
        when 2
            if size<1> == '1' then UNDEFINED;
            if size<0> == '0' then
                index = if size<1> == '1' then UnallocatedEncoding();
                if size<0> == '0' then
                    index = UInt(Q:S);          // S[0-3]
                else
                    if S == '1' then UnallocatedEncoding(Q:S);          // S[0-3]
                else
                    if S == '1' then UNDEFINED;
                end;
            end;
            index = UInt(Q);            // D[0-1]
        end;
    scale = 3;

MemOp memop = if L == '1' then MemOp_LOAD else MemOp_STORE;
integer datasize = if Q == '1' then 128 else 64;
integer esize = 8 << scale;
```
if HaveMTEExt() then
  SetNotTagCheckedInstruction(!wback && n == 31);

CheckFPAdvSIMDEnabled64();

bits(64) address;
bits(64) offs;
bits(128) rval;
bits(esize) element;

integer ebytes = esize DIV 8;

if n == 31 then
  CheckSPAlignment();
  address = SP[];
else
  address = X[n];

offs = Zeros();
if replicate then
  // load and replicate to all elements
  for s = 0 to selem-1
    element = Mem[address + offs, ebytes, AccType_VEC];
    // replicate to fill 128- or 64-bit register
    V[t] = Replicate(element, datasize DIV esize);
  offs = offs + ebytes;
  t = (t + 1) MOD 32;
else
  // load/store one element per register
  for s = 0 to selem-1
    rval = V[t];
    if memop == MemOp_LOAD then
      // insert into one lane of 128-bit register
      Elem[rval, index, esize] = Mem[address + offs, ebytes, AccType_VEC];
    V[t] = rval;
    else // memop == MemOp_STORE
      // extract from one lane of 128-bit register
      Mem[address + offs, ebytes, AccType_VEC] = Elem[rval, index, esize];
    offs = offs + ebytes;
    t = (t + 1) MOD 32;

if wback then
  if m != 31 then
    offs = X[m];
  if n == 31 then
    SP[] = address + offs;
  else
    X[n] = address + offs;

Operational information

If PSTATE.DIT is 1, the timing of this instruction is insensitive to the value of the data being loaded or stored.
LD2 (multiple structures)

Load multiple 2-element structures to two registers. This instruction loads multiple 2-element structures from memory and writes the result to the two SIMD&FP registers, with de-interleaving.

For an example of de-interleaving, see LD3 (multiple structures).

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

It has encodings from 2 classes: No offset and Post-index

No offset

```
31  30  29  28  27  26  25  24  23  22  21  20  19  18  17  16  15  14  13  12  11  10  9  8  7  6  5  4  3  2  1  0
  0  Q  0  0  1  1  0  0  0  1  0  0  0  0  0  0  1  0  0  0  size  Rn  Rt
     L

integer t = UInt(Rt);
integer n = UInt(Rn);
integer m = integer UNKNOWN;
boolean wback = FALSE;
```

Post-index

```
31  30  29  28  27  26  25  24  23  22  21  20  19  18  17  16  15  14  13  12  11  10  9  8  7  6  5  4  3  2  1  0
  0  Q  0  0  1  1  0  0  1  1  0  Rm  1  0  0  0  size  Rn  Rt
     L

Immediate offset (Rm == 11111)

LD2 { <Vt>,<T>, <Vt2>,<T> }, [<Xn|SP>]

Register offset (Rm != 11111)

LD2 { <Vt>,<T>, <Vt2>,<T> }, [Xn], <imm>

Assembler Symbols

- `<Vt>` Is the name of the first or only SIMD&FP register to be transferred, encoded in the "Rt" field.
- `<T>` Is an arrangement specifier, encoded in “size:Q”:

<table>
<thead>
<tr>
<th>size</th>
<th>Q</th>
<th>&lt;T&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>0</td>
<td>8B</td>
</tr>
<tr>
<td>00</td>
<td>1</td>
<td>16B</td>
</tr>
<tr>
<td>01</td>
<td>0</td>
<td>4H</td>
</tr>
<tr>
<td>01</td>
<td>1</td>
<td>8H</td>
</tr>
<tr>
<td>10</td>
<td>0</td>
<td>2S</td>
</tr>
<tr>
<td>10</td>
<td>1</td>
<td>4S</td>
</tr>
<tr>
<td>11</td>
<td>0</td>
<td>RESERVED</td>
</tr>
<tr>
<td>11</td>
<td>1</td>
<td>2D</td>
</tr>
</tbody>
</table>
Is the name of the second SIMD&FP register to be transferred, encoded as "Rt" plus 1 modulo 32.

Is the 64-bit name of the general-purpose base register or stack pointer, encoded in the "Rn" field.

Is the post-index immediate offset, encoded in "Q":

<table>
<thead>
<tr>
<th>Q</th>
<th>&lt;imm&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>#16</td>
</tr>
<tr>
<td>1</td>
<td>#32</td>
</tr>
</tbody>
</table>

Is the 64-bit name of the general-purpose post-index register, excluding XZR, encoded in the "Rm" field.

**Shared Decode**

```java
MemOp memop = if L == '1' then MemOp_LOAD else MemOp_STORE;
Integer datasize = if Q == '1' then 128 else 64;
Integer esize = 8 << UInt(size);
Integer elements = datasize DIV esize;

Integer rpt; // number of iterations
Integer selem; // structure elements

case opcode of
    when '0000' rpt = 1; selem = 4;    // LD/ST4 (4 registers)
    when '0010' rpt = 4; selem = 1;    // LD/ST1 (4 registers)
    when '0100' rpt = 1; selem = 3;    // LD/ST3 (3 registers)
    when '0110' rpt = 3; selem = 1;    // LD/ST1 (3 registers)
    when '0111' rpt = 1; selem = 1;    // LD/ST1 (1 register)
    when '1000' rpt = 1; selem = 2;    // LD/ST2 (2 registers)
    when '1010' rpt = 2; selem = 1;    // LD/ST1 (2 registers)
    otherwise UNDEFINED;

// .1D format only permitted with LD1 & ST1
if size:Q == '110' && selem != 1 then UNDEFINED; otherwise UnallocatedEncoding();
```

// .1D format only permitted with LD1 & ST1
if size:Q == '110' && selem != 1 then ReservedValue();
Operation

```c
CheckFPAdvSIMDEnabled64();

bits(64) address;
bits(64) offs;
bits(datasize) rval;
integer tt;
integer e, r, s, tt;
constant integer ebytes = esize DIV 8;

if n == 31 then HaveMTEExt() then
    SetNotTagCheckedInstruction(!wback && n == 31);

if n == 31 then
    CheckSPAlignment();
    address = SP[0];
else
    address = X[n];

offs = Zeros();
for r = 0 to rpt-1
    for e = 0 to elements-1
        tt = (t + r) MOD 32;
        for s = 0 to selem-1
            rval = V[tt];
            if memop == MemOp_LOAD then
                Elem[rval, e, esize] = Mem[address + offs, ebytes, AccType_VEC];
                V[tt] = rval;
            else // memop == MemOp_STORE
                Mem[address + offs, ebytes, AccType_VEC] = Elem[rval, e, esize];
            offs = offs + ebytes;
            tt = (tt + 1) MOD 32;
    if wback then
        if m != 31 then
            offs = X[m];
        if n == 31 then
            SP[0] = address + offs;
        else
            X[n] = address + offs;
```

Operational information

If PSTATE.DIT is 1, the timing of this instruction is insensitive to the value of the data being loaded or stored.
**LD2 (single structure)**

Load single 2-element structure to one lane of two registers. This instruction loads a 2-element structure from memory and writes the result to the corresponding elements of the two SIMD&FP registers without affecting the other bits of the registers.

Depending on the settings in the `CPACR_EL1`, `CPTR_EL2`, and `CPTR_EL3` registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

It has encodings from 2 classes: *No offset* and *Post-index*.

### No offset

| Q | 0 | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | x | x | 0 | S | size | Rn | Rt |
| L | R | opcode |

#### 8-bit (opcode == 000)

LD2 `{<Vt>.B, <Vt2>.B}[<index>], [<Xn|SP]`

#### 16-bit (opcode == 010 && size == x0)

LD2 `{<Vt>.H, <Vt2>.H}[<index>], [<Xn|SP]`

#### 32-bit (opcode == 100 && size == 00)

LD2 `{<Vt>.S, <Vt2>.S}[<index>], [<Xn|SP]`

#### 64-bit (opcode == 100 && S == 0 && size == 01)

LD2 `{<Vt>.D, <Vt2>.D}[<index>], [<Xn|SP]`

integer t = `UInt(Rt);`
integer n = `UInt(Rn);`
integer m = integer UNKNOWN;
boolean wback = FALSE;

### Post-index

| Q | 0 | 0 | 1 | 1 | 0 | 1 | 1 | Rm | x | x | 0 | S | size | Rn | Rt |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| L | R | opcode |
8-bit, immediate offset (Rm == 11111 && opcode == 000)

LD2 { <Vt>.B, <Vt2>.B }[<index>], [<Xn|SP>], #2

8-bit, register offset (Rm != 11111 && opcode == 000)

LD2 { <Vt>.B, <Vt2>.B }[<index>], [<Xn|SP>], <Xm>

16-bit, immediate offset (Rm == 11111 && opcode == 010 && size == x0)

LD2 { <Vt>.H, <Vt2>.H }[<index>], [<Xn|SP>], #4

16-bit, register offset (Rm != 11111 && opcode == 010 && size == x0)

LD2 { <Vt>.H, <Vt2>.H }[<index>], [<Xn|SP>], <Xm>

32-bit, immediate offset (Rm == 11111 && opcode == 100 && size == 00)

LD2 { <Vt>.S, <Vt2>.S }[<index>], [<Xn|SP>], #8

32-bit, register offset (Rm != 11111 && opcode == 100 && size == 00)

LD2 { <Vt>.S, <Vt2>.S }[<index>], [<Xn|SP>], <Xm>

64-bit, immediate offset (Rm == 11111 && opcode == 100 && S == 0 && size == 01)

LD2 { <Vt>.D, <Vt2>.D }[<index>], [<Xn|SP>], #16

64-bit, register offset (Rm != 11111 && opcode == 100 && S == 0 && size == 01)

LD2 { <Vt>.D, <Vt2>.D }[<index>], [<Xn|SP>], <Xm>

integer t = UInt(Rt);
integer n = UInt(Rn);
integer m = UInt(Rm);
boolean wback = TRUE;

Assembler Symbols

<Vt> Is the name of the first or only SIMD&FP register to be transferred, encoded in the "Rt" field.
<Vt2> Is the name of the second SIMD&FP register to be transferred, encoded as "Rt" plus 1 modulo 32.
<index> For the 8-bit variant: is the element index, encoded in "Q:S:size".
          For the 16-bit variant: is the element index, encoded in "Q:S:size<1>".
          For the 32-bit variant: is the element index, encoded in "Q:S".
          For the 64-bit variant: is the element index, encoded in "Q".
<Xn|SP> Is the 64-bit name of the general-purpose base register or stack pointer, encoded in the "Rn" field.
<Xm> Is the 64-bit name of the general-purpose post-index register, excluding XZR, encoded in the "Rm" field.
integer scale = \texttt{UInt}(\texttt{opcode}<2:1>);  
integer selem = \texttt{UInt}(\texttt{opcode}<0>:R) + 1;  
boolean replicate = FALSE;  
integer index;  

\textbf{case scale of}  
\hspace{1em} \textbf{when } 3  
\hspace{2em} \textbf{// load and replicate}  
\hspace{3em} \textbf{if } L == '0' || S == '1' \textbf{ then } \texttt{UNDEFINED};  
\hspace{3em} scale = \texttt{if } L == '0' || S == '1' \texttt{ then } \texttt{UnallocatedEncoding}();  
\hspace{3em} scale = \texttt{UInt}(\texttt{size});  
\hspace{3em} replicate = \texttt{TRUE};  
\hspace{3em} \textbf{when } 0  
\hspace{4em} index = \texttt{UInt}(Q:S:}\texttt{size};  
\hspace{4em} \texttt{// B[0-15]}  
\hspace{3em} \textbf{when } 1  
\hspace{4em} \textbf{if } size<0> == '1' \textbf{ then } \texttt{UNDEFINED};  
\hspace{4em} index = \texttt{if } size<0> == '1' \texttt{ then } \texttt{UnallocatedEncoding}();  
\hspace{4em} index = \texttt{UInt}(Q:S:}\texttt{size<1>};  
\hspace{4em} \texttt{// H[0-7]}  
\hspace{3em} \textbf{when } 2  
\hspace{4em} \textbf{if } size<1> == '1' \textbf{ then } \texttt{UNDEFINED};  
\hspace{4em} \textbf{if } size<0> == '0' \texttt{ then}  
\hspace{5em} \textbf{if } size<0> == '1' \texttt{ then } \texttt{UnallocatedEncoding}();  
\hspace{5em} \textbf{if } size<0> == '0' \texttt{ then}  
\hspace{6em} \textbf{if } S == '1' \texttt{ then } \texttt{UnallocatedEncoding}(Q:S);  
\hspace{6em} \texttt{// S[0-3]}  
\hspace{5em} \textbf{else}  
\hspace{6em} \textbf{if } S == '1' \texttt{ then } \texttt{UnallocatedEncoding}(Q:S);  
\hspace{6em} \texttt{// S[0-3]}  
\hspace{4em} \textbf{else}  
\hspace{5em} \textbf{if } S == '1' \texttt{ then } \texttt{UnallocatedEncoding}();  
\hspace{5em} \textbf{else}  
\hspace{6em} \textbf{if } S == '1' \texttt{ then UNDEFINED};  
\hspace{4em} index = \texttt{UInt}(Q);  
\hspace{4em} \texttt{// D[0-1]}  
\hspace{3em} scale = 3;  

\texttt{MemOp memop = if } L == '1' \texttt{ then } \texttt{MemOp \texttt{LOAD}} \texttt{ else } \texttt{MemOp \texttt{STORE};}  
integer datasize = if Q == '1' \texttt{ then } 128 \texttt{ else } 64;  
integer esize = 8 \ll  scale;
if HaveMTEExt() then
    SetNotTagCheckedInstruction(!wback && n == 31);

CheckFPAdvsIMDEnabled64();

bits(64) address;
bits(64) offs;
bits(128) rval;
bits(esize) element;
integer ebytes;

constant integer ebytes = esize DIV 8;

if n == 31 then
    CheckSPAlignment();
    address = SP[];
else
    address = X[n];

offs = Zeros();
if replicate then
    // load and replicate to all elements
    for s = 0 to selem-1
        element = Mem[address + offs, ebytes, AccType_VEC];
    // replicate to fill 128- or 64-bit register
    V[t] = Replicate(element, datasize DIV esize);
    offs = offs + ebytes;
    t = (t + 1) MOD 32;
else
    // load/store one element per register
    for s = 0 to selem-1
        rval = V[t];
    if memop == MemOp_LOAD then
        // insert into one lane of 128-bit register
        Elem[rval, index, esize] = Mem[address + offs, ebytes, AccType_VEC];
        V[t] = rval;
    else // memop == MemOp_STORE
        // extract from one lane of 128-bit register
        Mem[address + offs, ebytes, AccType_VEC] = Elem[rval, index, esize];
        offs = offs + ebytes;
        t = (t + 1) MOD 32;

if wback then
    if m != 31 then
        offs = X[m];
    if n == 31 then
        SP[] = address + offs;
    else
        X[n] = address + offs;

Operational information

If PSTATE.DIT is 1, the timing of this instruction is insensitive to the value of the data being loaded or stored.
LD2R

Load single 2-element structure and Replicate to all lanes of two registers. This instruction loads a 2-element structure from memory and replicates the structure to all the lanes of the two SIMD&FP registers.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

It has encodings from 2 classes: No offset and Post-index

No offset

```
0 0 1 1 0 0 1 1 | 0 0 0 0 1 1 0 0 | size | Rn | Rt

0 0 0 0 1 1 0 1 | 1 0 0 0 1 1 0 0 | size | Rn | Rt
```

No offset

```c
LD2R { <Vt>..<T>, <Vt2>..<T> }, [<Xn|SP>]
```

```c
integer t = UInt(Rt);
integer n = UInt(Rn);
integer m = integer UNKNOWN;
boolean wback = FALSE;
```

Post-index

```
0 0 1 1 0 1 1 1 | Rm | 1 1 0 0 | size | Rn | Rt

0 0 1 1 0 1 1 1 | Rm | 1 1 0 0 | size | Rn | Rt
```

Immediate offset (Rm == 11111)

```
LD2R { <Vt>..<T>, <Vt2>..<T> }, [<Xn|SP>], <imm>
```

Register offset (Rm != 11111)

```
LD2R { <Vt>..<T>, <Vt2>..<T> }, [<Xn|SP>], <Xm>
```

```c
integer t = UInt(Rt);
integer n = UInt(Rn);
integer m = UInt(Rm);
boolean wback = TRUE;
```

Assembler Symbols

- `<V>` is the name of the first or only SIMD&FP register to be transferred, encoded in the "Rt" field.
- `<T>` is an arrangement specifier, encoded in "size:Q":

<table>
<thead>
<tr>
<th>size</th>
<th>Q</th>
<th>&lt;T&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>0</td>
<td>8B</td>
</tr>
<tr>
<td>00</td>
<td>1</td>
<td>16B</td>
</tr>
<tr>
<td>01</td>
<td>0</td>
<td>4H</td>
</tr>
<tr>
<td>01</td>
<td>1</td>
<td>8H</td>
</tr>
<tr>
<td>10</td>
<td>0</td>
<td>2S</td>
</tr>
<tr>
<td>10</td>
<td>1</td>
<td>4S</td>
</tr>
<tr>
<td>11</td>
<td>0</td>
<td>1D</td>
</tr>
<tr>
<td>11</td>
<td>1</td>
<td>2D</td>
</tr>
</tbody>
</table>

- `<Vt2>` is the name of the second SIMD&FP register to be transferred, encoded as "Rt" plus 1 modulo 32.
Is the 64-bit name of the general-purpose base register or stack pointer, encoded in the "Rn" field.

Is the post-index immediate offset, encoded in "size":

<table>
<thead>
<tr>
<th>size</th>
<th>&lt;imm&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>#2</td>
</tr>
<tr>
<td>01</td>
<td>#4</td>
</tr>
<tr>
<td>10</td>
<td>#8</td>
</tr>
<tr>
<td>11</td>
<td>#16</td>
</tr>
</tbody>
</table>

Is the 64-bit name of the general-purpose post-index register, excluding XZR, encoded in the "Rm" field.

**Shared Decode**

```plaintext
def integer scale = UInt(opcode<2:1>);
def integer selem = UInt(opcode<0>:R) + 1;
def integer index;
case scale of
  when 3
    // load and replicate
    if L == '0' || S == '1' then UNDEFINED;
    scale = if L == '0' || S == '1' then UnallocatedEncoding();
    replicate = TRUE;
    when 0
      index = UInt(Q:S:size); // B[0-15]
    when 1
      if size<0> == '1' then UNDEFINED;
      index = if size<0> == '1' then UnallocatedEncoding();
      index = UInt(Q:S:size<1>); // H[0-7]
    when 2
      if size<1> == '1' then UNDEFINED;
      if size<0> == '0' then
        index = if size<1> == '1' then UnallocatedEncoding();
        if size<0> == '0' then
          index = UInt(Q:S); // S[0-3]
        else
          if S == '1' then UnallocatedEncoding(Q:S); // S[0-3]
        else
          if S == '1' then UNDEFINED;
        end if
      else
        index = UInt(Q); // D[0-1]
        scale = 3;
      end if
      MemOp memop = if L == '1' then MemOp LOAD else MemOp STORE;
def integer datasize = if Q == '1' then 128 else 64;
def integer esize = 8 << scale;
```

LD2R
if HaveMTEExt() then
  SetNotTagCheckedInstruction(!wback && n == 31);

CheckFFAdvSIMDEnabled64();

bits(64) address;
bits(64) offs;
bits(128) rval;
bits(esize) element;

integer ebytes = esize DIV 8;

if n == 31 then
  CheckSPAlignment();
  address = SP[];
else
  address = X[n];

offs = Zeros();
if replicate then
  // load and replicate to all elements
  for s = 0 to selem-1
    element = Mem[address + offs, ebytes, AccType_VEC];
    // replicate to fill 128- or 64-bit register
    V[t] = Replicate(element, datasize DIV esize);
    offs = offs + ebytes;
    t = (t + 1) MOD 32;
else
  // load/store one element per register
  for s = 0 to selem-1
    rval = V[t];
    if memop == MemOp_LOAD then
      // insert into one lane of 128-bit register
      Elem[rval, index, esize] = Mem[address + offs, ebytes, AccType_VEC];
      V[t] = rval;
    else // memop == MemOp_STORE
      // extract from one lane of 128-bit register
      Mem[address + offs, ebytes, AccType_VEC] = Elem[rval, index, esize];
      offs = offs + ebytes;
      t = (t + 1) MOD 32;

if wback then
  if m != 31 then
    offs = X[m];
  if n == 31 then
    SP[] = address + offs;
  else
    X[n] = address + offs;

Operational information

If PSTATE.DIT is 1, the timing of this instruction is insensitive to the value of the data being loaded or stored.
LD3 (multiple structures)

Load multiple 3-element structures to three registers. This instruction loads multiple 3-element structures from memory and writes the result to the three SIMD&FP registers, with de-interleaving.

The following figure shows an example of the operation of de-interleaving of a LD3.16 (multiple 3-element structures) instruction:

A is a packed array of 3-element structures.
Each element is a 16-bit halfword.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

It has encodings from 2 classes: No offset and Post-index

No offset

```
<p>| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 |  9 |  8 |  7 |  6 |  5 |  4 |  3 |  2 |  1 |  0 |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0  | 0  | 0  | 1  | 1  | 0  | 0  | 0  | 0  | 1  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 1  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 1  | 0  | 0  | 0  |
| 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 1  | 0  | 0  | 0  | 0  | 0  | 0  | 1  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 1  | 0  | 0  | 0  |
|   L|    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |</p>
<table>
<thead>
<tr>
<th>opcode</th>
<th>size</th>
<th>Rn</th>
<th>Rt</th>
</tr>
</thead>
</table>
```

No offset

```
LD3 \{ <Vt>.<T>, <Vt2>.<T>, <Vt3>.<T> \}, \{<Xn|SP>\}
```

```plaintext
integer t = UInt(Rt);
integer n = UInt(Rn);
integer m = integer UNKNOWN;
boolean wback = FALSE;
```

Post-index

```
<table>
<thead>
<tr>
<th>31</th>
<th>30</th>
<th>29</th>
<th>28</th>
<th>27</th>
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<th>25</th>
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<tr>
<td>opcode</td>
<td>size</td>
<td>Rm</td>
<td>Rn</td>
<td>Rt</td>
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</tr>
</tbody>
</table>
```

Immediate offset (Rm == 11111)

```
LD3 \{ <Vt>.<T>, <Vt2>.<T>, <Vt3>.<T> \}, \{<Xn|SP>\}, <imm>
```

Register offset (Rm != 11111)

```
LD3 \{ <Vt>.<T>, <Vt2>.<T>, <Vt3>.<T> \}, \{<Xn|SP>\}, <Xm>
```

```plaintext
integer t = UInt(Rt);
integer n = UInt(Rn);
integer m = UInt(Rm);
boolean wback = TRUE;
```
Assembler Symbols

\(<Vt>\) Is the name of the first or only SIMD&FP register to be transferred, encoded in the "Rt" field.

\(<T>\) Is an arrangement specifier, encoded in “size:Q”:

<table>
<thead>
<tr>
<th>size</th>
<th>Q</th>
<th>&lt;T&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>0</td>
<td>8B</td>
</tr>
<tr>
<td>00</td>
<td>1</td>
<td>16B</td>
</tr>
<tr>
<td>01</td>
<td>0</td>
<td>4H</td>
</tr>
<tr>
<td>01</td>
<td>1</td>
<td>8H</td>
</tr>
<tr>
<td>10</td>
<td>0</td>
<td>2S</td>
</tr>
<tr>
<td>10</td>
<td>1</td>
<td>4S</td>
</tr>
<tr>
<td>11</td>
<td>0</td>
<td>RESERVED</td>
</tr>
<tr>
<td>11</td>
<td>1</td>
<td>2D</td>
</tr>
</tbody>
</table>

\(<Vt2>\) Is the name of the second SIMD&FP register to be transferred, encoded as "Rt" plus 1 modulo 32.

\(<Vt3>\) Is the name of the third SIMD&FP register to be transferred, encoded as "Rt" plus 2 modulo 32.

\(<Xn|SP>\) Is the 64-bit name of the general-purpose base register or stack pointer, encoded in the "Rn" field.

\(<imm>\) Is the post-index immediate offset, encoded in “Q”:

<table>
<thead>
<tr>
<th>Q</th>
<th>&lt;imm&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>#24</td>
</tr>
<tr>
<td>1</td>
<td>#48</td>
</tr>
</tbody>
</table>

\(<Xm>\) Is the 64-bit name of the general-purpose post-index register, excluding XZR, encoded in the "Rm" field.

Shared Decode

```plaintext
MemOp memop = if L == '1' then MemOp_LOAD else MemOp_STORE;
integer datasize = if Q == '1' then 128 else 64;
integer esize = 8 << UInt(size);
integer elements = datasize DIV esize;

integer rpt; // number of iterations
integer selem; // structure elements

case opcode of
  when '0000' rpt = 1; selem = 4; // LD/ST4 (4 registers)
  when '0010' rpt = 4; selem = 1; // LD/ST1 (4 registers)
  when '0100' rpt = 1; selem = 3; // LD/ST3 (3 registers)
  when '0110' rpt = 3; selem = 1; // LD/ST1 (3 registers)
  when '0111' rpt = 1; selem = 1; // LD/ST1 (1 register)
  when '1000' rpt = 1; selem = 2; // LD/ST2 (2 registers)
  when '1010' rpt = 2; selem = 1; // LD/ST1 (2 registers)
  otherwise UNDEFINED;

// .1D format only permitted with LD1 & ST1
if size:Q == '110' && selem != 1 then UNDEFINED; otherwise UnallocatedEncoding();

// .1D format only permitted with LD1 & ST1
if size:Q == '110' && selem != 1 then ReservedValue();
```

LD3 (multiple structures)
Operation

```
CheckFPAdvSIMDEnabled64();

bits(64) address;
bits(64) offs;
bits(datasize) rval;
integer tt;
integer e, r, s, tt;
constant integer ebytes = esize DIV 8;

if n == 31 then HaveMTEExt() then
    SetNotTagCheckedInstruction(!wback && n == 31);

if n == 31 then
    CheckSPAlignment();
    address = SP[];
else
    address = X[n];

offs = Zeros();
for r = 0 to rpt-1
    for e = 0 to elements-1
        tt = (t + r) MOD 32;
        for s = 0 to selem-1
            rval = V[tt];
            if memop == MemOp_LOAD then
                Elem[rval, e, esize] = Mem[address + offs, ebytes, AccType_VEC];
                V[tt] = rval;
            else // memop == MemOp_STORE
                Mem[address + offs, ebytes, AccType_VEC] = Elem[rval, e, esize];
            offs = offs + ebytes;
            tt = (tt + 1) MOD 32;

if wback then
    if m != 31 then
        offs = X[m];
    if n == 31 then
        SP[] = address + offs;
    else
        X[n] = address + offs;
```

Operational information

If PSTATE.DIT is 1, the timing of this instruction is insensitive to the value of the data being loaded or stored.
LD3 (single structure)

Load single 3-element structure to one lane of three registers. This instruction loads a 3-element structure from memory and writes the result to the corresponding elements of the three SIMD&FP registers without affecting the other bits of the registers.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

It has encodings from 2 classes: No offset and Post-index.

### No offset

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9  | 8  | 7  | 6  | 5  | 4  | 3  | 2  | 1  | 0 |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0  | Q  | 0  | 1  | 0  | 1  | 0  | 1  | 0  | 0  | 0  | 0  | 0  | 0  | x  | x  | 1  | S  | size | Rn | 0  | Rt |

L R       opcode

8-bit (opcode == 001)


16-bit (opcode == 011 && size == x0)

LD3 { <Vt>.H, <Vt2>.H, <Vt3>.H }[<index>], [<Xn|SP>]

32-bit (opcode == 101 && size == 00)


64-bit (opcode == 101 && S == 0 && size == 01)

LD3 { <Vt>.D, <Vt2>.D, <Vt3>.D }[<index>], [<Xn|SP>]

```
integer t = UInt(Rt);
integer n = UInt(Rn);
integer m = integer UNKNOWN;
boolean wback = FALSE;
```

### Post-index

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9  | 8  | 7  | 6  | 5  | 4  | 3  | 2  | 1  | 0 |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0  | Q  | 0  | 1  | 0  | 1  | 1  | 1  | 0  | Rm | x  | x  | 1  | S  | size | Rn | 0  | Rt |

L R       opcode
8-bit, immediate offset (Rm == 11111 && opcode == 001)

LD3 { <Vt>.B, <Vt2>.B, <Vt3>.B }[<index>], [<Xn|SP>], #3

8-bit, register offset (Rm != 11111 && opcode == 001)

LD3 { <Vt>.B, <Vt2>.B, <Vt3>.B }[<index>], [<Xn|SP>], <Xm>

16-bit, immediate offset (Rm == 11111 && opcode == 011 && size == x0)

LD3 { <Vt>.H, <Vt2>.H, <Vt3>.H }[<index>], [<Xn|SP>], #6

16-bit, register offset (Rm != 11111 && opcode == 011 && size == x0)

LD3 { <Vt>.H, <Vt2>.H, <Vt3>.H }[<index>], [<Xn|SP>], <Xm>

32-bit, immediate offset (Rm == 11111 && opcode == 101 && size == 00)

LD3 { <Vt>.S, <Vt2>.S, <Vt3>.S }[<index>], [<Xn|SP>], #12

32-bit, register offset (Rm != 11111 && opcode == 101 && size == 00)

LD3 { <Vt>.S, <Vt2>.S, <Vt3>.S }[<index>], [<Xn|SP>], <Xm>

64-bit, immediate offset (Rm == 11111 && opcode == 101 && S == 0 && size == 01)

LD3 { <Vt>.D, <Vt2>.D, <Vt3>.D }[<index>], [<Xn|SP>], #24

64-bit, register offset (Rm != 11111 && opcode == 101 && S == 0 && size == 01)

LD3 { <Vt>.D, <Vt2>.D, <Vt3>.D }[<index>], [<Xn|SP>], <Xm>

integer t = UInt(Rt);
integer n = UInt(Rn);
integer m = UInt(Rm);
boolean wback = TRUE;

Assembler Symbols

<VT> Is the name of the first or only SIMD&FP register to be transferred, encoded in the "Rt" field.
<VT2> Is the name of the second SIMD&FP register to be transferred, encoded as "Rt" plus 1 modulo 32.
<VT3> Is the name of the third SIMD&FP register to be transferred, encoded as "Rt" plus 2 modulo 32.
<INDEX> For the 8-bit variant: is the element index, encoded in "Q:S:size".
For the 16-bit variant: is the element index, encoded in "Q:S:size<1>".
For the 32-bit variant: is the element index, encoded in "Q:S".
For the 64-bit variant: is the element index, encoded in "Q".
<XN|SP> Is the 64-bit name of the general-purpose base register or stack pointer, encoded in the "Rn" field.
<XM> Is the 64-bit name of the general-purpose post-index register, excluding XZR, encoded in the "Rm" field.
integer scale = UInt(opcode<2:1>);
integer selem = UInt(opcode<0>:R) + 1;
boolean replicate = FALSE;
integer index;

case scale of
    when 3
        // load and replicate
        if L == '0' || S == '1' then UNDEFINED;
        scale = if L == '0' || S == '1' then UnallocatedEncoding();
        scale = UInt(size);
        replicate = TRUE;
    when 0
        index = UInt(Q:S:size);   // B[0-15]
        when 1
            if size<0> == '1' then UNDEFINED;
            index = if size<0> == '1' then UnallocatedEncoding();
            index = UInt(Q:S:size<1>);   // H[0-7]
        when 2
            if size<1> == '1' then UNDEFINED;
            if size<0> == '0' then
                index = if size<1> == '1' then UnallocatedEncoding();
                index = UInt(Q:S);   // S[0-3]
            else
                if S == '1' then UnallocatedEncoding(Q:S);  // S[0-3]
                else
                    if S == '1' then UNDEFINED;
                    index = UInt(Q);   // D[0-1]
                    scale = 3;
    MemOp memop = if L == '1' then MemOp_LOAD else MemOp_STORE;
    integer datasize = if Q == '1' then 128 else 64;
    integer esize = 8 << scale;
    }

LD3 (single structure)
if HaveMTEExt() then
    SetNotTagCheckedInstruction(!wback && n == 31);

CheckFPAdvSIMDEnabled64();

bits(64) address;
bits(64) offs;
bits(128) rval;
bits(esize) element;

integer sz;
constant integer ebytes = esize DIV 8;

if n == 31 then
    CheckSPAlignment();
    address = SP[];
else
    address = X[n];

offs = Zeros();
if replicate then
    // load and replicate to all elements
    for s = 0 to selem-1
        element = Mem[address + offs, ebytes, AccType_VEC];
    // replicate to fill 128- or 64-bit register
    V[t] = Replicate(element, datasize DIV esize);
    offs = offs + ebytes;
    t = (t + 1) MOD 32;
else
    // load/store one element per register
    for s = 0 to selem-1
        rval = V[t];
    if memop == MemOp_LOAD then
        // insert into one lane of 128-bit register
        Elem[rval, index, esize] = Mem[address + offs, ebytes, AccType_VEC];
        V[t] = rval;
    else // memop == MemOp_STORE
        // extract from one lane of 128-bit register
        Mem[address + offs, ebytes, AccType_VEC] = Elem[rval, index, esize];
        offs = offs + ebytes;
        t = (t + 1) MOD 32;
if wback then
    if m != 31 then
        offs = X[m];
    if n == 31 then
        SP[] = address + offs;
    else
        X[n] = address + offs;

Operational information

If PSTATE.DIT is 1, the timing of this instruction is insensitive to the value of the data being loaded or stored.
LD3R

Load single 3-element structure and Replicate to all lanes of three registers. This instruction loads a 3-element structure from memory and replicates the structure to all the lanes of the three SIMD&FP registers.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

It has encodings from 2 classes: No offset and Post-index.

No offset

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9  | 8  | 7  | 6  | 5  | 4  | 3  | 2  | 1  | 0  |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0  | Q  | 0  | 0  | 1  | 1  | 0  | 1  | 0  | 0  | 0  | 0  | 0  | 1  | 1  | 1  | 0  |
|    | L  | R  |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |

No offset

```ld3r { <Vt>.<T>, <Vt2>.<T>, <Vt3>.<T> }, [<Xn|SP>]```

```integer t = Uint(Rt); integer n = Uint(Rn); integer m = integer UNKNOWN; boolean wback = FALSE;```

Post-index

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9  | 8  | 7  | 6  | 5  | 4  | 3  | 2  | 1  | 0  |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0  | Q  | 0  | 0  | 1  | 1  | 0  | 1  | 1  | 0  |    | 1  | 1  | 1  | 0  |
|    | L  | R  |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |

Immediate offset (Rm == 11111)

```
LD3R { <Vt>.<T>, <Vt2>.<T>, <Vt3>.<T> }, [<Xn|SP>], <imm>
```

Register offset (Rm != 11111)

```
LD3R { <Vt>.<T>, <Vt2>.<T>, <Vt3>.<T> }, [<Xn|SP>], <Xm>
```

```integer t = Uint(Rt); integer n = Uint(Rn); integer m =Uint(Rm); boolean wback = TRUE;```

Assembler Symbols

```
<Vt> Is the name of the first or only SIMD&FP register to be transferred, encoded in the "Rt" field.

<T> Is an arrangement specifier, encoded in "size:Q":
```

<table>
<thead>
<tr>
<th>size</th>
<th>Q</th>
<th>&lt;T&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>0</td>
<td>8B</td>
</tr>
<tr>
<td>00</td>
<td>1</td>
<td>16B</td>
</tr>
<tr>
<td>01</td>
<td>0</td>
<td>4H</td>
</tr>
<tr>
<td>01</td>
<td>1</td>
<td>8H</td>
</tr>
<tr>
<td>10</td>
<td>0</td>
<td>2S</td>
</tr>
<tr>
<td>10</td>
<td>1</td>
<td>4S</td>
</tr>
<tr>
<td>11</td>
<td>0</td>
<td>1D</td>
</tr>
<tr>
<td>11</td>
<td>1</td>
<td>2D</td>
</tr>
</tbody>
</table>

```

```
<Vt2> Is the name of the second SIMD&FP register to be transferred, encoded as "Rt" plus 1 modulo 32.
```
Is the name of the third SIMD&FP register to be transferred, encoded as "Rt" plus 2 modulo 32.

Is the 64-bit name of the general-purpose base register or stack pointer, encoded in the "Rn" field.

Is the post-index immediate offset, encoded in "size":

<table>
<thead>
<tr>
<th>size</th>
<th>&lt;imm&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>#3</td>
</tr>
<tr>
<td>01</td>
<td>#6</td>
</tr>
<tr>
<td>10</td>
<td>#12</td>
</tr>
<tr>
<td>11</td>
<td>#24</td>
</tr>
</tbody>
</table>

Is the 64-bit name of the general-purpose post-index register, excluding XZR, encoded in the "Rm" field.

Shared Decode

```plaintext
integer scale = UInt(opcode<2:1>);
integer selem = UInt(opcode<0>:R) + 1;
boolean replicate = FALSE;
integer index;

case scale of
  when 3
    // load and replicate
    if L == '0' || S == '1' then UNDEFINED;
    scale = if L == '0' || S == '1' then UnallocatedEncoding();
    replicate = TRUE;
  when 0
    index = UInt(Q:S:size);         // B[0-15]
  when 1
    if size<0> == '1' then UNDEFINED;
    index = if size<0> == '1' then UnallocatedEncoding();
    index = UInt(Q:S:size<1>);      // H[0-7]
  when 2
    if size<1> == '1' then UNDEFINED;
    if size<0> == '0' then
      index = if size<1> == '1' then UnallocatedEncoding();
      index = UInt(Q:S);          // S[0-3]
    else
      if S == '1' then UnallocatedEncoding(Q:S); // S[0-3]
    else
      if S == '1' then UNDEFINED;
    end
    index = UInt(Q);            // D[0-1]
    scale = 3;
  end

MemOp memop = if L == '1' then MemOp_LOAD else MemOp_STORE;
integer datasize = if Q == '1' then 128 else 64;
integer esize = 8 << scale;
```
Operation

```c
if HaveMTEExt() then
    SetNotTagCheckedInstruction(!wback && n == 31);

CheckFPAdvSIMDEnabled64();

bits(64) address;
bits(64) offs;
bits(128) rval;
bits(esize) element;

integer s;
constant integer ebytes = esize DIV 8;

if n == 31 then
    CheckSPAlignment();
    address = SP[];
else
    address = X[n];

offs = Zeros();
if replicate then
    // load and replicate to all elements
    for s = 0 to selem-1
        element = Mem[address + offs, ebytes, AccType_VEC];
    // replicate to fill 128- or 64-bit register
    V[t] = Replicate(element, datasize DIV esize);
    offs = offs + ebytes;
    t = (t + 1) MOD 32;
else
    // load/store one element per register
    for s = 0 to selem-1
        rval = V[t];
        if memop == MemOp_LOAD then
            Elem[rval, index, esize] = Mem[address + offs, ebytes, AccType_VEC];
            V[t] = rval;
        else // memop == MemOp_STORE
            // extract from one lane of 128-bit register
            Mem[address + offs, ebytes, AccType_VEC] = Elem[rval, index, esize];
            offs = offs + ebytes;
            t = (t + 1) MOD 32;
if wback then
    if m != 31 then
        offs = X[m];
    if n == 31 then
        SP[] = address + offs;
    else
        X[n] = address + offs;
```

Operational information

If PSTATE.DIT is 1, the timing of this instruction is insensitive to the value of the data being loaded or stored.

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LD4 (multiple structures)

Load multiple 4-element structures to four registers. This instruction loads multiple 4-element structures from memory and writes the result to the four SIMD&FP registers, with de-interleaving.

For an example of de-interleaving, see LD3 (multiple structures).

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

It has encodings from 2 classes: No offset and Post-index

No offset

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9  | 8  | 7  | 6  | 5  | 4  | 3  | 2  | 1  | 0  |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| Q  | 0  | 0  | 1  | 1  | 0  | 0  | 0  | 1  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  |
| L  |    | opcode | Rn |    | Rt |

No offset

LD4 \{ <Vt>.<T>, <Vt2>.<T>, <Vt3>.<T>, <Vt4>.<T> \}, [<Xn|SP>]

```
integer t = UInt(Rt);
integer n = UInt(Rn);
integer m = integer UNKNOWN;
boolean wback = FALSE;
```

Post-index

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9  | 8  | 7  | 6  | 5  | 4  | 3  | 2  | 1  | 0  |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| Q  | 0  | 0  | 1  | 1  | 0  | 0  | 1  | 1  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  |
| L  |    | opcode | Rm |    | Rn |    | Rt |

Immediate offset (Rm == 11111)

LD4 \{ <Vt>.<T>, <Vt2>.<T>, <Vt3>.<T>, <Vt4>.<T> \}, [<Xn|SP>], <imm>

Register offset (Rm != 11111)

LD4 \{ <Vt>.<T>, <Vt2>.<T>, <Vt3>.<T>, <Vt4>.<T> \}, [<Xn|SP>], <xm>

```
integer t = UInt(Rt);
integer n = UInt(Rn);
integer m = UInt(Rm);
boolean wback = TRUE;
```

Assembler Symbols

<Vt> Is the name of the first or only SIMD&FP register to be transferred, encoded in the "Rt" field.
<T> Is an arrangement specifier, encoded in “size:Q”:

<table>
<thead>
<tr>
<th>size</th>
<th>Q</th>
<th>&lt;T&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>0</td>
<td>8B</td>
</tr>
<tr>
<td>00</td>
<td>1</td>
<td>16B</td>
</tr>
<tr>
<td>01</td>
<td>0</td>
<td>4H</td>
</tr>
<tr>
<td>01</td>
<td>1</td>
<td>8H</td>
</tr>
<tr>
<td>10</td>
<td>0</td>
<td>2S</td>
</tr>
<tr>
<td>10</td>
<td>1</td>
<td>4S</td>
</tr>
<tr>
<td>11</td>
<td>0</td>
<td>RESERVED</td>
</tr>
<tr>
<td>11</td>
<td>1</td>
<td>2D</td>
</tr>
</tbody>
</table>
Is the name of the second SIMD&FP register to be transferred, encoded as "Rt" plus 1 modulo 32.

Is the name of the third SIMD&FP register to be transferred, encoded as "Rt" plus 2 modulo 32.

Is the name of the fourth SIMD&FP register to be transferred, encoded as "Rt" plus 3 modulo 32.

Is the 64-bit name of the general-purpose base register or stack pointer, encoded in the "Rn" field.

Is the post-index immediate offset, encoded in "Q":

<table>
<thead>
<tr>
<th>Q</th>
<th>&lt;imm&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>#32</td>
</tr>
<tr>
<td>1</td>
<td>#64</td>
</tr>
</tbody>
</table>

Is the 64-bit name of the general-purpose post-index register, excluding XZR, encoded in the "Rm" field.

Shared Decode

```cpp
MemOp memop = if L == '1' then MemOp_LOAD else MemOp_STORE;
integer datasize = if Q == '1' then 128 else 64;
integer esize = 8 << UInt(size);
integer elements = datasize DIV esize;

integer rpt; // number of iterations
integer selem; // structure elements

case opcode of
    when '0000' rpt = 1; selem = 4; // LD/ST4 (4 registers)
    when '0010' rpt = 4; selem = 1; // LD/ST1 (4 registers)
    when '0100' rpt = 1; selem = 3; // LD/ST3 (3 registers)
    when '0110' rpt = 3; selem = 1; // LD/ST1 (3 registers)
    when '0111' rpt = 1; selem = 1; // LD/ST1 (1 register)
    when '1000' rpt = 1; selem = 2; // LD/ST2 (2 registers)
    when '1010' rpt = 2; selem = 1; // LD/ST1 (2 registers)
otherwise UNDEFINED;

// .1D format only permitted with LD1 & ST1
if size:Q == '110' && selem != 1 then UNDEFINED; otherwise UnallocatedEncoding();

// .1D format only permitted with LD1 & ST1
if size:Q == '110' && selem != 1 then ReservedValue();
```

LD4 (multiple structures)
Operation

```c
Operation

CheckFPAdvSIMDEnabled64();

bits(64) address;
bits(64) offs;
bits(datasize) rval;
integer tt;
integer e, r, s, tt;
constant integer ebytes = esize DIV 8;

if n == 31 then
    if HaveMTEExt() then
        SetNotTagCheckedInstruction(!wback && n == 31);
    if n == 31 then
        CheckSPAlignment();
    address = SP[];
else
    address = X[n];

offs = zeros();
for r = 0 to rpt-1
    for e = 0 to elements-1
        tt = (t + r) MOD 32;
        for s = 0 to selem-1
            rval = V[tt];
            if memop == MemOp_LOAD then
                Elem[rval, e, esize] = Mem[address + offs, ebytes, AccType_VEC];
            else // memop == MemOp_STORE
                Mem[address + offs, ebytes, AccType_VEC] = Elem[rval, e, esize];
            offs = offs + ebytes;
            tt = (tt + 1) MOD 32;
if wback then
    if m != 31 then
        offs = X[m];
    if n == 31 then
        SP[] = address + offs;
    else
        X[n] = address + offs;

```

Operational information

If PSTATE.DIT is 1, the timing of this instruction is insensitive to the value of the data being loaded or stored.
LD4 (single structure)

Load single 4-element structure to one lane of four registers. This instruction loads a 4-element structure from memory and writes the result to the corresponding elements of the four SIMD&FP registers without affecting the other bits of the registers.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

It has encodings from 2 classes: No offset and Post-index

No offset

8-bit (opcode == 001)


16-bit (opcode == 011 && size == x0)


32-bit (opcode == 101 && size == 00)


64-bit (opcode == 101 && S == 0 && size == 01)


integer t = UInt(Rt);
integer n = UInt(Rn);
integer m = integer UNKNOWN;
boolean wback = FALSE;

Post-index

integer t = UInt(Rt);
integer n = UInt(Rn);
integer m = integer UNKNOWN;
boolean wback = FALSE;
8-bit, immediate offset (Rm == 11111 && opcode == 001)

8-bit, register offset (Rm != 11111 && opcode == 001)

16-bit, immediate offset (Rm == 11111 && opcode == 011 && size == x0)

16-bit, register offset (Rm != 11111 && opcode == 011 && size == x0)

32-bit, immediate offset (Rm == 11111 && opcode == 101 && size == 00)

32-bit, register offset (Rm != 11111 && opcode == 101 && size == 00)

64-bit, immediate offset (Rm == 11111 && opcode == 101 && S == 0 && size == 01)

64-bit, register offset (Rm != 11111 && opcode == 101 && S == 0 && size == 01)

integer t = UInt(Rt);
integer n = UInt(Rn);
integer m = UInt(Rm);
boolean wback = TRUE;

Assembler Symbols

<Vt> Is the name of the first or only SIMD&FP register to be transferred, encoded in the "Rt" field.
<Vt2> Is the name of the second SIMD&FP register to be transferred, encoded as "Rt" plus 1 modulo 32.
<Vt3> Is the name of the third SIMD&FP register to be transferred, encoded as "Rt" plus 2 modulo 32.
<Vt4> Is the name of the fourth SIMD&FP register to be transferred, encoded as "Rt" plus 3 modulo 32.
<index> For the 8-bit variant: is the element index, encoded in "Q:S:size".
For the 16-bit variant: is the element index, encoded in "Q:S:size<1>".
For the 32-bit variant: is the element index, encoded in "Q:S".
For the 64-bit variant: is the element index, encoded in "Q".
<Xn|SP> Is the 64-bit name of the general-purpose base register or stack pointer, encoded in the "Rn" field.
<Xm> Is the 64-bit name of the general-purpose post-index register, excluding XZR, encoded in the "Rm" field.
integer scale = Uint(opcode<2:1>);
integer selem = Uint(opcode<0>:R) + 1;
boolean replicate = FALSE;
integer index;
case scale of
  when 3
    // load and replicate
    if L == '0' || S == '1' then UNDEFINED;
    scale = if L == '0' || S == '1' then UnallocatedEncoding();
    scale = Uint(size);
    replicate = TRUE;
  when 0
    index = Uint(Q:S:size); // B[0-15]
  when 1
    if size<0> == '1' then UNDEFINED;
    index = if size<0> == '1' then UnallocatedEncoding();
    index = Uint(Q:S:size<1>); // H[0-7]
  when 2
    if size<1> == '1' then UNDEFINED;
    if size<0> == '0' then
      index = if size<1> == '1' then UnallocatedEncoding();
      index = Uint(Q:S); // S[0-3]
    else
      if S == '1' then UnallocatedEncoding(Q:S); // S[0-3]
    end
    if S == '1' then UNDEFINED;
    else
      index = Uint(Q); // D[0-1]
    end
  scale = 3;
MemOp memop = if L == '1' then MemOp_LOAD else MemOp_STORE;
integer datasize = if Q == '1' then 128 else 64;
integer esize = 8 << scale;
if HaveMTEExt() then
    SetNotTagCheckedInstruction(!wback && n == 31);

CheckFPAdvSIMDEnabled64();

bits(64) address;
broadcast(64) offs;
broadcast(128) rval;
bits(esize) element;

integer ebytes = esize DIV 8;

if n == 31 then
    CheckSPAlignment();
    address = SP[];
else
    address = X[n];

offs = Zeros();
if replicate then
    // load and replicate to all elements
    for s = 0 to selem-1
        element = Mem[address + offs, ebytes, AccType_VEC];
        offs = offs + ebytes;
        t = (t + 1) MOD 32;
else
    // load/store one element per register
    for s = 0 to selem-1
        rval = V[t];
        if memop == MemOp_LOAD then
            // insert into one lane of 128-bit register
            Elem[rval, index, esize] = Mem[address + offs, ebytes, AccType_VEC];
            V[t] = rval;
        else // memop == MemOp_STORE
            // extract from one lane of 128-bit register
            Mem[address + offs, ebytes, AccType_VEC] = Elem[rval, index, esize];
            offs = offs + ebytes;
            t = (t + 1) MOD 32;

if wback then
    if m != 31 then
        offs = X[m];
    if n == 31 then
        SP[] = address + offs;
    else
        X[n] = address + offs;

Operational information

If PSTATE.DIT is 1, the timing of this instruction is insensitive to the value of the data being loaded or stored.
LD4R

Load single 4-element structure and Replicate to all lanes of four registers. This instruction loads a 4-element structure from memory and replicates the structure to all the lanes of the four SIMD&FP registers.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

It has encodings from 2 classes: No offset and Post-index

No offset

```
| 0 | Q | 0 | 0 | 1 | 1 | 0 | 1 | 0 | 1 | 1 | 1 | 0 | size | Rn | Rt |
```

| L | R | opcode | S |

```
LD4R { <Vt>.,<T>, <Vt2>.,<T>, <Vt3>.,<T>, <Vt4>..<T> }, [<Xn|SP>] |
```

```
integer t = UInt(Rt);
integer n = UInt(Rn);
integer m = integer UNKNOWN;
boolean wback = FALSE;
```

Post-index

```
| 0 | Q | 0 | 0 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | size | Rm | Rn | Rt |
```

| L | R | opcode | S |

```
Immediate offset (Rm == 11111)
```

```
LD4R { <Vt>.,<T>, <Vt2>.,<T>, <Vt3>.,<T>, <Vt4>..<T> }, [<Xn|SP>], <imm>
```

```
Register offset (Rm != 11111)
```

```
LD4R { <Vt>.,<T>, <Vt2>.,<T>, <Vt3>.,<T>, <Vt4>..<T> }, [<Xn|SP>], <Xm>
```

```
integer t = UInt(Rt);
integer n = UInt(Rn);
integer m = UInt(Rm);
boolean wback = TRUE;
```

Assembler Symbols

```
<Vt> Is the name of the first or only SIMD&FP register to be transferred, encoded in the "Rt" field.
```

```
<T> Is an arrangement specifier, encoded in "size:Q":
```

<table>
<thead>
<tr>
<th>size</th>
<th>Q</th>
<th>&lt;T&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>0</td>
<td>8B</td>
</tr>
<tr>
<td>00</td>
<td>1</td>
<td>16B</td>
</tr>
<tr>
<td>01</td>
<td>0</td>
<td>4H</td>
</tr>
<tr>
<td>01</td>
<td>1</td>
<td>8H</td>
</tr>
<tr>
<td>10</td>
<td>0</td>
<td>2S</td>
</tr>
<tr>
<td>10</td>
<td>1</td>
<td>4S</td>
</tr>
<tr>
<td>11</td>
<td>0</td>
<td>1D</td>
</tr>
<tr>
<td>11</td>
<td>1</td>
<td>2D</td>
</tr>
</tbody>
</table>

```
<Vt2> Is the name of the second SIMD&FP register to be transferred, encoded as "Rt" plus 1 modulo 32.
Is the name of the third SIMD&FP register to be transferred, encoded as "Rt" plus 2 modulo 32.

Is the name of the fourth SIMD&FP register to be transferred, encoded as "Rt" plus 3 modulo 32.

Is the 64-bit name of the general-purpose base register or stack pointer, encoded in the "Rn" field.

Is the post-index immediate offset, encoded in "size":

<table>
<thead>
<tr>
<th>size</th>
<th>&lt;imm&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>#4</td>
</tr>
<tr>
<td>01</td>
<td>#8</td>
</tr>
<tr>
<td>10</td>
<td>#16</td>
</tr>
<tr>
<td>11</td>
<td>#32</td>
</tr>
</tbody>
</table>

Is the 64-bit name of the general-purpose post-index register, excluding XZR, encoded in the "Rm" field.

**Shared Decode**

```plaintext
integer scale = UInt(opcode<2:1>);
integer selem = UInt(opcode<0>:R) + 1;
boolean replicate = FALSE;
integer index;

case scale of
  when 3
    // load and replicate
    if L == '0' || S == '1' then UNDEFINED;
    scale = UInt(size);
    replicate = TRUE;
  when 0
    index = UInt(Q:S:size);         // B[0-15]
  when 1
    if size<0> == '1' then UNDEFINED;
    index = if size<0> == '1' then UnallocatedEncoding();
    index = UInt(Q:S:size<1>);      // H[0-7]
  when 2
    if size<1> == '1' then UNDEFINED;
    if size<0> == '0' then
      index = if size<1> == '1' then UnallocatedEncoding();
      index = UInt(Q:S);            // S[0-3]
    else
      if S == '1' then UnallocatedEncoding(Q:S);        // S[0-3]
      else
        if S == '1' then UNDEFINED;
        index = UInt(Q);            // D[0-1]
        scale = 3;
  else
    MemOp memop = if L == '1' then MemOp_LOAD else MemOp_STORE;
integer datasize = if Q == '1' then 128 else 64;
integer esize = 8 << scale;
```
if `HaveMTEExt()` then
    `SetNotTagCheckedInstruction(!wback && n == 31);`

`CheckFPAAdvSIMDEnabled64();`

bits(64) address;
bits(64) offs;
bits(128) rval;
bits(esize) element;
integer ebytes;

constant integer ebytes = esize DIV 8;

if n == 31 then
    `CheckSPAlignment();`
else
    address = `X[n];`

offs = `Zeros();`
if replicate then
    // load and replicate to all elements
    for s = 0 to selem-1
        element = `Mem[address + offs, ebytes, AccType_VEC];`
        // replicate to fill 128- or 64-bit register
        `V[t] = Replicate(element, datasize DIV esize);`
        offs = offs + ebytes;
        t = (t + 1) MOD 32;
else
    // load/store one element per register
    for s = 0 to selem-1
        rval = `V[t];`
        if memop == MemOp_LOAD then
            // insert into one lane of 128-bit register
            `Elem[rval, index, esize] = Mem[address + offs, ebytes, AccType_VEC];`
            `V[t] = rval;`
        else // memop == MemOp_STORE
            // extract from one lane of 128-bit register
            `Mem[address + offs, ebytes, AccType_VEC] = Elem[rval, index, esize];`
            offs = offs + ebytes;
            t = (t + 1) MOD 32;

if wback then
    if m != 31 then
        offs = `X[m];`
    if n == 31 then
        `SP[] = address + offs;`
    else
        `X[n] = address + offs;`

Operational information

If PSTATE.DIT is 1, the timing of this instruction is insensitive to the value of the data being loaded or stored.

Internal version only: isa v30.25-v29.05, AdvSIMD v27.01-v26.0, pseudocode v85-xml-00bet8 rc325; Build timestamp: 2018-09-13T13:0045 2018-06-16T09:04:45

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LDADD, LDADDA, LDADDAL, LDADDL

Atomic add on word or doubleword in memory atomically loads a 32-bit word or 64-bit doubleword from memory, adds the value held in a register to it, and stores the result back to memory. The value initially loaded from memory is returned in the destination register.

- If the destination register is not one of WZR or XZR, LDADDA and LDADDAL load from memory with acquire semantics.
- LDADDL and LDADDAL store to memory with release semantics.
- LDADD has no memory ordering requirements.

For more information about memory ordering semantics see `Load-Acquire, Store-Release`.
For information about memory accesses see `Load/Store addressing modes`.

This instruction is used by the alias `STADD, STADDL`.

Integer (ARMv8.1)

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 |  9 |  8 |  7 |  6 |  5 |  4 |  3 |  2 |  1 |  0 |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| x  | 1  | 1  | 1  | 0  | 0  | A  | R  | 1  | Rs | 0  | 0  | 0  | 0  | 0  | Rn |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |

size opc
32-bit LDADD (size == 10 & A == 0 & R == 0)
LDADD <Ws>, <Wt>, [<Xn|SP>]

32-bit LDADDA (size == 10 & A == 1 & R == 0)
LDADDA <Ws>, <Wt>, [<Xn|SP>]

32-bit LDADDAL (size == 10 & A == 1 & R == 1)
LDADDAL <Ws>, <Wt>, [<Xn|SP>]

32-bit LDADDL (size == 10 & A == 0 & R == 1)
LDADDL <Ws>, <Wt>, [<Xn|SP>]

64-bit LDADD (size == 11 & A == 0 & R == 0)
LDADD <Xs>, <Xt>, [<Xn|SP>]

64-bit LDADDA (size == 11 & A == 1 & R == 0)
LDADDA <Xs>, <Xt>, [<Xn|SP>]

64-bit LDADDAL (size == 11 & A == 1 & R == 1)
LDADDAL <Xs>, <Xt>, [<Xn|SP>]

64-bit LDADDL (size == 11 & A == 0 & R == 1)
LDADDL <Xs>, <Xt>, [<Xn|SP>]

if !HaveAtomicExt() then UNDEFINED;
integer t = UInt(Rt);
integer n = UInt(Rn);
integer s = UInt(Rs);
integer datasize = 8 << UInt(size);
integer regsize = if datasize == 64 then 64 else 32;
AccType ldacctype = if A == '1' && Rt != '11111' then AccType_ORDEREDATOMICRW else AccType_ORDEREDRW;
AccType stacctype = if R == '1' then AccType_ORDEREDATOMICRW else AccType_ATOMICRW;
MemAtomicOp op;
case opc of
  when '000' op = MemAtomicOp_ADD;
  when '001' op = MemAtomicOp_BIC;
  when '010' op = MemAtomicOp_EOR;
  when '011' op = MemAtomicOp_ORR;
  when '100' op = MemAtomicOp_SMAX;
  when '101' op = MemAtomicOp_SMIN;
  when '110' op = MemAtomicOp_UMAX;
  when '111' op = MemAtomicOp_UMIN;

Assembler Symbols

<Ws> Is the 32-bit name of the general-purpose register holding the data value to be operated on with the contents of the memory location, encoded in the "Rs" field.

<Wt> Is the 32-bit name of the general-purpose register to be loaded, encoded in the "Rt" field.

<Xs> Is the 64-bit name of the general-purpose register holding the data value to be operated on with the contents of the memory location, encoded in the "Rs" field.
Is the 64-bit name of the general-purpose register to be loaded, encoded in the "Rt" field.

Is the 64-bit name of the general-purpose base register or stack pointer, encoded in the "Rn" field.

### Alias Conditions

<table>
<thead>
<tr>
<th>Alias</th>
<th>Is preferred when</th>
</tr>
</thead>
<tbody>
<tr>
<td>STADD, STADDL</td>
<td>A == '0' &amp;&amp; Rt == '11111'</td>
</tr>
</tbody>
</table>

### Operation

```plaintext
bits(64) address;
bits(datasize) value;
bits(datasize) data;
bits(datasize) result;

if HaveMTEExt() then
    SetNotTagCheckedInstruction(n == 31);

value = X[s];
if n == 31 then
    CheckSPAlignment();
    address = SP[];
else
    address = X[n];

// All observers in the shareability domain observe the
// following load and store atomically.
data = Mem[address, datasize DIV 8, ldacctype];

case op of
    when MemAtomicOp_ADD   result = data + value;
    when MemAtomicOp_BIC   result = data AND NOT(value);
    when MemAtomicOp_EOR   result = data EOR value;
    when MemAtomicOp_ORR   result = data OR value;
    when MemAtomicOp_SMAX  result = if SInt(data) > SInt(value) then data else value;
    when MemAtomicOp_SMIN  result = if SInt(data) > SInt(value) then value else data;
    when MemAtomicOp_UMAX  result = if UInt(data) > UInt(value) then value else data;
    when MemAtomicOp_UMIN  result = if UInt(data) > UInt(value) then value else data;

    Mem[address, datasize DIV 8, stacctype] = result;

if t != 31 then
    X[t] = ZeroExtend(data, regsize);
```

### Operational information

If PSTATE.DIT is 1, the timing of this instruction is insensitive to the value of the data being loaded or stored.

---

(old) **htmldiff from-** **(new)**
LDADDB, LDADDAB, LDADDALB, LDADDLB

Atomic add on byte in memory atomically loads an 8-bit byte from memory, adds the value held in a register to it, and stores the result back to memory. The value initially loaded from memory is returned in the destination register.

- If the destination register is not WZR, LDADDAB and LDADDALB load from memory with acquire semantics.
- LDADDLB and LDADDALB store to memory with release semantics.
- LDADDB has no memory ordering requirements.

For more information about memory ordering semantics see *Load-Acquire, Store-Release*. For information about memory accesses see *Load/Store addressing modes*.

This instruction is used by the alias STADDB, STADDLB.

### Integer (ARMv8.1)

<table>
<thead>
<tr>
<th>00</th>
<th>1</th>
<th>1</th>
<th>1</th>
<th>A</th>
<th>R</th>
<th>0</th>
<th>0</th>
<th>A</th>
<th>Rs</th>
<th>0</th>
<th>0</th>
<th>0</th>
<th>0</th>
<th>Rn</th>
<th>Rt</th>
</tr>
</thead>
<tbody>
<tr>
<td>size</td>
<td>opc</td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

LDADDB (A == 1 && R == 0)

LDADDB <Ws>, <Wt>, [<Xn|SP>]

LDADDALB (A == 1 && R == 1)

LDADDALB <Ws>, <Wt>, [Xn|SP>]

LDADDB (A == 0 && R == 0)

LDADDB <Ws>, <Wt>, [Xn|SP>]

LDADDB (A == 0 && R == 1)

LDADDB <Ws>, <Wt>, [Xn|SP>]

```plaintext
if !HaveAtomicExt() then UNDEFINED;
integer t = 1 then UnallocatedEncoding();
integer t = UInt(Rt);
integer n = UInt(Rn);
integer s = UInt(Rs);

integer datasize = 8 << UInt(size);
integer regsize = if datasize == 64 then 64 else 32;
AccType ldacctype = if A == '1' && Rt != '11111' then AccType_ORDEREDATOMICRW else AccType_ATOMICRW;
AccType stacctype = if R == '1' then AccType_ORDEREDATOMICRW else AccType_ATOMICRW;
MemAtomicOp op;

case opc of
when '000' op = MemAtomicOp ADD;
when '001' op = MemAtomicOp BIC;
when '010' op = MemAtomicOp EOR;
when '011' op = MemAtomicOp ORR;
when '100' op = MemAtomicOp SMAX;
when '101' op = MemAtomicOp SMIN;
when '110' op = MemAtomicOp UMAX;
when '111' op = MemAtomicOp UMIN;
```

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Assembler Symbols

<Ws> Is the 32-bit name of the general-purpose register holding the data value to be operated on with the contents of the memory location, encoded in the "Rs" field.

<Wt> Is the 32-bit name of the general-purpose register to be loaded, encoded in the "Rt" field.

<Xn|SP> Is the 64-bit name of the general-purpose base register or stack pointer, encoded in the "Rn" field.

Alias Conditions

<table>
<thead>
<tr>
<th>Alias</th>
<th>Is preferred when</th>
</tr>
</thead>
<tbody>
<tr>
<td>STADDB, STADDLB</td>
<td>A == '0' &amp; Rt == '11111'</td>
</tr>
</tbody>
</table>

Operation

```plaintext
bits(64) address;
bits(datasize) value;
bits(datasize) data;
bits(datasize) result;

if value = HaveMTEExt() then
    SetNotTagCheckedInstruction(n == 31);

value = X[s];
if n == 31 then
    CheckSPAlignment();
    address = SP[];
else
    address = X[n];

// All observers in the shareability domain observe the
// following load and store atomically.
data = Mem[address, datasize DIV 8, ldacctype];

case op of
    when MemAtomicOp_ADD result = data + value;
    when MemAtomicOp_BIC result = data AND NOT(value);
    when MemAtomicOp_EOR result = data EOR value;
    when MemAtomicOp_ORR result = data OR value;
    when MemAtomicOp_SMAX result = if SInt(data) > SInt(value) then data else value;
    when MemAtomicOp_SMIN result = if SInt(data) < SInt(value) then value else data;
    when MemAtomicOp_UMAX result = if UInt(data) > UInt(value) then value else data;
    when MemAtomicOp_UMIN result = if UInt(data) < UInt(value) then data else value;

    Mem[address, datasize DIV 8, stacctype] = result;

if t != 31 then
    X[t] = ZeroExtend(data, regsize);
```

Operational information

If PSTATE.DIT is 1, the timing of this instruction is insensitive to the value of the data being loaded or stored.

Internal version only: isa v30.25, AdvSIMD v27.0, pseudocode v85-xml-00bet8_rc3_145; Build timestamp: 2018-09-13 13:20:45
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LDADDH, LDADDAH, LDADDALH, LDADDLH

Atomic add on halfword in memory atomically loads a 16-bit halfword from memory, adds the value held in a register to it, and stores the result back to memory. The value initially loaded from memory is returned in the destination register.

- If the destination register is not WZR, LDADDAH and LDADDALH load from memory with acquire semantics.
- LDADDLH and LDADDALH store to memory with release semantics.
- LDADDH has no memory ordering requirements.

For more information about memory ordering semantics see Load-Acquire, Store-Release.
For information about memory accesses see Load/Store addressing modes.

This instruction is used by the alias STADDDH, STADDDLH.

Integer
(ARMv8.1)

```
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9  | 8  | 7  | 6  | 5  | 4  | 3  | 2  | 1  | 0 |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0  | 1  | 1  | 1  | 0  | 0  | A  | R  | 1  | Rs | 0  | 0  | 0  | 0  | 0  | Rn |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
```

group size opc

LDADDAH (A == 1 && R == 0)

LDADDAH <Ws>, <Wt>, [<Xn|SP]>

LDADDALH (A == 1 && R == 1)

LDADDALH <Ws>, <Wt>, [<Xn|SP]>

LDADDH (A == 0 && R == 0)

LDADDH <Ws>, <Wt>, [<Xn|SP]>

LDADDLH (A == 0 && R == 1)

LDADDLH <Ws>, <Wt>, [<Xn|SP]>

```python
if !HaveAtomicExt() then UNDEFINED;
integer t = Integer(Rt);
integer n = Integer(Rn);
integer s = Integer(Rs);

integer datasize = 8 << Integer(size);
integer regsize = if datasize == 64 then 64 else 32;

AccType ldacctype = if A == '1' & R != '11111' then AccType_ORDERED_ATOMICRW else AccType_ATOMIC_RW;
AccType stacctype = if R == '1' then AccType_ORDERED_ATOMICRW else AccType_ATOMIC_RW;

MemAtomicOp op;

case opc of
    when '000' op = MemAtomicOp_ADD;
    when '001' op = MemAtomicOp_BIC;
    when '010' op = MemAtomicOp_EOR;
    when '011' op = MemAtomicOp_ORR;
    when '100' op = MemAtomicOp_SMAX;
    when '101' op = MemAtomicOp_SMIN;
    when '110' op = MemAtomicOp_UMAX;
    when '111' op = MemAtomicOp_UMIN;
```
Assembler Symbols

<Ws> Is the 32-bit name of the general-purpose register holding the data value to be operated on with the contents of the memory location, encoded in the "Rs" field.

<Wt> Is the 32-bit name of the general-purpose register to be loaded, encoded in the "Rt" field.

<Xn|SP> Is the 64-bit name of the general-purpose base register or stack pointer, encoded in the "Rn" field.

Alias Conditions

<table>
<thead>
<tr>
<th>Alias</th>
<th>Is preferred when</th>
</tr>
</thead>
<tbody>
<tr>
<td>STADDH, STADDLH</td>
<td>A == '0' &amp; &amp; Rt == '11111'</td>
</tr>
</tbody>
</table>

Operation

bits(64) address;
bits(datasize) value;
bits(datasize) data;
bits(datasize) result;

if value = HaveMTEExt() then
  SetNotTagCheckedInstruction(n == 31);

value = X[s];
if n == 31 then
  CheckSPAlignment();
  address = SP[];
else
  address = X[n];

// All observers in the shareability domain observe the
// following load and store atomically.
data = Mem[address, datasize DIV 8, ldacctype];

case op of
  when MemAtomicOp_ADD result = data + value;
  when MemAtomicOp_BIC result = data AND NOT(value);
  when MemAtomicOp_EOR result = data EOR value;
  when MemAtomicOp_ORR result = data OR value;
  when MemAtomicOp_SMAX result = if SInt(data) > SInt(value) then data else value;
  when MemAtomicOp_SMIN result = if SInt(data) > SInt(value) then value else data;
  when MemAtomicOp_UMAX result = if UInt(data) > UInt(value) then value else data;
  when MemAtomicOp_UMIN result = if UInt(data) > UInt(value) then value else data;

Mem[address, datasize DIV 8, stacctype] = result;

if t != 31 then
  X[t] = ZeroExtend(data, regsize);

Operational information

If PSTATE.DIT is 1, the timing of this instruction is insensitive to the value of the data being loaded or stored.
Load-Acquire RCpc Register derives an address from a base register value, loads a 32-bit word or 64-bit doubleword from the derived address in memory, and writes it to a register.

The instruction has memory ordering semantics as described in *Load-Acquire, Load-AcquirePC, and Store-Release*, except that:

- There is no ordering requirement, separate from the requirements of a Load-AcquirePC or a Store-Release, created by having a Store-Release followed by a Load-AcquirePC instruction.
- The reading of a value written by a Store-Release by a Load-AcquirePC instruction by the same observer does not make the write of the Store-Release globally observed.

This difference in memory ordering is not described in the pseudocode.

For information about memory accesses, see *Load/Store addressing modes*.

### Integer (ARMv8.3)

32-bit (size == 10)

```plaintext
LDAPR <Wt>, [<Xn|SP> {,#0}]
```

64-bit (size == 11)

```plaintext
LDAPR <Xt>, [<Xn|SP> {,#0}]
```

```plaintext
integer n = UInt(Rn);
integer t = UInt(Rt);
integer s = UInt(Rs);  // ignored by all loads and store-release

AccType acctype = AccType_ORDERED;
integer elsize = 8 << UInt(size);
integer regsize = if elsize == 64 then 64 else 32;
integer datasize = elsize;
```

### Assembler Symbols

- `<Wt>` Is the 32-bit name of the general-purpose register to be loaded, encoded in the "Rt" field.
- `<Xt>` Is the 64-bit name of the general-purpose register to be loaded, encoded in the "Rt" field.
- `<Xn|SP>` Is the 64-bit name of the general-purpose base register or stack pointer, encoded in the "Rn" field.
Operation

bits(64) address;
bits(datasize) data;
constant integer dbytes = datasize DIV 8;

if n == 31 then
    HaveMTEExt() then
        SetNotTagCheckedInstruction(n == 31);
    end
if n == 31 then
    CheckSPAAlignment();
    address = SP[];
else
    address = X[n];
end

data = Mem[address, dbytes, acctype];
X[t] = ZeroExtend(data, regsize);

Operational information

If PSTATE.DIT is 1, the timing of this instruction is insensitive to the value of the data being loaded or stored.
LDAPRB

Load-Acquire RCpc Register Byte derives an address from a base register value, loads a byte from the derived address in memory, zero-extends it and writes it to a register.

The instruction has memory ordering semantics as described in Load-Acquire, Load-AcquirePC, and Store-Release, except that:

- There is no ordering requirement, separate from the requirements of a Load-AcquirePC or a Store-Release, created by having a Store-Release followed by a Load-AcquirePC instruction.
- The reading of a value written by a Store-Release by a Load-AcquirePC instruction by the same observer does not make the write of the Store-Release globally observed.

This difference in memory ordering is not described in the pseudocode.

For information about memory accesses, see Load/Store addressing modes.

### Integer (ARMv8.3)

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<th>3</th>
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<th>1</th>
<th>0</th>
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</thead>
<tbody>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### Integer

```
LDAPRB <Wt>, [<Xn|SP> {,#0}]
```

integer n = UInt(Rn);
integer t = UInt(Rt);
integer s = UInt(Rs); // ignored by all loads and store-release

AccType acctype = AccType_ORDERED;
integer elsize = 8 <<< UInt(size);
integer regsize = if elsize == 64 then 64 else 32;
integer datasize = elsize;

#### Assembler Symbols

- `<Wt>` Is the 32-bit name of the general-purpose register to be loaded, encoded in the "Rt" field.
- `<Xn|SP>` Is the 64-bit name of the general-purpose base register or stack pointer, encoded in the "Rn" field.

#### Operation

```
bits(64) address;
bits(datasize) data;
constant integer dbytes = datasize DIV 8;
if n == 31 then HaveMTEExt() then
  SetNotTagCheckedInstruction(n == 31);
if n == 31 then
  CheckSPAlignment();
  address = SP[];
else
  address = X[n];
data = Mem[address, dbytes, acctype];
X[t] = ZeroExtend(data, regsize);
```

#### Operational information

If PSTATE.DIT is 1, the timing of this instruction is insensitive to the value of the data being loaded or stored.
LDAPRH

Load-Acquire RCpc Register Halfword derives an address from a base register value, loads a halfword from the derived address in memory, zero-extends it and writes it to a register.

The instruction has memory ordering semantics as described in Load-Acquire, Load-AcquirePC, and Store-Release, except that:

- There is no ordering requirement, separate from the requirements of a Load-AcquirePC or a Store-Release, created by having a Store-Release followed by a Load-AcquirePC instruction.
- The reading of a value written by a Store-Release by a Load-AcquirePC instruction by the same observer does not make the write of the Store-Release globally observed.

This difference in memory ordering is not described in the pseudocode.

For information about memory accesses, see Load/Store addressing modes.

Integer
(ARMv8.3)

<p>| |</p>
<table>
<thead>
<tr>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>31</td>
</tr>
<tr>
<td>0</td>
</tr>
<tr>
<td>size</td>
</tr>
</tbody>
</table>

Integer

LDAPRH <Wt>, [<Xn|SP> {,#0}]

integer n = UInt(Rn);
integer t = UInt(Rt);
integer s = UInt(Rs); // ignored by all loads and store-release

AccType acctype = AccType_ORDERED;
integer elsize = 8 << UInt(size);
integer regsize = if elsize == 64 then 64 else 32;
integer datasize = elsize;

Assembler Symbols

<Wt> Is the 32-bit name of the general-purpose register to be loaded, encoded in the "Rt" field.
<Xn|SP> Is the 64-bit name of the general-purpose base register or stack pointer, encoded in the "Rn" field.

Operation

bits(64) address;
bits(datasize) data;
constant integer dbytes = datasize DIV 8;

if n == 31 then HaveMTEExt() then
  SetNotTagCheckedInstruction(n == 31);
if n == 31 then
  CheckSPAlignment();
  address = SP[];
else
  address = X[n];
data = Mem[address, dbytes, acctype];
X[t] = ZeroExtend(data, regsize);

Operational information

If PSTATE.DIT is 1, the timing of this instruction is insensitive to the value of the data being loaded or stored.
LDAPUR

Load-Acquire RCpc Register (unscaled) calculates an address from a base register and an immediate offset, loads a 32-bit word or 64-bit doubleword from memory, zero-extends it, and writes it to a register.

The instruction has memory ordering semantics as described in Load-Acquire, Load-AcquirePC, and Store-Release, except that:

• There is no ordering requirement, separate from the requirements of a Load-AcquirePC or a Store-Release, created by having a Store-Release followed by a Load-AcquirePC instruction.
• The reading of a value written by a Store-Release by a Load-AcquirePC instruction by the same observer does not make the write of the Store-Release globally observed.

This difference in memory ordering is not described in the pseudocode.

For information about memory accesses, see Load/Store addressing modes.

32-bit (size == 10)

LDAPUR <Wt>, [<Xn|SP>{, #<simm}>]

64-bit (size == 11)

LDAPUR <Xt>, [<Xn|SP>{, #<simm}>]

boolean wback = FALSE;
boolean postindex = FALSE;
integer scale = UInt(size);
bits(64) offset = SignExtend(imm9, 64);

Assembler Symbols

<Wt> Is the 32-bit name of the general-purpose register to be transferred, encoded in the "Rt" field.
<Xt> Is the 64-bit name of the general-purpose register to be transferred, encoded in the "Rt" field.
<Xn|SP> Is the 64-bit name of the general-purpose base register or stack pointer, encoded in the "Rn" field.
<simm> Is the optional signed immediate byte offset, in the range -256 to 255, defaulting to 0 and encoded in the "imm9" field.
integer n = UInt(Rn);
integer t = UInt(Rt);
AccType accType = AccType_ORDERED;
MemOp memop;
boolean signed;
integer regsize;
if opc<1> == '0' then
    // store or zero-extending load
    memop = if opc<0> == '1' then MemOp_LOAD else MemOp_STORE;
    regsize = if size == '11' then 64 else 32;
    signed = FALSE;
else
    if size == '11' then
        memop = MemOp_PREFETCH;
        if opc<0> == '1' then UNDEFINED;
    else
        // sign-extending load
        memop = if opc<0> == '1' then UnallocatedEncoding()
        else
            // sign-extending load
            memop = MemOp_LOAD;
            if size == '10' && opc<0> == '1' then UnallocatedEncoding;
        end
        regsize = if opc<0> == '1' then 32 else 64;
        signed = TRUE;
end
integer datasize = 8 << scale;
if bits(64) address;
bounds(datasize) data;
boolean wb_unknown = FALSE;
boolean rt_unknown = FALSE;

if memop == HaveMTEExt() then
  boolean is_load_store = memop IN {MemOp STORE, MemOp LOAD};
  SetNotTagCheckedInstruction(is_load_store & n == 31 & wback);

bits(64) address;
bounds(datasize) data;
boolean wb_unknown = FALSE;
boolean rt_unknown = FALSE;

if memop == rt wback t n == t & n != 31 then
  c = ConstrainUnpredictable(Unpredictable_WBOVERLAPLD);
  assert c IN {Constraint_WBSUPPRESS, Constraint_UNKNOWN, Constraint_UNDEF, Constraint_NOP};
  case c of
    when Constraint_WBSUPPRESS wback = FALSE; // writeback is suppressed
    when Constraint_UNKNOWN wb_unknown = TRUE; // writeback is UNKNOWN
    when Constraint_UNDEF rt_unknown = FALSE; // value stored is original value
    when UnallocatedEncoding();
    when Constraint_NOP EndOfInstruction();

if memop == MemOp STORE & wback & n == t & n != 31 then
  c = ConstrainUnpredictable(Unpredictable_WBOVERLAPST);
  assert c IN {Constraint_NONE, Constraint_UNKNOWN, Constraint_UNDEF, Constraint_NOP};
  case c of
    when Constraint_NONE rt_unknown = FALSE; // value stored is original value
    when Constraint_UNKNOWN rt_unknown = TRUE; // value stored is UNKNOWN
    when Constraint_UNDEF UnallocatedEncoding();
    when Constraint_NOP EndOfInstruction();

if n == 31 then
  if memop != MemOp_PREFETCH then CheckSPAkmement();
  address = SP[];
else
  address = X[n];

if ! postindex then
  address = address + offset;

  case memop of
    when MemOp STORE
      if rt_unknown then
        data = bounds(datasize) UNKNOWN;
      else
        data = X[t];
        Mem[address, datasize DIV 8, acctype] = data;
    when MemOp LOAD
      data = Mem[address, datasize DIV 8, acctype];
      if signed then
        X[t] = SignExtend(data, regsize);
      else
        X[t] = ZeroExtend(data, regsize);
      when MemOp_PREFETCHPrefetch(address, t<4:0>);

if wback then
  if wb_unknown then
    address = bits(64) UNKNOWN;
  elseif postindex then
    address = address + offset;
  if n == 31 then
    SP[] = address;
else

\( X[n] = \text{address}; \)

**Operational information**

If PSTATE.DIT is 1, the timing of this instruction is insensitive to the value of the data being loaded or stored.
LDAPURB

Load-Acquire RCpc Register Byte (unscaled) calculates an address from a base register and an immediate offset, loads a byte from memory, zero-extends it, and writes it to a register.

The instruction has memory ordering semantics as described in *Load-Acquire, Load-AcquirePC, and Store-Release*, except that:

- There is no ordering requirement, separate from the requirements of a Load-AcquirePC or a Store-Release, created by having a Store-Release followed by a Load-AcquirePC instruction.
- The reading of a value written by a Store-Release by a Load-AcquirePC instruction by the same observer does not make the write of the Store-Release globally observed.

This difference in memory ordering is not described in the pseudocode.

For information about memory accesses, see *Load/Store addressing modes*.

For information about memory accesses, see *Load/Store addressing modes*.

### Unscaled offset

```
LDAPURB <Wt>, [<Xn|SP>{, #<simm>}]
```

boolean wback = FALSE;
boolean postindex = FALSE;
integer scale = UInt(size);
bv(64) offset = SignExtend(imm9, 64);

### Assembler Symbols

- `<Wt>`: Is the 32-bit name of the general-purpose register to be transferred, encoded in the "Rt" field.
- `<Xn|SP>`: Is the 64-bit name of the general-purpose base register or stack pointer, encoded in the "Rn" field.
- `<simm>`: Is the optional signed immediate byte offset, in the range -256 to 255, defaulting to 0 and encoded in the "imm9" field.
integer n = UINT(Rn);
integer t = UINT(Rt);
AccType acctype = AccType_ORDERED;
MemOp memop;
boolean signed;
integer regsize;

if opc<1> == '0' then
    // store or zero-extending load
    memop = if opc<0> == '1' then MemOp_LOAD else MemOp_STORE;
    regsize = if size == '11' then 64 else 32;
    signed = FALSE;
else
    if size == '11' then
        memop = MemOp_PREFETCH;
        if opc<0> == '1' then UNDEFINED;
    else
        // sign-extending load
        memop = if opc<0> == '1' then UnallocatedEncoding();
        else
            // sign-extending load
            memop = MemOp_LOAD;
            if size == '10' && opc<0> == '1' then UNDEFINED;
        else
            regsize = if opc<0> == '1' then 32 else 64;
            signed = TRUE;

integer datasize = 8 << scale;
if bits(64) address;
bits(datasize) data;

boolean wb_unknown = FALSE;
boolean rt_unknown = FALSE;

if memop == HaveMTEExt() then
  // more code here

SetNotTagCheckedInstruction(is_load_store && n == 31 && !wback);

bits(64) address;
bits(datasize) data;

boolean wb_unknown = FALSE;
boolean rt_unknown = FALSE;

if memop == MemOp_STORE && wback && n == 31 then
  c = ConstrainUnpredictable(Unpredictable_WBOVERLAPST);

assert c IN {Constraint_NONE, Constraint_UNKNOWN, Constraint_UNDEF, Constraint_NOP};

case c of
  when Constraint_NONE rt_unknown = FALSE;  // value stored is original value
  when Constraint_UNKNOWN rt_unknown = TRUE;  // value stored is UNKNOWN
  when Constraint_UNDEF UnallocatedEncoding UNDEFINED;
  when Constraint_NOP EndOfInstruction();

if n == 31 then
  if memop != MemOp_PREFETCH then CheckSPAlignment();
  address = SP[];
else
  address = X[n];

if ! postindex then
  address = address + offset;

case memop of
  when MemOp_STORE
    if rt_unknown then
      data = bits(datasize) UNKNOWN;
    else
      data = X[t];
      Mem[address, datasize DIV 8, acctype] = data;
  when MemOp_LOAD
    data = Mem[address, datasize DIV 8, acctype];
    if signed then
      X[t] = SignExtend(data, regsize);
    else
      X[t] = ZeroExtend(data, regsize);

  when MemOp_PREFETCHPrefetch(address, t<4:0>);

if wback then
  if wb_unknown then
    address = bits(64) UNKNOWN;
  elseif postindex then
    address = address + offset;
  if n == 31 then
    SP[] = address;
else
    \texttt{X[n] = address;}

\textbf{Operational information}

If \textsc{PSTATE.DIT} is 1, the timing of this instruction is insensitive to the value of the data being loaded or stored.
LDAPURH

Load-Acquire RCpc Register Halfword (unscaled) calculates an address from a base register and an immediate offset, loads a halfword from memory, zero-extends it, and writes it to a register.

The instruction has memory ordering semantics as described in *Load-Acquire, Load-AcquirePC, and Store-Release*, except that:

- There is no ordering requirement, separate from the requirements of a Load-AcquirePC or a Store-Release, created by having a Store-Release followed by a Load-AcquirePC instruction.
- The reading of a value written by a Store-Release by a Load-AcquirePC instruction by the same observer does not make the write of the Store-Release globally observed.

This difference in memory ordering is not described in the pseudocode.

For information about memory accesses, see *Load/Store addressing modes*.

### Unscaled offset

```
LDAPURH <Wt>, [<Xn|SP>{, #<simm>}]  

boolean wback = FALSE;  
boolean postindex = FALSE;  
integer scale = UInt(size);  
bits(64) offset = SignExtend(imm9, 64);  
```

#### Assembler Symbols

- `<Wt>` Is the 32-bit name of the general-purpose register to be transferred, encoded in the "Rt" field.
- `<Xn|SP>` Is the 64-bit name of the general-purpose base register or stack pointer, encoded in the "Rn" field.
- `<simm>` Is the optional signed immediate byte offset, in the range -256 to 255, defaulting to 0 and encoded in the "imm9" field.
integer n = UInt(Rn);
integer t = UInt(Rt);
AccType acctype = AccType_ORDERED;
MemOp memop;
boolean signed;
integer regsize;

if opc<1> == '0' then
  // store or zero-extending load
  memop = if opc<0> == '1' then MemOp_LOAD else MemOp_STORE;
  regsize = if size == '11' then 64 else 32;
  signed = FALSE;
else
  if size == '11' then
    memop = MemOp_PREFETCH;
  if opc<0> == '1' then UNDEFINED;
  else
    // sign-extending load
    memop = if opc<0> == '1' then UnallocatedEncoding() else
    // sign-extending load
    memop = if size == '10' && opc<0> == '1' then UnallocatedEncoding;
    if size == '10' && opc<0> == '1' then UNDEFINED;
    regsize = if opc<0> == '1' then 32 else 64;
    signed = TRUE;

integer datasize = 8 << scale;
if bits(64) address;
bits(datasize) data;
boolean wb_unknown = FALSE;
boolean rt_unknown = FALSE;
if memop == HaveMTEExt() then
    boolean is_load_store = memop IN {MemOp STORE, MemOp LOAD};
    SetNotTagCheckedInstruction(is_load_store && n == 31 && !wback);
    bits(64) address;
    bits(datasize) data;
    boolean wb_unknown = FALSE;
    boolean rt_unknown = FALSE;
    if memop == MemOp LOAD && wback && n == t && n != 31 then
        c = ConstrainUnpredictable(Unpredictable_WBOVERLAPLD);
        assert c IN {Constraint_WBSUPPRESS, Constraint_UNKNOWN, Constraint_UNDEF, Constraint_NOP};
        case c of
            when Constraint_WBSUPPRESS wback = FALSE;       // writeback is suppressed
            when Constraint_UNKNOWN wb_unknown = TRUE;       // writeback is UNKNOWN
            when Constraint_UNDEF
                when UnallocatedEncoding() 
                when Constraint_NOP EndOfInstruction();
    end
    if memop == MemOp STORE && wback && n == t && n != 31 then
        c = ConstrainUnpredictable(Unpredictable_WBOVERLAPST);
        assert c IN {Constraint_NONE, Constraint_UNKNOWN, Constraint_UNDEF, Constraint_NOP};
        case c of
            when Constraint_NONE rt_unknown = FALSE;  // value stored is original value
            when Constraint_UNKNOWN rt_unknown = TRUE;  // value stored is UNKNOWN
            when Constraint_UNDEF
                when UnallocatedEncoding() 
                when Constraint_NOP EndOfInstruction();
    end
    if n == 31 then
        if memop != MemOp_PREFETCH then CheckSPAlignment();
        address = SP[];
    else
        address = X[n];
    if ! postindex then
        address = address + offset;
    end
    case memop of
        when MemOp STORE
            if rt_unknown then
                data = bits(datasize) UNKNOWN;
            else
                data = X[t];
                Mem[address, datasize DIV 8, acctype] = data;
            end
        when MemOp LOAD
            data = Mem[address, datasize DIV 8, acctype];
            if signed then
                X[t] = SignExtend(data, regsize);
            else
                X[t] = ZeroExtend(data, regsize);
            end
        when MemOp_PREFETCH
            Prefetch(address, t<4:0>);
    end
    if wback then
        if wb_unknown then
            address = bits(64) UNKNOWN;
        elsif postindex then
            address = address + offset;
        end
        if n == 31 then
            SP[] = address;
else
    \( X[n] = \text{address}; \)

**Operational information**

If PSTATE.DIT is 1, the timing of this instruction is insensitive to the value of the data being loaded or stored.

Internal version only: isa v30.25, AdvSIMD v27.01, pseudocode v85-xml-00bet8_rc3354; Build timestamp: 2018-09-13 13:04

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LDAPURSB

Load-Acquire RCpc Register Signed Byte (unscaled) calculates an address from a base register and an immediate offset, loads a signed byte from memory, sign-extends it, and writes it to a register.

The instruction has memory ordering semantics as described in *Load-Acquire, Load-AcquirePC, and Store-Release*, except that:

- There is no ordering requirement, separate from the requirements of a Load-AcquirePC or a Store-Release, created by having a Store-Release followed by a Load-AcquirePC instruction.
- The reading of a value written by a Store-Release by a Load-AcquirePC instruction by the same observer does not make the write of the Store-Release globally observed.

This difference in memory ordering is not described in the pseudocode.

For information about memory accesses, see *Load/Store addressing modes*.

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9  | 8  | 7  | 6  | 5  | 4  | 3  | 2  | 1  | 0  |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0  | 0  | 1  | 1  | 0  | 0  | 1  | x  | 0  | imm9 | 0  | 0  | Rn  |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |

32-bit (opc == 11)

```
LDAPURSB <Wt>, [<Xn|SP>{, #<simm>}
```

64-bit (opc == 10)

```
LDAPURSB <Xt>, [<Xn|SP>{, #<simm>}
```

```java
boolean wback = FALSE;
boolean postindex = FALSE;
integer scale = UInt(size);
bits(64) offset = SignExtend(imm9, 64);
```

**Assembler Symbols**

- `<Wt>` Is the 32-bit name of the general-purpose register to be transferred, encoded in the "Rt" field.
- `<Xt>` Is the 64-bit name of the general-purpose register to be transferred, encoded in the "Rt" field.
- `<Xn|SP>` Is the 64-bit name of the general-purpose base register or stack pointer, encoded in the "Rn" field.
- `<simm>` Is the optional signed immediate byte offset, in the range -256 to 255, defaulting to 0 and encoded in the "imm9" field.
integer n = UInt(Rn);
integer t = UInt(Rt);
AccType acctype = AccType.ORDERED;
MemOp memop;
boolean signed;
integer regsize;

if opc<1> == '0' then
  // store or zero-extending load
  memop = if opc<0> == '1' then MemOp.LOAD else MemOp.STORE;
  regsize = if size == '11' then 64 else 32;
  signed = FALSE;
else
  if size == '11' then
    memop = MemOp.PREFETCH;
  else
    // sign-extending load
    memop = if opc<0> == '1' then UnallocatedEncoding();
    else
      // sign-extending load
      memop = MemOp.LOAD;
  if size == '10' && opc<0> == '1' then UnallocatedEncoding();
  if size == '10' && opc<0> == '1' then UNDEFINED;
  regsize = if opc<0> == '1' then 32 else 64;
  signed = TRUE;

integer datasize = 8 << scale;
if bits(64) address;
bits(datasize) data;
boolean wb_unknown = FALSE;
boolean rt_unknown = FALSE;

if memop == HaveMTEExt() then
    boolean is_load_store = memop IN {MemOp_STORE, MemOp_LOAD};
    SetNotTagCheckedInstruction(is_load_store && n == 31 && !wback);

bits(64) address;
bits(datasize) data;
boolean wb_unknown = FALSE;
boolean rt_unknown = FALSE;

if memop == MemOp_LOAD && wback && n == t && n != 31 then
    c = ConstrainUnpredictable(Unpredictable_WBOVERLAPLD);
    assert c IN {Constraint_WBSUPPRESS, Constraint_UNKNOWN, Constraint_UNDEF, Constraint_NOP};
    case c of
        when Constraint_WBSUPPRESS wback = FALSE; // writeback is suppressed
        when Constraint_UNKNOWN wb_unknown = TRUE; // writeback is UNKNOWN
        when Constraint_UNDEF
            UnallocatedEncoding(t);
        when Constraint_NOP
            EndOfInstruction();

if memop == MemOp_PREFETCH then
    Prefetch(address, t<4:0>);
if wback then
    if wb_unknown then
        address = bits(64) UNKNOWN;
    elsif postindex then
        address = address + offset;
    if n == 31 then
        if memop != MemOp_PREFETCH then CheckSPAlignment();
        address = SP[];
    else
        address = X[n];

if ! postindex then
    address = address + offset;

    case memop of
        when MemOp_STORE
            if rt_unknown then
                data = bits(datasize) UNKNOWN;
            else
                data = X[t];
                Mem[address, datasize DIV 8, acctype] = data;
        when MemOp_LOAD
            data = Mem[address, datasize DIV 8, acctype];
            if signed then
                X[t] = SignExtend(data, regsize);
            else
                X[t] = ZeroExtend(data, regsize);

            when MemOp_PREFETCH
                Prefetch(address, t<4:0>);

if wback then
    if wb_unknown then
        address = bits(64) UNKNOWN;
    elseif postindex then
        address = address + offset;
    if n == 31 then
        SP[] = address;
else
    X[n] = address;

Operational information

If PSTATE.DIT is 1, the timing of this instruction is insensitive to the value of the data being loaded or stored.
LDAPURSH

Load-Acquire RCpc Register Signed Halfword (unscaled) calculates an address from a base register and an immediate offset, loads a signed halfword from memory, sign-extends it, and writes it to a register.

The instruction has memory ordering semantics as described in *Load-Acquire, Load-AcquirePC, and Store-Release*, except that:

- There is no ordering requirement, separate from the requirements of a Load-AcquirePC or a Store-Release, created by having a Store-Release followed by a Load-AcquirePC instruction.
- The reading of a value written by a Store-Release by a Load-AcquirePC instruction by the same observer does not make the write of the Store-Release globally observed.

This difference in memory ordering is not described in the pseudocode.

For information about memory accesses, see *Load/Store addressing modes*.

### Assembler Symbols

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;Wt&gt;</td>
<td>Is the 32-bit name of the general-purpose register to be transferred, encoded in the &quot;Rt&quot; field.</td>
</tr>
<tr>
<td>&lt;Xt&gt;</td>
<td>Is the 64-bit name of the general-purpose register to be transferred, encoded in the &quot;Rt&quot; field.</td>
</tr>
<tr>
<td>&lt;Xn</td>
<td>SP&gt;</td>
</tr>
<tr>
<td>&lt;simm&gt;</td>
<td>Is the optional signed immediate byte offset, in the range -256 to 255, defaulting to 0 and encoded in the &quot;imm9&quot; field.</td>
</tr>
</tbody>
</table>
integer n = UInt(Rn);
integer t = UInt(Rt);
AccType acctype = AccType_ORDERED;
MemOp memop;
boolean signed;
integer regsize;
if opc<1> == '0' then
    // store or zero-extending load
    memop = if opc<0> == '1' then MemOp_LOAD else MemOp_STORE;
    regsize = if size == '11' then 64 else 32;
    signed = FALSE;
else
    if size == '11' then
        memop = MemOp_PREFETCH;
        if opc<0> == '1' then UNDEFINED;
    else
        // sign-extending load
        memop = if opc<0> == '1' then UnallocatedEncoding() else
        else
            // sign-extending load
            memop = MemOp_LOAD;
            if size == '10' && opc<0> == '1' then UnallocatedEncoding();
    else
        // sign-extending load
        memop = MemOp_LOAD;
        if size == '10' && opc<0> == '1' then UNDEFINED;
    end;
    regsize = if opc<0> == '1' then 32 else 64;
    signed = TRUE;
integer datasize = 8 << scale;
if bits(64) address;
    bits(datasize) data;
    boolean wb_unknown = FALSE;
    boolean rt_unknown = FALSE;

if memop == HaveMTEExt() then
    boolean is_load_store = memop IN {MemOp STORE, MemOp LOAD};
    SetNotTagCheckedInstruction(is_load_store && n == 31 && !wback);

bits(64) address;
    bits(datasize) data;
    boolean wb_unknown = FALSE;
    boolean rt_unknown = FALSE;

if memop == MemOp LOAD && wback && n == 31 && n != 31 then
    boolean is_load_store = memop IN {MemOp_STORE,
    MemOp_LOAD};
    SetNotTagCheckedInstruction(is_load_store && n == 31 && !wback);
    bits(64) address;
    bits(datasize) data;
    boolean wb_unknown = FALSE;
    boolean rt_unknown = FALSE;

if memop == MemOp_LOAD && wback && n == 31 then
    assert c IN {Constraint_WBSUPPRESS, Constraint_UNKNOWN, Constraint_UNDEF, Constraint_NOP};
    case c of
        when Constraint_WBSUPPRESS wback = FALSE; // writeback is suppressed
        when Constraint_UNKNOWN wb(Unknown = TRUE); // writeback is UNKNOWN
        when Constraint_UNDEF
            UNDEFINED;
        when UnallocatedEncoding() EndOfInstruction();
    when Constraint_NOP
        EndOfInstruction();

if memop == MemOp_STORE && wback && n == 31 then
    assert c IN {Constraint_NONE, Constraint_UNKNOWN, Constraint_UNDEF, Constraint_NOP};
    case c of
        when Constraint_NONE rt_unknown = FALSE; // value stored is original value
        when Constraint_UNKNOWN rt_unknown = TRUE; // value stored is UNKNOWN
        when Constraint_UNDEF
            UNDEFINED;
    when Constraint_NOP
        EndOfInstruction();

if n == 31 then
    if memop != MemOp_PREFETCH then CheckSPAlignment();
    address = SP[];
else
    address = X[n];

if ! postindex then
    address = address + offset;

case memop of
    when MemOp STORE
        if rt_unknown then
            data = bits(datasize) UNKNOWN;
        else
            data = X[t];
        Mem[address, datasize DIV 8, acctype] = data;
    when MemOp LOAD
        data = Mem[address, datasize DIV 8, acctype];
        if signed then
            X[t] = SignExtend(data, regsize);
        else
            X[t] = ZeroExtend(data, regsize);
        when MemOp_PREFETCH
            Prefetch(address, t<4:0>);

if wback then
    if wb_unknown then
        address = bits(64) UNKNOWN;
    else if postindex then
        address = address + offset;
    if n == 31 then
        SP[] = address;

else
  X[n] = address;

Operational information

If PSTATE.DIT is 1, the timing of this instruction is insensitive to the value of the data being loaded or stored.
LDAPURSW

Load-Acquire RCpc Register Signed Word (unscaled) calculates an address from a base register and an immediate offset, loads a signed word from memory, sign-extends it, and writes it to a register.

The instruction has memory ordering semantics as described in *Load-Acquire, Load-AcquirePC, and Store-Release*, except that:

- There is no ordering requirement, separate from the requirements of a Load-AcquirePC or a Store-Release, created by having a Store-Release followed by a Load-AcquirePC instruction.
- The reading of a value written by a Store-Release by a Load-AcquirePC instruction by the same observer does not make the write of the Store-Release globally observed.

This difference in memory ordering is not described in the pseudocode.

For information about memory accesses, see *Load/Store addressing modes*.

For information about memory accesses, see *Load/Store addressing modes*.

### Unscaled offset

```
LDAPURSW <Xt>, [<Xn|SP>{, #<simm>}]  
```

boolean wback = FALSE;
boolean postindex = FALSE;
integer scale = Uint(size);
bits(64) offset = SignExtend(imm9, 64);

### Assembler Symbols

- `<Xt>`
  - Is the 64-bit name of the general-purpose register to be transferred, encoded in the "Rt" field.
- `<Xn|SP>`
  - Is the 64-bit name of the general-purpose base register or stack pointer, encoded in the "Rn" field.
- `<simm>`
  - Is the optional signed immediate byte offset, in the range -256 to 255, defaulting to 0 and encoded in the "imm9" field.
integer n = UInt(Rn);
integer t = UInt(Rt);
AccType acctype = AccType.ORDERED;
MemOp memop;
boolean signed;
integer regsize;

if opc<1> == '0' then
  // store or zero-extending load
  memop = if opc<0> == '1' then MemOp.LOAD else MemOp.STORE;
  regsize = if size == '11' then 64 else 32;
  signed = FALSE;
else
  if size == '11' then
    memop = MemOp.PREFETCH;
    if opc<0> == '1' then UNDEFINED;
  else
    // sign-extending load
    memop = if opc<0> == '1' then UnallocatedEncoding();
    else
      // sign-extending load
      memop = MemOp.LOAD;
      if size == '10' && opc<0> == '1' then UnallocatedEncoding();
      if size == '10' && opc<0> == '1' then UNDEFINED;
      if opc<0> == '1' then 32 else 64;
      signed = TRUE;

integer datasize = 8 << scale;
if memop == HaveMTEExt() then
    boolean is_load_store = memop IN {MemOp_STORE, MemOp_LOAD};
    SetNotTagCheckedInstruction(is_load_store && n == 31 && !wback);

bits(64) address;
bits(datasize) data;

boolean wb_unknown = FALSE;
boolean rt_unknown = FALSE;

if memop == MemOp_LOAD && wback && n == t && n != 31 then
    c = ConstrainUnpredictable(Unpredictable_WBOVERLAPLD);
    assert c IN {Constraint_WBSUPPRESS, Constraint_UNKNOWN, Constraint_UNDEF, Constraint_NOP};
    case c of
        when Constraint_WBSUPPRESS
            wback = FALSE;       // writeback is suppressed
        when Constraint_UNKNOWN
            wb_unknown = TRUE;   // writeback is UNKNOWN
        when Constraint_UNDEF
            UNDEFINED;
        when UnallocatedEncoding()
            rt_unknown = FALSE;  // value stored is original value
        when Constraint_NOP
            EndOfInstruction();

if memop == MemOp_STORE && wback && n == t && n != 31 then
    c = ConstrainUnpredictable(Unpredictable_WBOVERLAPST);
    assert c IN {Constraint_NONE, Constraint_UNKNOWN, Constraint_UNDEF, Constraint_NOP};
    case c of
        when Constraint_NONE
            rt_unknown = FALSE;  // value stored is original value
        when Constraint_UNKNOWN
            rt_unknown = TRUE;   // value stored is UNKNOWN
        when Constraint_UNDEF
            UNDEFINED;
        when Constraint_NOP
            EndOfInstruction();

if n == 31 then
    if memop != MemOp_PREFETCH then CheckSPALignment();
    address = SP[];
else
    address = X[n];

if ! postindex then
    address = address + offset;

case memop of
when MemOp_STORE
    if rt_unknown then
        data = bits(datasize) UNKNOWN;
    else
        data = X[t];
    Mem[address, datasize DIV 8, acctype] = data;
when MemOp_LOAD
    data = Mem[address, datasize DIV 8, acctype];
    if signed then
        X[t] = SignExtend(data, regsize);
    else
        X[t] = ZeroExtend(data, regsize);
    when MemOp_PREFETCH
        Prefetch(address, t<4:0>);

if wback then
    if wb_unknown then
        address = bits(64) UNKNOWN;
    elsif postindex then
        address = address + offset;
    if n == 31 then
        SP[] = address;
else
   X[n] = address;

Operational information

If PSTATE.DIT is 1, the timing of this instruction is insensitive to the value of the data being loaded or stored.
LDAR

Load-Acquire Register derives an address from a base register value, loads a 32-bit word or 64-bit doubleword from memory, and writes it to a register. The instruction also has memory ordering semantics as described in Load-Acquire, Store-Release. For information about memory accesses, see Load/Store addressing modes.

For this instruction, if the destination is WZR/ZXR, it is impossible for software to observe the presence of the acquire semantic other than its effect on the arrival at endpoints.

32-bit (size == 10)

LDAR <Wt>, [<Xn|SP>{,#0}]

64-bit (size == 11)

LDAR <Xt>, [<Xn|SP>{,#0}]

integer n = UInt(Rn);
integer t = UInt(Rt);
integer t2 = UInt(Rt2); // ignored by load/store single register
integer s = UInt(Rs);   // ignored by all loads and store-release

AccType acctype = if o0 == '0' then AccType_LIMITEDORDERED else AccType_ORDERED;
MemOp memop = if L == '1' then MemOp_LOAD else MemOp_STORE;
integer elsize = 8 << UInt(size);
integer regsize = if elsize == 64 then 64 else 32;
integer datasize = elsize;

Assembler Symbols

<Wt> Is the 32-bit name of the general-purpose register to be transferred, encoded in the "Rt" field.
<Xt> Is the 64-bit name of the general-purpose register to be transferred, encoded in the "Rt" field.
<Xn|SP> Is the 64-bit name of the general-purpose base register or stack pointer, encoded in the "Rn" field.

Operation

bits(64) address;
bits(datasize) data;
constant integer dbytes = datasize DIV 8;

if n == 31 then HaveMTEExt() then
    SetNotTagCheckedInstruction(n == 31);

if n == 31 then
    CheckSAPAlignment();
    address = SP[];
else
    address = X[n];

case memop of
    when MemOp_STORE
        data = X[t];
        Mem[address, dbytes, acctype] = data;
    when MemOp_LOAD
        data = Mem[address, dbytes, acctype];
        X[t] = ZeroExtend(data, regsize);
Operational information

If PSTATE.DIT is 1, the timing of this instruction is insensitive to the value of the data being loaded or stored.
LDARB

Load-Acquire Register Byte derives an address from a base register value, loads a byte from memory, zero-extends it and writes it to a register. The instruction also has memory ordering semantics as described in Load-Acquire, Store-Release. For information about memory accesses, see Load/Store addressing modes.

For this instruction, if the destination is WZR/ZXR, it is impossible for software to observe the presence of the acquire semantic other than its effect on the arrival at endpoints.

Assembly Symbols

<Wt> Is the 32-bit name of the general-purpose register to be transferred, encoded in the "Rt" field.

<Xn|SP> Is the 64-bit name of the general-purpose base register or stack pointer, encoded in the "Rn" field.

Operational information

If PSTATE.DIT is 1, the timing of this instruction is insensitive to the value of the data being loaded or stored.
LDARH

Load-Acquire Register Halfword derives an address from a base register value, loads a halfword from memory, zero-extends it, and writes it to a register. The instruction also has memory ordering semantics as described in Load-Acquire, Store-Release. For information about memory accesses, see Load/Store addressing modes.

For this instruction, if the destination is WZR/ZXR, it is impossible for software to observe the presence of the acquire semantic other than its effect on the arrival at endpoints.

```
<table>
<thead>
<tr>
<th>size</th>
<th>L</th>
<th>Rs</th>
<th>o0</th>
<th>Rn</th>
<th>Rt</th>
</tr>
</thead>
</table>
```

No offset

LDARH <Wt>, [<Xn|SP>{, #0}]

integer n = UInt(Rn);
integer t = UInt(Rt);
integer t2 = UInt(Rt2); // ignored by load/store single register
integer s = UInt(Rs);   // ignored by all loads and store-release

AccType acctype = if o0 == '0' then AccType_LIMITEDORDERED else AccType_ORDERED;
MemOp memop = if L == '1' then MemOp_LOAD else MemOp_STORE;
integer elsize = 8 << UInt(size);
integer regsize = if elsize == 64 then 64 else 32;
integer datasize = elsize;

Assembler Symbols

<Wt> Is the 32-bit name of the general-purpose register to be transferred, encoded in the "Rt" field.
<Xn|SP> Is the 64-bit name of the general-purpose base register or stack pointer, encoded in the "Rn" field.

Operation

bits(64) address;
bits(datasize) data;
constant integer dbytes = datasize DIV 8;

```
if n == 31 then HaveMTEExt() then SetNotTagCheckedInstruction(n == 31);
```

```
if n == 31 then CheckSPAlignment();
    address = SP[ ];
else
    address = X[n];
```

case memop of
    when MemOp STORE
        data = X[t];
        Mem[address, dbytes, acctype] = data;
    when MemOp LOAD
        data = Mem[address, dbytes, acctype];
        X[t] = ZeroExtend(data, regsize);
```

Operational information

If PSTATE.DIT is 1, the timing of this instruction is insensitive to the value of the data being loaded or stored.
LDAXP

Load-Acquire Exclusive Pair of Registers derives an address from a base register value, loads two 32-bit words or two 64-bit doublewords from memory, and writes them to two registers. A 32-bit pair requires the address to be doubleword aligned and is single-copy atomic at doubleword granularity. A 64-bit pair requires the address to be quadword aligned and is single-copy atomic for each doubleword at doubleword granularity. The PE marks the physical address being accessed as an exclusive access. This exclusive access mark is checked by Store Exclusive instructions. See Synchronization and semaphores. The instruction also has memory ordering semantics as described in Load-Acquire, Store-Release. For information about memory accesses see Load/Store addressing modes.

32-bit (sz == 0)

LDAXP <Wt1>, <Wt2>, [<Xn|SP>{,#0}]

64-bit (sz == 1)

LDAXP <Xt1>, <Xt2>, [<Xn|SP>{,#0}]

integer n = UInt(Rn);
integer t = UInt(Rt);
integer t2 = UInt(Rt2); // ignored by load/store single register
integer s = UInt(Rs);   // ignored by all loads and store-release
integer elsize = 32 << UInt(sz); // ignored by load/store single register
integer datasize = if pair then elsize * 2 else elsize;

AccType acctype = if o0 == '1' then AccType_ORDERED_ATOMIC else AccType_ATOMIC;
boolean pair = TRUE;
MemOp memop = if L == '1' then MemOp_LOAD else MemOp_STORE;
integer regsize = 32 << UInt(sz);
integer datasize = if pair then elsize * 2 else elsize;

For information about the CONSTRAINED UNPREDICTABLE behavior of this instruction, see Architectural Constraints on UNPREDICTABLE behaviors, and particularly LDAXP.

Assembler Symbols

<Wt1> Is the 32-bit name of the first general-purpose register to be transferred, encoded in the "Rt" field.
<Wt2> Is the 32-bit name of the second general-purpose register to be transferred, encoded in the "Rt2" field.
<Xt1> Is the 64-bit name of the first general-purpose register to be transferred, encoded in the "Rt" field.
<Xt2> Is the 64-bit name of the second general-purpose register to be transferred, encoded in the "Rt2" field.
<Xn|SP> Is the 64-bit name of the general-purpose base register or stack pointer, encoded in the "Rn" field.
bits(64) address;
bits(datasize) data;
constant integer dbytes = datasize DIV 8;
boolean rt_unknown = FALSE;
boolean rn_unknown = FALSE;

if memop == MemOp STORE then
  bool is_load_store = memop IN {MemOp STORE, MemOp LOAD};
  SetNotTagCheckedInstruction(is_load_store && n == 31);

if memop == MemOp LOAD && pair && t == t2 then
  Constraint c = ConstrainUnpredictable(Unpredictable_LDPOVERLAP);
  assert c IN {Constraint_UNKNOWN, Constraint_UNDEF, Constraint_NOP};
  case c of
    when Constraint_UNKNOWN then rt_unknown = TRUE; // result is UNKNOWN
    when Constraint_UNDEF then UNDEFINED;
    when Constraint_NOP then EndOfInstruction();

if memop == MemOp STORE then
  if s == t || (pair && s == t2) then
    Constraint c = ConstrainUnpredictable(Unpredictable_DATAOVERLAP);
    assert c IN {Constraint_UNKNOWN, Constraint_NONE, Constraint_UNDEF, Constraint_NOP};
    case c of
      when Constraint_UNKNOWN then rt_unknown = TRUE; // store UNKNOWN value
      when Constraint_NONE then rt_unknown = FALSE; // store original value
      when Constraint_UNDEF then UNDEFINED;
      when Constraint_NOP then EndOfInstruction();
  end if s == n && n != 31 then
    Constraint c = ConstrainUnpredictable(Unpredictable_BASEOVERLAP);
    assert c IN {Constraint_UNKNOWN, Constraint_NONE, Constraint_UNDEF, Constraint_NOP};
    case c of
      when Constraint_UNKNOWN then rn_unknown = TRUE; // address is UNKNOWN
      when Constraint_NONE then rn_unknown = FALSE; // address is original base
      when Constraint_UNDEF then UNDEFINED;
      when Constraint_NOP then EndOfInstruction();
  end if n == 31 then
    CheckSPAlignment();
    address = SP[];
  elsif rn_unknown then
    address = bits(64) UNKNOWN;
  else
    address = X[n];
  end if memop of
  case memop of
    when MemOp STORE
      if rt_unknown then
        data = bits(datasize) UNKNOWN;
      elsif pair then
        bits(datasize DIV 2) el1 = X[t];
        bits(datasize DIV 2) el2 = X[t2];
        data = if BigEndian() then el1 : el2 else el2 : el1;
      else
        data = X[t];
      end if
      bit status = '1';
      // Check whether the Exclusives monitors are set to include the
      // physical memory locations corresponding to virtual address
      // range [address, address+dbytes-1].
      if AArch64.ExclusiveMonitorsPass(address, dbytes) then
        // This atomic write will be rejected if it does not refer
        // to the same physical locations after address translation.
        Mem [address, dbytes, acctype] = data;
        status = ExclusiveMonitorsStatus();
        X[s] = ZeroExtend(status, 32);
      end if
    end when
  end case

when MemOp LOAD
// Tell the Exclusives monitors to record a sequence of one or more atomic
// memory reads from virtual address range [address, address+dbytes-1].
// The Exclusives monitor will only be set if all the reads are from the
// same dbytes-aligned physical address, to allow for the possibility of
// an atomicity break if the translation is changed between reads.
AArch64.SetExclusiveMonitors(address, dbytes);

if pair then
  if rt_unknown then
    // ConstrainedUNPREDICTABLE case
    X[t] = bits(datasize) UNKNOWN;
  elsif elsize == 32 then
    // 32-bit load exclusive pair (atomic)
    data = Mem[address, dbytes, acctype];
    if BigEndian() then
      X[t] = data<datasize-1:elsize>;
      X[t2] = data<elsize-1:0>;
    else
      X[t] = data<elsize-1:0>;
      X[t2] = data<datasize-1:elsize>;
  else // elsize == 64
    // 64-bit load exclusive pair (not atomic),
    // but must be 128-bit aligned
    if address != Align(address, dbytes) then
      iswrite = FALSE;
      secondstage = FALSE;
      AArch64.Abort(address, AArch64.AlignmentFault(acctype, iswrite, secondstage));
    X[t] = Mem[address + 0, 8, acctype];
    X[t2] = Mem[address + 8, 8, acctype];
  else
    data = Mem[address, dbytes, acctype];
    X[t] = ZeroExtend(data, regsize);

Operational information

If PSTATE.DIT is 1, the timing of this instruction is insensitive to the value of the data being loaded or stored.
LDAXR

Load-Acquire Exclusive Register derives an address from a base register value, loads a 32-bit word or 64-bit doubleword from memory, and writes it to a register. The memory access is atomic. The PE marks the physical address being accessed as an exclusive access. This exclusive access mark is checked by Store Exclusive instructions. See Synchronization and semaphores. The instruction also has memory ordering semantics as described in Load-Acquire, Store-Release. For information about memory accesses see Load/Store addressing modes.

32-bit (size == 10)

LDAXR <Wt>, [<Xn|SP>{,0}]

64-bit (size == 11)

LDAXR <Xt>, [<Xn|SP>{,0}]

integer n = UInt(Rn);
integer t = UInt(Rt);
integer t2 = UInt(Rt2); // ignored by load/store single register
integer s = UInt(Rs); // ignored by all loads and store-release

AccType accType = if o0 == '1' then AccType_ORDEREDATOMIC else AccType_ATOMIC;
boolean pair = FALSE;
MemOp memop = if L == '1' then MemOp_LOAD else MemOp_STORE;
integer elsize = 8 << UInt(size);
integer regsize = if elsize == 64 then 64 else 32;
integer datasize = if pair then elsize * 2 else elsize;

Assembler Symbols

<Wt> Is the 32-bit name of the general-purpose register to be transferred, encoded in the "Rt" field.
<Xt> Is the 64-bit name of the general-purpose register to be transferred, encoded in the "Rt" field.
<Xn|SP> Is the 64-bit name of the general-purpose base register or stack pointer, encoded in the "Rn" field.
bits(64) address;
bits(datasize) data;
constant integer dbytes = datasize DIV 8;
boolean rt_unknown = FALSE;
boolean rn_unknown = FALSE;

if memop == HaveMTEExt() then
    boolean is_load_store = memop IN {MemOp STORE, MemOp LOAD};
    SetNotTagCheckedInstruction(is_load_store && n == 31);

if memop == MemOp LOAD && pair && t == t2 then
    Constraint c = ConstrainUnpredictable(Unpredictable_LDPOVERLAP);
    assert c IN {Constraint_UNKNOWN, Constraint_UNDEF, Constraint_NOP};
    case c of
        when Constraint_UNKNOWN rt_unknown = TRUE;  // result is UNKNOWN
        when Constraint_UNDEF rt_unknown = FALSE;  // store original value
        when Constraint_NOP EndOfInstruction();

if memop == MemOp STORE then
    if s == t || (pair && s == t2) then
        Constraint c = ConstrainUnpredictable(Unpredictable_DATAOVERLAP);
        assert c IN {Constraint_UNKNOWN, Constraint_NONE, Constraint_UNDEF, Constraint_NOP};
        case c of
            when Constraint_UNKNOWN rt_unknown = TRUE;  // store UNKNOWN value
            when Constraint_NONE rt_unknown = FALSE;  // store original value
            when Constraint_UNDEF EndOfInstruction();
        end;

        if s == n && n != 31 then
            Constraint c = ConstrainUnpredictable(Unpredictable_BASEOVERLAP);
            assert c IN {Constraint_UNKNOWN, Constraint_NONE, Constraint_UNDEF, Constraint_NOP};
            case c of
                when Constraint_UNKNOWN rn_unknown = TRUE;  // address is UNKNOWN
                when Constraint_UNDEF EndOfInstruction();  // address is original base
                when Constraint_NOP unallocatedEncoding();
            end;

        end;

if n == 31 then
    CheckSPAlignment();
    address = SP[];
elsif rn_unknown then
    address = bits(64) UNKNOWN;
else
    address = X[n];
end;

case memop of
    when MemOp STORE
        if rt_unknown then
            data = bits(datasize) UNKNOWN;
        elsif pair then
            bits(datasize DIV 2) el1 = X[t];
            bits(datasize DIV 2) el2 = X[t2];
            data = if BigEndian() then el1 : el2 else el2 : el1;
        else
            data = X[t];
        end;
        bit status = '1';
        // Check whether the Exclusives monitors are set to include the
        // physical memory locations corresponding to virtual address
        // range [address, address+dbytes-1].
        if AArch64.ExclusiveMonitorsPass(address, dbytes) then
            // This atomic write will be rejected if it does not refer
            // to the same physical locations after address translation.
            Mem[address, dbytes, acctype] = data;
            status = ExclusiveMonitorsStatus();
            X[s] = ZeroExtend(status, 32);
        end;
    when MemOp LOAD
        // Check whether the Exclusives monitors are set to include the
        // physical memory locations corresponding to virtual address
        // range [address, address+dbytes-1].
        if AArch64.ExclusiveMonitorsPass(address, dbytes) then
            // This atomic write will be rejected if it does not refer
            // to the same physical locations after address translation.
            Mem[address, dbytes, acctype] = data;
            status = ExclusiveMonitorsStatus();
            X[s] = ZeroExtend(status, 32);
        end;
Tell the Exclusives monitors to record a sequence of one or more atomic
memory reads from virtual address range [address, address+dbytes-1].
The Exclusives monitor will only be set if all the reads are from the
same dbytes-aligned physical address, to allow for the possibility of
an atomicity break if the translation is changed between reads.
AArch64.SetExclusiveMonitors(address, dbytes);

if pair then
  if rt_unknown then
    // ConstrainedUNPREDICTABLE case
    X[t] = bits(datasize) UNKNOWN;
  elsif elsize == 32 then
    // 32-bit load exclusive pair (atomic)
    data = Mem[address, dbytes, acctype];
    if BigEndian() then
      X[t] = data<datasize-1:elsize>;
      X[t2] = data<elsize-1:0>;
    else
      X[t] = data<elsize-1:0>;
      X[t2] = data<datasize-1:elsize>;
  else // elsize == 64
    // 64-bit load exclusive pair (not atomic),
    // but must be 128-bit aligned
    if address != Align(address, dbytes) then
      iswrite = FALSE;
      secondstage = FALSE;
      AArch64.Abort(address, AArch64.AlignmentFault(acctype, iswrite, secondstage));
      X[t] = Mem[address + 0, 8, acctype];
      X[t2] = Mem[address + 8, 8, acctype];
    else
      data = Mem[address, dbytes, acctype];
      X[t] = ZeroExtend(data, regsize);

Operational information

If PSTATE.DIT is 1, the timing of this instruction is insensitive to the value of the data being loaded or stored.
LDAXRB

Load-Acquire Exclusive Register Byte derives an address from a base register value, loads a byte from memory, zero-extends it and writes it to a register. The memory access is atomic. The PE marks the physical address being accessed as an exclusive access. This exclusive access mark is checked by Store Exclusive instructions. See Synchronization and semaphores. The instruction also has memory ordering semantics as described in Load-Acquire, Store-Release. For information about memory accesses see Load/Store addressing modes.

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9  | 8  | 7  | 6  | 5  | 4  | 3  | 2  | 1  | 0  |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0  | 0  | 0  | 0  | 1  | 0  | 0  | 0  | 1  | 0  | (1) | (1) | (1) | (1) | 1  | (1) | (1) | (1) | (1) |   |   |   |   |   |   |   |   |   |   |   |

size  L  Rs  o0  Rt  

No offset

LDAXRB <Wt>, [<Xn|SP>{,#0})

integer n = UInt(Rn);
integer t = UInt(Rt);
integer t2 = UInt(Rt2); // ignored by load/store single register
integer s = UInt(Rs);   // ignored by all loads and store-release

AccType acctype = if o0 == '1' then AccType_ORDEREDATOMIC else AccType_ATOMIC;
boolean pair = FALSE;
MemOp memop = if L == '1' then MemOp_LOAD else MemOp_STORE;
integer elsize = 8 << UInt(size);
integer datasize = if elsize == 64 then 64 else 32;

Assembler Symbols

<Wt> Is the 32-bit name of the general-purpose register to be transferred, encoded in the "Rt" field.
<Xn|SP> Is the 64-bit name of the general-purpose base register or stack pointer, encoded in the "Rn" field.
bits(64) address;
bits(_datasize) data;
constant integer dbytes = _datasize_ DIV 8;
boolean rt_unknown = FALSE;
boolean rn_unknown = FALSE;

if memop == HaveMTEExt() then
  boolean is_load_store = memop IN {MemOp_STORE, MemOp_LOAD};
  SetNotTagCheckedInstruction(is_load_store && n == 31);

if memop == MemOp_LOAD && pair && t == t2 then
  Constraint c = ConstrainUnpredictable(Unpredictable_LDPOVERLAP);
  assert c IN {Constraint_UNKNOWN, Constraint_UNDEF, Constraint_NOP};
  case c of
    when Constraint_UNKNOWN
      rt_unknown = TRUE;    // result is UNKNOWN
    when Constraint_UNDEF
      UNDEFINED;
    when Constraint_NOP
      EndOfInstruction();
if memop == MemOp_STORE then
  if s == t || (pair && s == t2) then
    Constraint c = ConstrainUnpredictable(Unpredictable_DATAOVERLAP);
    assert c IN {Constraint_UNKNOWN, Constraint_NONE, Constraint_UNDEF, Constraint_NOP};
    case c of
      when Constraint_UNKNOWN
        rt_unknown = TRUE;    // store UNKNOWN value
      when Constraint_NONE
        rt_unknown = FALSE;   // store original value
      when Constraint_UNDEF
        UNDEFINED;
      when Constraint_NOP
        EndOfInstruction();
  if s == n && n != 31 then
    Constraint c = ConstrainUnpredictable(Unpredictable_BASEOVERLAP);
    assert c IN {Constraint_UNKNOWN, Constraint_NONE, Constraint_UNDEF, Constraint_NOP};
    case c of
      when Constraint_UNKNOWN
        rn_unknown = TRUE;    // address is UNKNOWN
      when Constraint_NONE
        rn_unknown = FALSE;   // address is original base
      when Constraint_UNDEF
        UnallocatedEncoding();
      when Constraint_NOP
        EndOfInstruction();
if n == 31 then
  CheckSPAlignment();
  address = SP[];
elsif rn_unknown then
  address = bits(64) UNKNOWN;
else
  address = X[n];

case memop of
  when MemOp_STORE
    if rt_unknown then
      data = bits(_datasize) UNKNOWN;
    elsif pair then
      bits(_datasize DIV 2) el1 = X[t];
      bits(_datasize DIV 2) el2 = X[t2];
      data = if BigEndian() then el1 : el2 else el2 : el1;
    else
      data = X[t];
    bit status = '1';
    // Check whether the Exclusives monitors are set to include the
    // physical memory locations corresponding to virtual address
    // range [address, address+dbytes-1].
    if AArch64.ExclusiveMonitorsPass(address, dbytes) then
      // This atomic write will be rejected if it does not refer
      // to the same physical locations after address translation.
      Mem[address, dbytes, acctype] = data;
      status = ExclusiveMonitorsStatus();
      X[s] = ZeroExtend(status, 32);
  when MemOp_LOAD

Tell the Exclusives monitors to record a sequence of one or more atomic memory reads from virtual address range [address, address+dbytes-1]. The Exclusives monitor will only be set if all the reads are from the same dbytes-aligned physical address, to allow for the possibility of an atomicity break if the translation is changed between reads.

```c
AArch64.SetExclusiveMonitors(address, dbytes);
```

```c
if pair then
if rt_unknown then
    // ConstrainedUNPREDICTABLE case
    X[t] = bits(datasize) UNKNOWN;
elsif elsize == 32 then
    // 32-bit load exclusive pair (atomic)
    data = Mem[address, dbytes, acctype];
    if BigEndian() then
        X[t] = data<datasize-1:elsize>;
        X[t2] = data<elsize-1:0>;
    else
        X[t] = data<elsize-1:0>;
        X[t2] = data<datasize-1:elsize>;
else // elsize == 64
    // 64-bit load exclusive pair (not atomic),
    // but must be 128-bit aligned
    if address != Align(address, dbytes) then
        iswrite = FALSE;
        secondstage = FALSE;
        AArch64.Abort(address, AArch64.AlignmentFault(acctype, iswrite, secondstage));
    X[t] = Mem[address + 0, 8, acctype];
    X[t2] = Mem[address + 8, 8, acctype];
else
    data = Mem[address, dbytes, acctype];
    X[t] = ZeroExtend(data, regsize);
```

**Operational information**

If PSTATE.DIT is 1, the timing of this instruction is insensitive to the value of the data being loaded or stored.
LDAXRH

Load-Acquire Exclusive Register Halfword derives an address from a base register value, loads a halfword from memory, zero-extends it and writes it to a register. The memory access is atomic. The PE marks the physical address being accessed as an exclusive access. This exclusive access mark is checked by Store Exclusive instructions. See Synchronization and semaphores. The instruction also has memory ordering semantics as described in Load-Acquire, Store-Release. For information about memory accesses see Load/Store addressing modes.

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</tr>
</tbody>
</table>

No offset

LDAXRH <Wt>, [<Xn|SP>{,#0}]

integer n = UInt(Rn);
integer t = UInt(Rt);
integer t2 = UInt(Rt2); // ignored by load/store single register
integer s = UInt(Rs);   // ignored by all loads and store-release

AccType acctype = if o0 == '1' then AccType_ORDEREDATOMIC else AccType_ATOMIC;
boolean pair = FALSE;
MemOp memop = if L == '1' then MemOp_LOAD else MemOp_STORE;
integer elsize = 8 << UInt(size);
integer datasize = if pair then elsize * 2 else elsize;

Assembler Symbols

<Wt> Is the 32-bit name of the general-purpose register to be transferred, encoded in the "Rt" field.
<Xn|SP> Is the 64-bit name of the general-purpose base register or stack pointer, encoded in the "Rn" field.
bits(64) address;  
bias(dataSize) data;  
constant integer dbytes = dataSize DIV 8;  
boolean rt_unknown = FALSE;  
boolean rn_unknown = FALSE;  

if memop == HaveMTEExt() then  
  boolean is_load_store = memop IN {MemOp STORE, MemOp LOAD};  
  SetNotTagCheckedInstruction(is_load_store & & n == 31);  

if memop == MemOp STORE then  
  if s == t || (pair & & t == t2) then  
    Constraint c = ConstrainUnpredictable(Unpredictable_LDPOVERLAP);  
    assert c IN {Constraint_UNKNOWN, Constraint_UNDEF, Constraint_NOP};  
    case c of  
      when Constraint_UNKNOWN then  
        rt_unknown = TRUE;  // result is UNKNOWN  
      when Constraint_UNDEF then  
        UNDEFINED;  
      when UnallocatedEncoding() then  
        EndOfInstruction();  
      when Constraint_NOP then  
        EndOfInstruction();  
    if s == n & & n != 31 then  
      Constraint c = ConstrainUnpredictable(Unpredictable_BASEOVERLAP);  
      assert c IN {Constraint_UNKNOWN, Constraint_UNDEF, Constraint_NOP};  
      case c of  
        when Constraint_UNKNOWN then  
          rn_unknown = TRUE;  // address is UNKNOWN  
        when Constraint_UNDEF then  
          UNDEFINED;  
        when UnallocatedEncoding() then  
          EndOfInstruction();  
        when Constraint_NOP then  
          EndOfInstruction();  
      if CheckSPAlignment() then  
        address = SP[];  
      elsif rn_unknown then  
        address = bits(64) UNKNOWN;  
      else  
        address = X[n];  
      case memop of  
        when MemOp_STORE then  
          if rt_unknown then  
            data = bits(dataSize) UNKNOWN;  
          elsif pair then  
            bits(dataSize DIV 2) el1 = X[t];  
            bits(dataSize DIV 2) el2 = X[t2];  
            data = if BigEndian() then el1 : el2 else el2 : el1;  
          else  
            data = X[t];  
          bit status = '1';  
          // Check whether the Exclusives monitors are set to include the  
          // physical memory locations corresponding to virtual address  
          // range [address, address+dbytes-1].  
          if AArch64.ExclusiveMonitorsPass(address, dbytes) then  
            // This atomic write will be rejected if it does not refer  
            // to the same physical locations after address translation.  
            Mem[address, dbytes, acctype] = data;  
            status = ExclusiveMonitorsStatus();  
            X[s] = ZeroExtend(status, 32);  
          when MemOp LOAD then  
            _
Tell the Exclusives monitors to record a sequence of one or more atomic memory reads from virtual address range [address, address+dbytes-1]. The Exclusives monitor will only be set if all the reads are from the same dbytes-aligned physical address, to allow for the possibility of an atomicity break if the translation is changed between reads.

`AArch64.SetExclusiveMonitors(address, dbytes);`

if pair then
  if rt_unknown then
    // ConstrainedUNPREDICTABLE case
    X[t] = bits(datasize) UNKNOWN;
  elsif elsize == 32 then
    // 32-bit load exclusive pair (atomic)
    data = Mem[address, dbytes, acctype];
    if BigEndian() then
      X[t] = data<datasize-1:elsize>;
      X[t2] = data<elsize-1:0>;
    else
      X[t] = data<elsize-1:0>;
      X[t2] = data<datasize-1:elsize>;
  else // elsize == 64
    // 64-bit load exclusive pair (not atomic), must be 128-bit aligned
    if address != Align(address, dbytes) then
      iswrite = FALSE;
      secondstage = FALSE;
      AArch64.Abort(address, AArch64.AlignmentFault(acctype, iswrite, secondstage));
    X[t] = Mem[address + 0, 8, acctype];
    X[t2] = Mem[address + 8, 8, acctype];
  else
    data = Mem[address, dbytes, acctype];
    X[t] = ZeroExtend(data, regsize);
  end;

Operational information

If PSTATE.DIT is 1, the timing of this instruction is insensitive to the value of the data being loaded or stored.

Internal version only: isa v30.25, AdvSIMD v27.01, pseudocode v85-xml-00bet8_RC3; Build timestamp: 2018-09-13T13:20:45Z
LDCLR, LDCLRA, LDCLRAL, LDCLRL

Atomic bit clear on word or doubleword in memory atomically loads a 32-bit word or 64-bit doubleword from memory, performs a bitwise AND with the complement of the value held in a register on it, and stores the result back to memory. The value initially loaded from memory is returned in the destination register.

- If the destination register is not one of WZR or XZR, LDCLRA and LDCLRAL load from memory with acquire semantics.
- LDCLRL and LDCLRAL store to memory with release semantics.
- LDCLR has no memory ordering requirements.

For more information about memory ordering semantics see Load-Acquire, Store-Release.
For information about memory accesses see Load/Store addressing modes.

This instruction is used by the alias STCLR, STCLRL.

Integer
(ARMv8.1)

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9  | 8  | 7  | 6  | 5  | 4  | 3  | 2  | 1  | 0  |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 1  | x  | 1  | 1  | 1  | 0  | 0  | A  | R  | 1  | Rs | 0  | 0  | 0  | 1  | 0  | 0  | Rn | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  |

size            opc
32-bit LDCLR (size == 10 && A == 0 && R == 0)
LDCLR <Ws>, <Wt>, [Xn|SP]

32-bit LDCLA (size == 10 && A == 1 && R == 0)
LDCLA <Ws>, <Wt>, [Xn|SP]

32-bit LDCLRAL (size == 10 && A == 1 && R == 1)
LDCLRAL <Ws>, <Wt>, [Xn|SP]

32-bit LDCLRL (size == 10 && A == 0 && R == 1)
LDCLRL <Ws>, <Wt>, [Xn|SP]

64-bit LDCLR (size == 11 && A == 0 && R == 0)
LDCLR <Xs>, <Xt>, [Xn|SP]

64-bit LDCLA (size == 11 && A == 1 && R == 0)
LDCLA <Xs>, <Xt>, [Xn|SP]

64-bit LDCLRAL (size == 11 && A == 1 && R == 1)
LDCLRAL <Xs>, <Xt>, [Xn|SP]

64-bit LDCLRL (size == 11 && A == 0 && R == 1)
LDCLRL <Xs>, <Xt>, [Xn|SP]

\[
\text{if } \text{!HaveAtomicExt}\() \text{ then UNDEFINED;}
\]
\[
\text{integer } t = \text{UInt}(\text{Rt});
\]
\[
\text{integer } n = \text{UInt}(\text{Rn});
\]
\[
\text{integer } s = \text{UInt}(\text{Rs});
\]
\[
\text{integer } \text{datasize} = 8 \ll \text{UInt}(\text{size});
\]
\[
\text{integer } \text{regsize} = \text{if } \text{datasize} = 64 \text{ then 64 else 32};
\]
\[
\text{AccType } \text{ldacctype} = \text{if } A = '1' \&\& \text{Rt} = '11111' \text{ then AccType ORDERED_ATOMIC_RW else AccType ORDERED_RW;}
\]
\[
\text{AccType } \text{stacctype} = \text{if } R = '1' \text{ then AccType ORDERED_ATOMIC_RW else AccType ATOMIC_RW;}
\]
\[
\text{MemAtomicOp } \text{op};
\]
\[
\text{case } \text{opc of}
\]
\[
\text{when } '000' \text{ op = MemAtomicOp ADD;}
\]
\[
\text{when } '001' \text{ op = MemAtomicOp BIC;}
\]
\[
\text{when } '010' \text{ op = MemAtomicOp EOR;}
\]
\[
\text{when } '011' \text{ op = MemAtomicOp ORR;}
\]
\[
\text{when } '100' \text{ op = MemAtomicOp SMAX;}
\]
\[
\text{when } '101' \text{ op = MemAtomicOp SMIN;}
\]
\[
\text{when } '110' \text{ op = MemAtomicOp UMAX;}
\]
\[
\text{when } '111' \text{ op = MemAtomicOp UMIN;}
\]

Assembler Symbols

<Ws> Is the 32-bit name of the general-purpose register holding the data value to be operated on with the contents of the memory location, encoded in the "Rs" field.

<Wt> Is the 32-bit name of the general-purpose register to be loaded, encoded in the "Rt" field.

<Xs> Is the 64-bit name of the general-purpose register holding the data value to be operated on with the contents of the memory location, encoded in the "Rs" field.
<Xt> Is the 64-bit name of the general-purpose register to be loaded, encoded in the "Rt" field.
<Xn|SP> Is the 64-bit name of the general-purpose base register or stack pointer, encoded in the "Rn" field.

### Alias Conditions

<table>
<thead>
<tr>
<th>Alias</th>
<th>Is preferred when</th>
</tr>
</thead>
<tbody>
<tr>
<td>STCLR, STCLRL</td>
<td>A == '0' &amp;&amp; Rt == '11111'</td>
</tr>
</tbody>
</table>

### Operation

```plaintext
bits(64) address;
bits(datasize) value;
bits(datasize) data;
bits(datasize) result;

if value = HaveMTEExt() then
  SetNotTagCheckedInstruction(n == 31);

value = X[s];
if n == 31 then
  CheckSPAAlignment();
  address = SP[];
else
  address = X[n];

// All observers in the shareability domain observe the
// following load and store atomically.
data = Mem[address, datasize DIV 8, ldacctype];

case op of
  when MemAtomicOp_ADD result = data + value;
  when MemAtomicOp_BIC result = data AND NOT(value);
  when MemAtomicOp_EOR result = data EOR value;
  when MemAtomicOp_ORR result = data OR value;
  when MemAtomicOp_SMAX result = if SInt(data) > SInt(value) then data else value;
  when MemAtomicOp_SMIN result = if SInt(data) > SInt(value) then value else data;
  when MemAtomicOp_UMAX result = if UInt(data) > UInt(value) then data else value;
  when MemAtomicOp_UMIN result = if UInt(data) > UInt(value) then value else data;

  Mem[address, datasize DIV 8, stacctype] = result;

if t != 31 then
  X[t] = ZeroExtend(data, regsize);
```

### Operational information

If PSTATE.DIT is 1, the timing of this instruction is insensitive to the value of the data being loaded or stored.

---

(old) htmldiff from- (new)
LDCLRAB, LDCLRAB, LDCLRALB, LDCLRLB

Atomic bit clear on byte in memory atomically loads an 8-bit byte from memory, performs a bitwise AND with the complement of the value held in a register on it, and stores the result back to memory. The value initially loaded from memory is returned in the destination register.

- If the destination register is not WZR, LDCLRAB and LDCLRALB load from memory with acquire semantics.
- LDCLRLB and LDCLRALB store to memory with release semantics.
- LDCLRAB has no memory ordering requirements.

For more information about memory ordering semantics see *Load-Acquire, Store-Release*. For information about memory accesses see *Load/Store addressing modes*.

This instruction is used by the alias STCLRB, STCLRLB.

### Integer

**(ARMv8.1)**

<table>
<thead>
<tr>
<th>31</th>
<th>30</th>
<th>29</th>
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<th>4</th>
<th>3</th>
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<td><strong>size</strong></td>
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</tr>
</tbody>
</table>

**LDCLRAB (A == 1 & R == 0)**

LDCLRAB <Ws>, <Wt>, [<Xn|SP>]

**LDCLRALB (A == 1 & R == 1)**

LDCLRALB <Ws>, <Wt>, [<Xn|SP>]

**LDCLRB (A == 0 & R == 0)**

LDCLRB <Ws>, <Wt>, [<Xn|SP>]

**LDCLRLB (A == 0 & R == 1)**

LDCLRLB <Ws>, <Wt>, [<Xn|SP>]

if !HaveAtomicExt() then UNDEFINED;
integer t = UInt(Rt);
integer n = UInt(Rn);
integer s = UInt(Rs);

integer datasize = 8 << UInt(size);
integer regsize = if datasize == 64 then 64 else 32;

AccType ldacctype = if A == '1' & Rt != '11111' then AccType_ORDEREDATOMICRW else AccType_ATOMICRW;

AccType stacctype = if R == '1' then AccType_ORDEREDATOMICRW else AccType_ATOMICRW;

MemAtomicOp op;

case opc of
  when '000' op = MemAtomicOp_ADD;
  when '001' op = MemAtomicOp_BIC;
  when '010' op = MemAtomicOp_EOR;
  when '011' op = MemAtomicOp_2RR;
  when '100' op = MemAtomicOp_SMX;
  when '101' op = MemAtomicOp_SMIN;
  when '110' op = MemAtomicOp_UMX;
  when '111' op = MemAtomicOp_UMIN;
Assembler Symbols

<Ws> Is the 32-bit name of the general-purpose register holding the data value to be operated on with the contents of the memory location, encoded in the "Rs" field.

<Wt> Is the 32-bit name of the general-purpose register to be loaded, encoded in the "Rt" field.

<Xn|SP> Is the 64-bit name of the general-purpose base register or stack pointer, encoded in the "Rn" field.

Alias Conditions

<table>
<thead>
<tr>
<th>Alias</th>
<th>Is preferred when</th>
</tr>
</thead>
<tbody>
<tr>
<td>STCLR, STCLR LB</td>
<td>A == '0' &amp; &amp; Rt == '11111'</td>
</tr>
</tbody>
</table>

Operation

```plaintext
bits(64) address;
bits(datasize) value;
bits(datasize) data;
bits(datasize) result;

if value = HaveMTEExt() then
    SetNotTagCheckedInstruction(n == 31);
value = X[s];
if n == 31 then
    CheckSPAlignment();
    address = SP[];
else
    address = X[n];

// All observers in the shareability domain observe the
// following load and store atomically.
data = Mem[address, datasize DIV 8, ldacctype];

case op of
    when MemAtomicOp_ADD result = data + value;
    when MemAtomicOp_BIC result = data AND NOT(value);
    when MemAtomicOp_EOR result = data EOR value;
    when MemAtomicOp_ORR result = data OR value;
    when MemAtomicOp_SMX result = if SInt(data) > SInt(value) then data else value;
    when MemAtomicOp_SMIN result = if SInt(data) > SInt(value) then value else data;
    when MemAtomicOp_UMAX result = if UInt(data) > UInt(value) then data else value;
    when MemAtomicOp_UMIN result = if UInt(data) > UInt(value) then value else data;

Mem[address, datasize DIV 8, stacctype] = result;

if t != 31 then
    X[t] = ZeroExtend(data, regsize);
```

Operational information

If PSTATE.DIT is 1, the timing of this instruction is insensitive to the value of the data being loaded or stored.
LDCLRH, LDCLRAH, LDCLRALH, LDCLRLH

Atomic bit clear on halfword in memory atomically loads a 16-bit halfword from memory, performs a bitwise AND with the complement of the value held in a register on it, and stores the result back to memory. The value initially loaded from memory is returned in the destination register.

- If the destination register is not WZR, LDCLRAH and LDCLRALH load from memory with acquire semantics.
- LDCLRLH and LDCLRALH store to memory with release semantics.
- LDCLRH has no memory ordering requirements.

For more information about memory ordering semantics see Load-Acquire, Store-Release. For information about memory accesses see Load/Store addressing modes.

This instruction is used by the alias STCLRH, STCLRLH.

Integer
(ARMv8.1)

<table>
<thead>
<tr>
<th>A</th>
<th>R</th>
<th>Rs</th>
<th>size</th>
<th>opc</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

LDCLRAH (A == 1 && R == 0)

LDCLRAH <Ws>, <Wt>, [<Xn|SP>]

LDCLRALH (A == 1 && R == 1)

LDCLRALH <Ws>, <Wt>, [<Xn|SP>]

LDCLRH (A == 0 && R == 0)

LDCLRH <Ws>, <Wt>, [<Xn|SP>]

LDCLRLH (A == 0 && R == 1)

LDCLRLH <Ws>, <Wt>, [<Xn|SP>]

if !HaveAtomicExt() then UNDEFINED;
integer t = 1 then UnallocatedEncoding();
integer t = UInt(Rt);
integer n = UInt(Rn);
integer s = UInt(Rs);

integer datasize = 8 << UInt(size);
integer regsize = if datasize == 64 then 64 else 32;
AccType ldacctype = if A == '1' && Rt != '11111' then AccType_ORDEREDATOMICRW else AccType_ATOMICRW;
AccType stacctype = if R == '1' then AccType_ORDEREDATOMICRW else AccType_ATOMICRW;
MemAtomicOp op;
case opc of
  when '000' op = MemAtomicOp ADD;
  when '001' op = MemAtomicOp BIC;
  when '010' op = MemAtomicOp EOR;
  when '011' op = MemAtomicOp ORR;
  when '100' op = MemAtomicOp SMAX;
  when '101' op = MemAtomicOp SMIN;
  when '110' op = MemAtomicOp UMAX;
  when '111' op = MemAtomicOp UMIN;
Assembler Symbols

<Ws> Is the 32-bit name of the general-purpose register holding the data value to be operated on with the contents of the memory location, encoded in the "Rs" field.

<Wt> Is the 32-bit name of the general-purpose register to be loaded, encoded in the "Rt" field.

<Xn|SP> Is the 64-bit name of the general-purpose base register or stack pointer, encoded in the "Rn" field.

Alias Conditions

<table>
<thead>
<tr>
<th>Alias</th>
<th>Is preferred when</th>
</tr>
</thead>
<tbody>
<tr>
<td>STCLRH, STCLRLH</td>
<td>A == '0' &amp; &amp; Rt == '1111'</td>
</tr>
</tbody>
</table>

Operation

```
bits(64) address;
bits(datasize) value;
bits(datasize) data;
bits(datasize) result;

if value = HaveMTExtn then
    SetNotTagCheckedInstruction(n == 31);

value = X[s];
if n == 31 then
    CheckSPAlignment();
    address = SP[];
else
    address = X[n];

// All observers in the shareability domain observe the
// following load and store atomically.
data = Mem[address, datasize DIV 8, ldacctype];

case op of
    when MemAtomicOp_ADD result = data + value;
    when MemAtomicOp_BIC result = data AND NOT(value);
    when MemAtomicOp_EOR result = data EOR value;
    when MemAtomicOp_ORR result = data OR value;
    when MemAtomicOp_SMAX result = if SInt(data) > SInt(value) then data else value;
    when MemAtomicOp_SMIN result = if SInt(data) > SInt(value) then value else data;
    when MemAtomicOp_UMAX result = if UInt(data) > UInt(value) then value else data;
    when MemAtomicOp_UMIN result = if UInt(data) > UInt(value) then data else value;

Mem[address, datasize DIV 8, stacctype] = result;

if t != 31 then
    X[t] = ZeroExtend(data, regsize);
```
LDEOR, LDEORA, LDEORAL, LDEORL

Atomic exclusive OR on word or doubleword in memory atomically loads a 32-bit word or 64-bit doubleword from memory, performs an exclusive OR with the value held in a register on it, and stores the result back to memory. The value initially loaded from memory is returned in the destination register.

- If the destination register is not one of WZR or XZR, LDEORA and LDEORAL load from memory with acquire semantics.
- LDEORL and LDEORAL store to memory with release semantics.
- LDEOR has no memory ordering requirements.

For more information about memory ordering semantics see Load-Acquire, Store-Release. For information about memory accesses see Load/Store addressing modes.

This instruction is used by the alias STEOR, STEORL.

Integer
(ARMv8.1)

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 1  | x  | 1  | 1  | 1  | 0  | 0  | 0  | A  | R  | 1  | Rs | 0  | 0  | 1  | 0  | 0  | Rn | 0  | 0  | 1  | 0  | 0  | Rn | 0  | 0  | 1  | 0  | 0  | Rn | 0  | 0  | 1  | 0  | 0  | Rn |

size opc
32-bit LDEOR (size == 10 && A == 0 && R == 0)
LDEOR <Ws>, <Wt>, [<Xn|SP>]

32-bit LDEORA (size == 10 && A == 1 && R == 0)
LDEORA <Ws>, <Wt>, [<Xn|SP>]

32-bit LDEORAL (size == 10 && A == 1 && R == 1)
LDEORAL <Ws>, <Wt>, [<Xn|SP>]

32-bit LDEORL (size == 10 && A == 0 && R == 1)
LDEORL <Ws>, <Wt>, [<Xn|SP>]

64-bit LDEOR (size == 11 && A == 0 && R == 0)
LDEOR <Xs>, <Xt>, [<Xn|SP>]

64-bit LDEORA (size == 11 && A == 1 && R == 0)
LDEORA <Xs>, <Xt>, [<Xn|SP>]

64-bit LDEORAL (size == 11 && A == 1 && R == 1)
LDEORAL <Xs>, <Xt>, [<Xn|SP>]

64-bit LDEORL (size == 11 && A == 0 && R == 1)
LDEORL <Xs>, <Xt>, [<Xn|SP>]

Assembler Symbols

<Ws> Is the 32-bit name of the general-purpose register holding the data value to be operated on with the contents of the memory location, encoded in the "Rs" field.

<Wt> Is the 32-bit name of the general-purpose register to be loaded, encoded in the "Rt" field.

<Xs> Is the 64-bit name of the general-purpose register holding the data value to be operated on with the contents of the memory location, encoded in the "Rs" field.
Is the 64-bit name of the general-purpose register to be loaded, encoded in the "Rt" field.

Is the 64-bit name of the general-purpose base register or stack pointer, encoded in the "Rn" field.

### Alias Conditions

<table>
<thead>
<tr>
<th>Alias</th>
<th>Is preferred when</th>
</tr>
</thead>
<tbody>
<tr>
<td>STEOR, STEORL</td>
<td>A == '0' &amp; Rt == '11111'</td>
</tr>
</tbody>
</table>

### Operation

```plaintext
bits(64) address;
bits(datasize) value;
bits(datasize) data;
bits(datasize) result;

if value = HaveMTEExt() then
  SetNotTagCheckedInstruction(n == 31);

value = X[s];
if n == 31 then
  CheckSPABytes();
  address = SP[];
else
  address = X[n];

// All observers in the shareability domain observe the
// following load and store atomically.
data = Mem[address, datasize DIV 8, ldacctype];

case op of
  when MemAtomicOp_ADD   result = data + value;
  when MemAtomicOp_BIC   result = data AND NOT(value);
  when MemAtomicOp_EOR   result = data EOR value;
  when MemAtomicOp_ORR   result = data OR value;
  when MemAtomicOp_SMAX  result = if SInt(data) > SInt(value) then data else value;
  when MemAtomicOp_SMIN  result = if SInt(data) > SInt(value) then value else data;
  when MemAtomicOp_UMAX  result = if UInt(data) > UInt(value) then data else value;
  when MemAtomicOp_UMIN  result = if UInt(data) > UInt(value) then value else data;

  Mem[address, datasize DIV 8, stacctype] = result;

if t != 31 then
  X[t] = ZeroExtend(data, regsize);
```

### Operational information

If PSTATE.DIT is 1, the timing of this instruction is insensitive to the value of the data being loaded or stored.
LDEORB, LDEORAB, LDEORALB, LDEORLB

Atomic exclusive OR on byte in memory atomically loads an 8-bit byte from memory, performs an exclusive OR with the value held in a register on it, and stores the result back to memory. The value initially loaded from memory is returned in the destination register.

- If the destination register is not WZR, LDEORAB and LDEORALB load from memory with acquire semantics.
- LDEORLB and LDEORALB store to memory with release semantics.
- LDEORB has no memory ordering requirements.

For more information about memory ordering semantics see Load-Acquire, Store-Release. For information about memory accesses see Load/Store addressing modes.

This instruction is used by the alias STEORB, STEORLB.

Integer (ARMv8.1)

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0  | 0  | 1  | 1  | 0  | 0  | A  | R  | 1  | Rs | 0  | 0  | 1  | 0  | 0  | Rn | 0  | 0  | 0  | 0  | 1  | 0  | 0  | 0  | 0  | 1  | 0  | 0  | 0  | 1  | 0  | 0  | 0  | 1  | 0  | 0  | 0  | 1  | 0  | 0  | 0  | 1  | 0  | 0  | 0  | 1  | 0  | 0  |

size opc

LDEORAB (A == 1 && R == 0)

LDEORAB <Ws>, <Wt>, [<Xn|SP]>

LDEORALB (A == 1 && R == 1)

LDEORALB <Ws>, <Wt>, [<Xn|SP]>

LDEORB (A == 0 && R == 0)

LDEORB <Ws>, <Wt>, [<Xn|SP]>

LDEORLB (A == 0 && R == 1)

LDEORLB <Ws>, <Wt>, [<Xn|SP]>

```lxml
if !HaveAtomicExt() then UNDEFINED;
integer t = 1 then UnallocatedEncoding();
integer t = UInt(Rt);
integer n = UInt(Rn);
integer s = UInt(Rs);

integer datasize = 8 << UInt(size);
integer regsize = if datasize == 64 then 64 else 32;

AccType ldacctype = if A == '1' && Rt != '11111' then AccType_ORDEREDATOMICRW else AccType_ATOMICRW;
AccType stacctype = if R == '1' then AccType_ORDEREDATOMICRW else AccType_ATOMICRW;

MemAtomicOp op;

case opc of
    when '000' op = MemAtomicOp_ADD;
    when '001' op = MemAtomicOp_BIC;
    when '010' op = MemAtomicOp_EOR;
    when '011' op = MemAtomicOp_ORR;
    when '100' op = MemAtomicOp_SMAX;
    when '101' op = MemAtomicOp_SMIN;
    when '110' op = MemAtomicOp_UMAX;
    when '111' op = MemAtomicOp_UMIN;
```
Assembler Symbols

<Ws> Is the 32-bit name of the general-purpose register holding the data value to be operated on with the contents of the memory location, encoded in the "Rs" field.

<Wt> Is the 32-bit name of the general-purpose register to be loaded, encoded in the "Rt" field.

<Xn|SP> Is the 64-bit name of the general-purpose base register or stack pointer, encoded in the "Rn" field.

Alias Conditions

<table>
<thead>
<tr>
<th>Alias</th>
<th>Is preferred when</th>
</tr>
</thead>
<tbody>
<tr>
<td>STEORB, STEORLB</td>
<td>A == '0' &amp;&amp; Rt == '1111'</td>
</tr>
</tbody>
</table>

Operation

```plaintext
bits(64) address;
bits(datasize) value;
bits(datasize) data;
bits(datasize) result;

if value = HaveMTEExt() then
    SetNotTagCheckedInstruction(n == 31);

value = X[s];
if n == 31 then
    CheckSPLAlignment();
    address = SP[];
else
    address = X[n];

// All observers in the shareability domain observe the
// following load and store atomically.

data = Mem[address, datasize DIV 8, ldacctype];

case op of
    when MemAtomicOp_ADD    result = data + value;
    when MemAtomicOp_BIC    result = data AND NOT(value);
    when MemAtomicOp_EOR    result = data EOR value;
    when MemAtomicOp_OR     result = data OR value;
    when MemAtomicOp_SMX    result = if SInt(data) > SInt(value) then data else value;
    when MemAtomicOp_SMIN   result = if SInt(data) > SInt(value) then value else data;
    when MemAtomicOp_UMAX   result = if UInt(data) > UInt(value) then value else data;
    when MemAtomicOp_UMIN   result = if UInt(data) > UInt(value) then data else value;

Mem[address, datasize DIV 8, stacctype] = result;

if t != 31 then
    X[t] = ZeroExtend(data, regsize);
```

Operational information

If PSTATE.DIT is 1, the timing of this instruction is insensitive to the value of the data being loaded or stored.
LDEORH, LDEORAH, LDEORALH, LDEORLH

Atomic exclusive OR on halfword in memory atomically loads a 16-bit halfword from memory, performs an exclusive OR with the value held in a register on it, and stores the result back to memory. The value initially loaded from memory is returned in the destination register.

- If the destination register is not WZR, LDEORAH and LDEORALH load from memory with acquire semantics.
- LDEORLH and LDEORALH store to memory with release semantics.
- LDEORH has no memory ordering requirements.

For more information about memory ordering semantics see Load-Acquire, Store-Release.
For information about memory accesses see Load/Store addressing modes.

This instruction is used by the alias STEORH, STEORLH.

Integer
(ARMv8.1)

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0  | 1  | 1  | 1  | 0  | 0  | A  | R  | 1  | Rs | 0  | 0  | 1  | 0  | 0  | Rn |  |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| size | opc |

LDEORAH (A == 1 && R == 0)
LDEORAH <Ws>, <Wt>, [<Xn|SP>]

LDEORALH (A == 1 && R == 1)
LDEORALH <Ws>, <Wt>, [<Xn|SP>]

LDEORH (A == 0 && R == 0)
LDEORH <Ws>, <Wt>, [<Xn|SP>]

LDEORLH (A == 0 && R == 1)
LDEORLH <Ws>, <Wt>, [<Xn|SP>]

if !HaveAtomicExt{} then UNDEFINED;
integer t = |uint(Rt);
integer n = uint(Rn);
integer s = uint(Rs);

integer datasize = 8 << uint(size);
integer regsize = if datasize == 64 then 64 else 32;

AccType ldacctype = if A == '1' && Rt != '11111' then AccType_ORDEREDATOMICRW else AccType_ATOMICRW;
AccType stacctype = if R == '1' then AccType_ORDEREDATOMICRW else AccType_ATOMICRW;
MemAtomicOp op;

case opc of
  when '000' op = MemAtomicOp_ADD;
  when '001' op = MemAtomicOp_BIC;
  when '010' op = MemAtomicOp_EOR;
  when '011' op = MemAtomicOp_ORR;
  when '100' op = MemAtomicOp_SMAX;
  when '101' op = Mem AtomicOp_SM IN;
  when '110' op = MemAtomicOp_UMAX;
  when '111' op = MemAtomicOp_UMIN;
Assembler Symbols

<Ws>  Is the 32-bit name of the general-purpose register holding the data value to be operated on with the contents of the memory location, encoded in the "Rs" field.

<Wt>  Is the 32-bit name of the general-purpose register to be loaded, encoded in the "Rt" field.

<Xn|SP>  Is the 64-bit name of the general-purpose base register or stack pointer, encoded in the "Rn" field.

Alias Conditions

<table>
<thead>
<tr>
<th>Alias</th>
<th>Is preferred when</th>
</tr>
</thead>
<tbody>
<tr>
<td>STEORH, STEORLH</td>
<td>A == '0' &amp; Rt == '11111'</td>
</tr>
</tbody>
</table>

Operation

```plaintext
bits(64) address;
bits(datasize) value;
bits(datasize) data;
bits(datasize) result;

if value = haveMTEExt() then
  SetNotTagCheckedInstruction(n == 31);

value = X[n];
if n == 31 then
  CheckSPAlignment();
  address = SP[];
else
  address = X[n];

// All observers in the shareability domain observe the
// following load and store atomically.
data = Mem[address, datasize DIV 8, ldacctype];

case op of
  when MemAtomicOp_ADD  result = data + value;
  when MemAtomicOp_BIC  result = data AND NOT(value);
  when MemAtomicOp_EOR  result = data EOR value;
  when MemAtomicOp_ORR  result = data OR value;
  when MemAtomicOp_SMX  result = if SInt(data) > SInt(value) then data else value;
  when MemAtomicOp_SMIN  result = if SInt(data) > SInt(value) then value else data;
  when MemAtomicOp_UMAX result = if UInt(data) > UInt(value) then value else data;
  when MemAtomicOp_UMIN result = if UInt(data) > UInt(value) then value else data;

Mem[address, datasize DIV 8, stacctype] = result;

if t != 31 then
  X[t] = ZeroExtend(data, regsize);
```

Operational information

If PSTATE.DIT is 1, the timing of this instruction is insensitive to the value of the data being loaded or stored.
LDG

Load Allocation Tag loads an Allocation Tag from a memory address, generates an address with the Logical Address Tag generated from the loaded Allocation Tag, and writes the result to the destination register. The address used for the load is calculated from the source register and an immediate signed offset scaled by the Tag granule.

**Integer**

*(ARMv8.5)*

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 1  | 1  | 1  | 0  | 1  | 0  | 1  | 1  | imm9 | 0 | 0 | Xn | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

**Integer**

LDG <Xt>, [<Xn|SP>{, #<simm>}]

```plaintext
integer t = UInt(Xt);
integer n = UInt(Xn);
bv(64) offset = LSL(SignExtend(imm9, 64), LOG2_TAG_GRANULE);
```

**Assembler Symbols**

<Xt> Is the 64-bit name of the general-purpose register to be transferred, encoded in the "Xt" field.

<Xn|SP> Is the 64-bit name of the general-purpose base register or stack pointer, encoded in the "Xn" field.

<simm> Is the optional signed immediate offset, a multiple of 16 in the range -4096 to 4080, defaulting to 0 and encoded in the "imm9" field.

**Operation**

```plaintext
bits(64) address;
bv(4) tag;

if n == 31 then
    CheckSPAlignment();
    address = SP[];
else
    address = X[n];

address = address + offset;
address = Align(address, TAG_GRANULE);
tag = MemTag[address];
address = AddressWithAllocationTag(address, tag);
X[t] = address;
```

Internal version only: isa v30.25, AdvSIMD v27.01, pseudocode v85-xml-00ver8_rc3 ; Build timestamp: 2018-09-13T13:04

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LDGV

Load Tag Vector loads an IMPLEMENTATIONDEFINED number of Allocation Tags from the naturally aligned array of 16 Allocation Tags which includes a tag whose address is the address in the source register, and writes them to the destination register. Bits of the destination register which do not store a tag are set to 0. The Allocation Tag at the address in the source register is always loaded, and the first source register is updated to the address of the first Allocation Tag at an address higher than the original address that was not loaded.

This instruction is UNDEFINED at EL0.

This instruction generates an Unchecked access.

### Integer

(ARMv8.5)

<table>
<thead>
<tr>
<th>31</th>
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<th>1</th>
<th>0</th>
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</thead>
<tbody>
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<td>Xt</td>
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<td></td>
</tr>
</tbody>
</table>

### Integer

LDGV `<Xt>` , `[<Xn|SP>]` !

```plaintext
integer t = UInt(Xt);
integer n = UInt(Xn);
boolean wback = TRUE;
boolean wb_unknown = FALSE;
```

### Assembler Symbols

`<Xt>`
Is the 64-bit name of the general-purpose register to be transferred, encoded in the "Xt" field.

`<Xn|SP>`
Is the 64-bit name of the general-purpose base register or stack pointer, encoded in the "Xn" field.
Operation

\[
\text{bits(64) data} = \text{Zeros(64)}; \\
\text{bits(64) address}; \\
\text{integer count}; \\
\]

if \( n == t \) then
  \[
  c = \text{ConstraintUnpredictable(Unpredictable_WBOVERLAPLD)}; \\
  \text{assert } c \in \{ \text{Constraint_WBSUPPRESS, Constraint_UNKNOWN, Constraint_UNDEF, Constraint_NOP} \}; \\
  \]

  \text{case } c \text{ of}
  \[
  \begin{align*}
  \text{when } & \text{Constraint_WBSUPPRESS} & \text{wback} = \text{FALSE}; & // \text{writeback is suppressed} \\
  \text{when } & \text{Constraint_UNKNOWN} & \text{wb_unknown} = \text{TRUE}; & // \text{writeback is UNKNOWN} \\
  \text{when } & \text{Constraint_UNDEF} & \text{UnallocatedEncoding}(); \\
  \text{when } & \text{Constraint_NOP} & \text{EndOfInstruction}(); \\
  \end{align*}
  \]

if \( n == 31 \) then
  \[
  \text{CheckSPAlignment}(); \\
  \text{address} = \text{SP[]};
  \]
else
  \[
  \text{address} = \text{X}[n];
  \]

\((\text{address}, \text{count}) = \text{ImpDefArrayStartAndCount(\text{address})};\)

for \( i = 0 \) to \( \text{count}-1 \)
  \[
  \text{integer index} = \text{UInt}(\text{address<LOG2_TAG_GRANULE+3:LOG2_TAG_GRANULE>}); \\
  \text{bits(4) tag} = \text{MemTag}[\text{address}]; \\
  \text{data<}(\text{index*4}+3:(\text{index*4}>) = \text{tag}; \\
  \text{address} = \text{address} + \text{TAG_GRANULE}; \\
  \]

\(\text{X}[\text{t}] = \text{data};\)

if \( \text{wback} \) then
  if \( \text{wb_unknown} \) then
    \[
    \text{address} = \text{bits(64) UNKNOWN}; \\
    \text{if } n == 31 \text{ then} \\
    \text{SP[]} = \text{address}; \\
    \text{else} \\
    \text{X}[n] = \text{address};
    \]

Internal version only: isa v30.25, AdvSIMD v27.01, pseudocode v85-xml-008er8_rc3 ; Build timestamp: 2018-09-13T13:04
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LDLAR

Load LOAcquire Register loads a 32-bit word or 64-bit doubleword from memory, and writes it to a register. The instruction also has memory ordering semantics as described in Load LOAcquire, Store LORelease. For information about memory accesses, see Load/Store addressing modes.

For this instruction, if the destination is WZR/ZXR, it is impossible for software to observe the presence of the acquire semantic other than its effect on the arrival at endpoints.

No offset
(ARMv8.1)

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9  | 8  | 7  | 6  | 5  | 4  | 3  | 2  | 1  | 0  |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 1  | x  | 0  | 0  | 1  | 0  | 0  | 0  | 1  | 1  | 0  | (1)| (1)| (1)| (1)| 0  | (1)| (1)| (1)| (1)| (1)|    |    |    |    |    |    |    |    |    |    |
| size|     | L  | Rs | o0 |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |

32-bit (size == 10)

LDLAR <Wt>, [<Xn|SP>{,#0}]

64-bit (size == 11)

LDLAR <Xt>, [<Xn|SP>{,#0}]

```plaintext
integer n = UInt(Rn);
integer t = UInt(Rt);
integer t2 = UInt(Rt2); // ignored by load/store single register
integer s = UInt(Rs);   // ignored by all loads and store-release

AccType accctype = if o0 == '0' then AccType_LIMITEDORDERED else AccType_ORDERED;
MemOp memop = if L == '1' then MemOp_LOAD else MemOp_STORE;
integer elsize = 8 << UInt(size);
integer regsize = if elsize == 64 then 64 else 32;
integer datasize = elsize;
```

Assembler Symbols

- `<Wt>` Is the 32-bit name of the general-purpose register to be transferred, encoded in the "Rt" field.
- `<Xt>` Is the 64-bit name of the general-purpose register to be transferred, encoded in the "Rt" field.
- `<Xn|SP>` Is the 64-bit name of the general-purpose base register or stack pointer, encoded in the "Rn" field.
Operation

bits(64) address;
bits(datasize) data;
constant integer dbytes = datasize DIV 8;

if n == 31 then HaveMTEExt() then
    SetNotTagCheckedInstruction(n == 31);
if n == 31 then
    CheckSPAlignment();
else
    address = X[n];
case memop of
    when MemOp_STORE
        data = X[t];
        Mem[address, dbytes, acctype] = data;
    when MemOp_LOAD
        data = Mem[address, dbytes, acctype];
        X[t] = ZeroExtend(data, regsize);

Operational information

If PSTATE.DIT is 1, the timing of this instruction is insensitive to the value of the data being loaded or stored.
LDLARB

Load LOAcquire Register Byte loads a byte from memory, zero-extends it and writes it to a register. The instruction also has memory ordering semantics as described in Load LOAcquire, Store LORelease. For information about memory accesses, see Load/Store addressing modes.

For this instruction, if the destination is WZR/ZXR, it is impossible for software to observe the presence of the acquire semantic other than its effect on the arrival at endpoints.

No offset
(ARMv8.1)

<table>
<thead>
<tr>
<th>0 0 0 0 1 0 0 0</th>
<th>1 1 0 (1) (1) (1) (1)</th>
<th>0 (1) (1) (1) (1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>size</td>
<td>L</td>
<td>Rs</td>
</tr>
<tr>
<td>o0</td>
<td>Rt2</td>
<td></td>
</tr>
</tbody>
</table>

No offset

LDLARB <Wt>, [<Xn|SP>{,#0}]

integer n = UInt(Rn);
integer t = UInt(Rt);
integer t2 = UInt(Rt2); // ignored by load/store single register
integer s = UInt(Rs);   // ignored by all loads and store-release

AccType accstype = if o0 == '0' then AccType_LIMITEDORDERED else AccType_ORDERED;
MemOp memop = if L == '1' then MemOp_LOAD else MemOp_STORE;
integer elsize = 8 << UInt(size);
integer regsize = if elsize == 64 then 64 else 32;
integer datasize = elsize;

Assembler Symbols

<Wt> Is the 32-bit name of the general-purpose register to be transferred, encoded in the "Rt" field.
<Xn|SP> Is the 64-bit name of the general-purpose base register or stack pointer, encoded in the "Rn" field.

Operation

bits(64) address;
bits(datasize) data;
constant integer dbytes = datasize DIV 8;
if n == 31 then HaveMTEExt() then
   SetNotTagCheckedInstruction(n == 31);
if n == 31 then
   CheckSPA[alignment]();
   address = SP[];
else
   address = X[n];
case memop of
when MemOp_STORE
   data = X[t];
   Mem[address, dbytes, accstype] = data;
when MemOp_LOAD
   data = Mem[address, dbytes, accstype];
   X[t] = ZeroExtend(data, regsize);
Operational information

If PSTATE.DIT is 1, the timing of this instruction is insensitive to the value of the data being loaded or stored.
LDLARH

Load LOAcquire Register Halfword loads a halfword from memory, zero-extends it, and writes it to a register. The instruction also has memory ordering semantics as described in Load LOAcquire, Store LORelease. For information about memory accesses, see Load/Store addressing modes.

For this instruction, if the destination is WZR/ZXR, it is impossible for software to observe the presence of the acquire semantic other than its effect on the arrival at endpoints.

No offset (ARMv8.1)

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9  | 8  | 7  | 6  | 5  | 4  | 3  | 2  | 1  | 0  |
|----|--|---|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|
Operational information

If PSTATE.DIT is 1, the timing of this instruction is insensitive to the value of the data being loaded or stored.
LDNP (SIMD&FP)

Load Pair of SIMD&FP registers, with Non-temporal hint. This instruction loads a pair of SIMD&FP registers from memory, issuing a hint to the memory system that the access is non-temporal. The address that is used for the load is calculated from a base register value and an optional immediate offset.

For information about non-temporal pair instructions, see Load/Store SIMD and Floating-point Non-temporal pair.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

**Assembler Symbols**

- `<Dt1>`: Is the 64-bit name of the first SIMD&FP register to be transferred, encoded in the "Rt" field.
- `<Dt2>`: Is the 64-bit name of the second SIMD&FP register to be transferred, encoded in the "Rt2" field.
- `<Qt1>`: Is the 128-bit name of the first SIMD&FP register to be transferred, encoded in the "Rt" field.
- `<Qt2>`: Is the 128-bit name of the second SIMD&FP register to be transferred, encoded in the "Rt2" field.
- `<St1>`: Is the 32-bit name of the first SIMD&FP register to be transferred, encoded in the "Rt" field.
- `<St2>`: Is the 32-bit name of the second SIMD&FP register to be transferred, encoded in the "Rt2" field.
- `<Xn|SP>`: Is the 64-bit name of the general-purpose base register or stack pointer, encoded in the "Rn" field.
- `<imm>`: For the 32-bit variant: is the optional signed immediate byte offset, a multiple of 4 in the range -256 to 252, defaulting to 0 and encoded in the "imm7" field as `<imm>/4`. For the 64-bit variant: is the optional signed immediate byte offset, a multiple of 8 in the range -512 to 504, defaulting to 0 and encoded in the "imm7" field as `<imm>/8`. For the 128-bit variant: is the optional signed immediate byte offset, a multiple of 16 in the range -1024 to 1008, defaulting to 0 and encoded in the "imm7" field as `<imm>/16`.

**Operands**

<table>
<thead>
<tr>
<th>opc</th>
<th>imm7</th>
<th>Rt2</th>
<th>Rn</th>
<th>Rt</th>
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<tr>
<td>32-bit (opc == 00)</td>
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</tr>
</tbody>
</table>
LDNP `<St1>`, `<St2>`, [<Xn|SP>{, #<imm>}] |

**64-bit (opc == 01)**
LDNP `<Dt1>`, `<Dt2>`, [<Xn|SP>{, #<imm>}] |

**128-bit (opc == 10)**
LDNP `<Qt1>`, `<Qt2>`, [<Xn|SP>{, #<imm>}] |

boolean wback = FALSE;
boolean postindex = FALSE;

For information about the CONSTRAINED UNPREDICTABLE behavior of this instruction, see Architectural Constraints on UNPREDICTABLE behaviors, and particularly LDNP (SIMD&FP).
integer n = UInt(Rn);
integer t = UInt(Rt);
integer t2 = UInt(Rt2);
AccType acctype = AccType_VECSTREAM;
MemOp memop = if L == '1' then MemOp_LOAD else MemOp_STORE;
if opc == '11' then UNDEFINED;
integer scale = 2 + UInt(opc);
integer datasize = 8 << scale;
bias(64) offset = LSL(SignExtend(imm7, 64), scale);

Operation

CheckFPAdvSIMDEnabled64();

if memop == MemOp_LOAD && t == t2 then
        Constraint c = ConstrainUnpredictable(Unpredictable_LDPOVERLAP);
        assert c IN {Constraint_UNKNOWN, Constraint_UNDEF, Constraint_NOP};
        case c of
            when Constraint_UNKNOWN rt_unknown = TRUE; // result is UNKNOWN
            when Constraint_UNDEF UnallocatedEncoding();
        EndOfInstruction();

if n == 31 then
    CheckSPAlignment();
    address = SP[];
else
    address = X[n];
if ! postindex then
    address = address + offset;

case memop of

when MemOp_STORE
    data1 = V[t];
    data2 = V[t2];
    Mem[address + 0 , dbytes, acctype] = data1;
    Mem[address + dbytes, dbytes, acctype] = data2;

when MemOp_LOAD
    data1 = Mem[address + 0 , dbytes, acctype];
    data2 = Mem[address + dbytes, dbytes, acctype];
    if rt_unknown then
        data1 = bits(datasize) UNKNOWN;
        data2 = bits(datasize) UNKNOWN;
        V[t] = data1;
        V[t2] = data2;
    if wback then
        if postindex then
            address = address + offset;
        if n == 31 then
            SP[] = address;
        else
            X[n] = address;
Operational information

If PSTATE.DIT is 1, the timing of this instruction is insensitive to the value of the data being loaded or stored.
LDNP

Load Pair of Registers, with non-temporal hint, calculates an address from a base register value and an immediate offset, loads two 32-bit words or two 64-bit doublewords from memory, and writes them to two registers.

For information about memory accesses, see Load/Store addressing modes. For information about Non-temporal pair instructions, see Load/Store Non-temporal pair.

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</tbody>
</table>

32-bit (opc == 00)

LDNP <Wt1>, <Wt2>, [<Xn|SP>{, #<imm>}

64-bit (opc == 10)

LDNP <Xt1>, <Xt2>, [<Xn|SP>{, #<imm>}

boolean wback = FALSE;
boolean postindex = FALSE;

For information about the CONSTRAINED UNPREDICTABLE behavior of this instruction, see Architectural Constraints on UNPREDICTABLE behaviors, and particularly LDNP.

Assembler Symbols

<Wt1> Is the 32-bit name of the first general-purpose register to be transferred, encoded in the "Rt" field.
<Wt2> Is the 32-bit name of the second general-purpose register to be transferred, encoded in the "Rt2" field.
<Xt1> Is the 64-bit name of the first general-purpose register to be transferred, encoded in the "Rt" field.
<Xt2> Is the 64-bit name of the second general-purpose register to be transferred, encoded in the "Rt2" field.
<Xn|SP> Is the 64-bit name of the general-purpose base register or stack pointer, encoded in the "Rn" field.
<imm> For the 32-bit variant: is the optional signed immediate byte offset, a multiple of 4 in the range -256 to 252, defaulting to 0 and encoded in the "imm7" field as <imm>/4.

For the 64-bit variant: is the optional signed immediate byte offset, a multiple of 8 in the range -512 to 504, defaulting to 0 and encoded in the "imm7" field as <imm>/8.

Shared Decode

```plaintext
def integer n = UInt(Rn);
def integer t = UInt(Rt);
def integer t2 = UInt(Rt2);
def AccType acctype = AccType_STREAM;
def MemOp memop = if L == '1' then MemOp_LOAD else MemOp_STORE;
def integer scale = 2 + if opc<0> == '1' then UnallocatedEncoding()
    integer scale = 2 + UInt(opc<1>);
def integer datasize = 8 << scale;
def bits(64) offset = LSL(SignExtend(imm7, 64), scale);
```
Operation

bits(64) address;
bits(datasize) data1;
bits(datasize) data2;
constant integer dbytes = datasize DIV 8;
boolean rt_unknown = FALSE;

if memop == HaveMTEExt() then
  boolean is_load_store = memop IN {MemOp_STORE, MemOp_LOAD};
  SetNotTagCheckedInstruction(is_load_store && n == 31 && !wback);
if memop == MemOp_LOAD && t == t2 then
  Constraint c = ConstrainUnpredictable(Unpredictable_LDPOVERLAP);
  assert c IN {Constraint_UNKNOWN, Constraint_UNDEF, Constraint_NOP};
case c of
  when Constraint_UNKNOWN rt_unknown = TRUE; // result is UNKNOWN
  when Constraint_UNDEF UnallocatedEncoding UNDEFINED;
  ...
  when Constraint_NOP EndOfInstruction();
if n == 31 then
  CheckSPAlignment();
else
  address = X[n];
if ! postindex then
  address = address + offset;
case memop of
  when MemOp_STORE
    if rt_unknown && t == n then
      data1 = bits(datasize) UNKNOWN;
    else
      data1 = X[t];
    if rt_unknown && t2 == n then
      data2 = bits(datasize) UNKNOWN;
    else
      data2 = X[t2];
    Mem[address + 0 , dbytes, acctype] = data1;
    Mem[address + dbytes, dbytes, acctype] = data2;
  when MemOp_LOAD
    data1 = Mem[address + 0 , dbytes, acctype];
    data2 = Mem[address + dbytes, dbytes, acctype];
    if rt_unknown then
      data1 = bits(datasize) UNKNOWN;
    data2 = bits(datasize) UNKNOWN;
    X[t] = data1;
    X[t2] = data2;
if wback then
  if postindex then
    address = address + offset;
  if n == 31 then
    SP[] = address;
else
  X[n] = address;

Operational information

If PSTATE.DIT is 1, the timing of this instruction is insensitive to the value of the data being loaded or stored.
LDP (SIMD&FP)

Load Pair of SIMD&FP registers. This instruction loads a pair of SIMD&FP registers from memory. The address that is used for the load is calculated from a base register value and an optional immediate offset.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

It has encodings from 3 classes: Post-index, Pre-index and Signed offset

**Post-index**

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</table>

32-bit (opc == 00)

LDP <St1>, <St2>, [<Xn|SP>], #<imm>

64-bit (opc == 01)

LDP <Dt1>, <Dt2>, [<Xn|SP>], #<imm>

128-bit (opc == 10)

LDP <Qt1>, <Qt2>, [<Xn|SP>], #<imm>

boolean wback = TRUE;
boolean postindex = TRUE;

**Pre-index**

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</tbody>
</table>

32-bit (opc == 00)

LDP <St1>, <St2>, [<Xn|SP>], #<imm>!

64-bit (opc == 01)

LDP <Dt1>, <Dt2>, [<Xn|SP>], #<imm>!

128-bit (opc == 10)

LDP <Qt1>, <Qt2>, [<Xn|SP>], #<imm>!

boolean wback = TRUE;
boolean postindex = FALSE;

**Signed offset**

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<td>Rt2</td>
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</tbody>
</table>

LDP (SIMD&FP)
32-bit (opc == 00)

```
LDP <St1>, <St2>, [<Xn|SP>{, #<imm>}]  
```  

64-bit (opc == 01)

```
LDP <Dt1>, <Dt2>, [<Xn|SP>{, #<imm>}]  
```  

128-bit (opc == 10)

```
LDP <Qt1>, <Qt2>, [<Xn|SP>{, #<imm>}]  
```  

```
boolean wback = FALSE;  
boolean postindex = FALSE;  
```

For information about the **CONSTRAINED UNPREDICTABLE** behavior of this instruction, see *Architectural Constraints on UNPREDICTABLE behaviors*, and particularly *LDP (SIMD&FP)*.

**Assembler Symbols**

- `<Dt1>`
  - Is the 64-bit name of the first SIMD&FP register to be transferred, encoded in the "Rt" field.
- `<Dt2>`
  - Is the 64-bit name of the second SIMD&FP register to be transferred, encoded in the "Rt2" field.
- `<Qt1>`
  - Is the 128-bit name of the first SIMD&FP register to be transferred, encoded in the "Rt" field.
- `<Qt2>`
  - Is the 128-bit name of the second SIMD&FP register to be transferred, encoded in the "Rt2" field.
- `<St1>`
  - Is the 32-bit name of the first SIMD&FP register to be transferred, encoded in the "Rt" field.
- `<St2>`
  - Is the 32-bit name of the second SIMD&FP register to be transferred, encoded in the "Rt2" field.
- `<Xn|SP>`
  - Is the 64-bit name of the general-purpose base register or stack pointer, encoded in the "Rn" field.
- `<imm>`
  - For the 32-bit post-index and 32-bit pre-index variant: is the signed immediate byte offset, a multiple of 4 in the range -256 to 252, encoded in the "imm7" field as <imm>/4.
  - For the 32-bit signed offset variant: is the optional signed immediate byte offset, a multiple of 4 in the range -256 to 252, defaulting to 0 and encoded in the "imm7" field as <imm>/4.
  - For the 64-bit post-index and 64-bit pre-index variant: is the signed immediate byte offset, a multiple of 8 in the range -512 to 504, encoded in the "imm7" field as <imm>/8.
  - For the 64-bit signed offset variant: is the optional signed immediate byte offset, a multiple of 8 in the range -512 to 504, defaulting to 0 and encoded in the "imm7" field as <imm>/8.
  - For the 128-bit post-index and 128-bit pre-index variant: is the signed immediate byte offset, a multiple of 16 in the range -1024 to 1008, encoded in the "imm7" field as <imm>/16.
  - For the 128-bit signed offset variant: is the optional signed immediate byte offset, a multiple of 16 in the range -1024 to 1008, defaulting to 0 and encoded in the "imm7" field as <imm>/16.

**Shared Decode**

```plaintext
integer n = UInt(Rn);  
integer t = UInt(Rt);  
integer t2 = UInt(Rt2);  
AccType accctype = AccType_VEC;  
MemOp memop = if L == '1' then MemOp_LOAD else MemOp_STORE;  
if opc == '11' then UNDEFINED;  
integer scale = 2 + if opc == '11' then UnallocatedEncoding() else UInt(opc);  
integer datasize = 8 << scale;  
bits(64) offset = LSL(SignExtend(imm7, 64), scale);  
```
Operation

```plaintext
CheckFPAdvSIMDEnabled64();

bits(64) address;
bits(datasize) data1;
bits(datasize) data2;
constant integer dbytes = datasize DIV 8;
boolean rt_unknown = FALSE;

if memop == HaveMTEExt() then
  boolean is_load_store = memop IN {MemOp STORE, MemOp LOAD};
  SetNotTagCheckedInstruction(is_load_store && n == 31 && !wback);

if memop == MemOp LOAD && t == t2 then
  Constraint c = ConstrainUnpredictable(Unpredictable_LDPOVERLAP);
  assert c IN {Constraint UNKNOWN, Constraint UNDEF, Constraint NOP};
  case c of
    when Constraint UNKNOWN rt_unknown = TRUE;       // result is UNKNOWN
    when Constraint UNDEF UnallocatedEncoding UNDEFINED;
    when Constraint NOP EndOfInstruction();

if n == 31 then
  CheckSPAlignment();
else
  address = X[n];

if ! postindex then
  address = address + offset;

case memop of
  when MemOp STORE
    data1 = V[t];
    data2 = V[t2];
    Mem[address + 0 , dbytes, acctype] = data1;
    Mem[address + dbytes, dbytes, acctype] = data2;
  when MemOp LOAD
    data1 = Mem[address + 0 , dbytes, acctype];
    data2 = Mem[address + dbytes, dbytes, acctype];
    if rt_unknown then
      data1 = bits(datasize) UNKNOWN;
      data2 = bits(datasize) UNKNOWN;
      V[t] = data1;
      V[t2] = data2;
  if wback then
    if postindex then
      address = address + offset;
    if n == 31 then
      SP[] = address;
    else
      X[n] = address;
```

Operational information

If PSTATE.DIT is 1, the timing of this instruction is insensitive to the value of the data being loaded or stored.

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LDP

Load Pair of Registers calculates an address from a base register value and an immediate offset, loads two 32-bit words or two 64-bit doublewords from memory, and writes them to two registers. For information about memory accesses, see Load/Store addressing modes.

It has encodings from 3 classes: Post-index, Pre-index and Signed offset

### Post-index

<table>
<thead>
<tr>
<th></th>
<th>0</th>
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<th>1</th>
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</thead>
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<td></td>
</tr>
</tbody>
</table>

32-bit (opc == 00)

```plaintext
LDP <Wt1>, <Wt2>, [<Xn|SP>], #<imm>
```

64-bit (opc == 10)

```plaintext
LDP <Xt1>, <Xt2>, [<Xn|SP>], #<imm>
```

bool wback = TRUE;
bool postindex = TRUE;

### Pre-index

<table>
<thead>
<tr>
<th></th>
<th>0</th>
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<th>1</th>
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<tbody>
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</tr>
</tbody>
</table>

32-bit (opc == 00)

```plaintext
LDP <Wt1>, <Wt2>, [<Xn|SP>], #<imm>!
```

64-bit (opc == 10)

```plaintext
LDP <Xt1>, <Xt2>, [<Xn|SP>], #<imm>!
```

bool wback = TRUE;
bool postindex = FALSE;

### Signed offset

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<th>Rn</th>
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</tr>
</tbody>
</table>

32-bit (opc == 00)

```plaintext
LDP <Wt1>, <Wt2>, [<Xn|SP>], #<imm>]
```

64-bit (opc == 10)

```plaintext
LDP <Xt1>, <Xt2>, [<Xn|SP>], #<imm>]
```

bool wback = FALSE;
bool postindex = FALSE;
For information about the CONstrained UNPREDICTABLE behavior of this instruction, see *Architectural Constraints on UNPREDICTABLE behaviors*, and particularly LDP.

**Assembler Symbols**

- `<Wt1>` Is the 32-bit name of the first general-purpose register to be transferred, encoded in the "Rt" field.
- `<Wt2>` Is the 32-bit name of the second general-purpose register to be transferred, encoded in the "Rt2" field.
- `<Xt1>` Is the 64-bit name of the first general-purpose register to be transferred, encoded in the "Rt" field.
- `<Xt2>` Is the 64-bit name of the second general-purpose register to be transferred, encoded in the "Rt2" field.
- `<Xn|SP>` Is the 64-bit name of the general-purpose base register or stack pointer, encoded in the "Rn" field.
- `<imm>` For the 32-bit post-index and 32-bit pre-index variant: is the signed immediate byte offset, a multiple of 4 in the range -256 to 252, encoded in the "imm7" field as `<imm>/4.
  
  For the 32-bit signed offset variant: is the optional signed immediate byte offset, a multiple of 4 in the range -256 to 252, defaulting to 0 and encoded in the "imm7" field as `<imm>/4.

  For the 64-bit post-index and 64-bit pre-index variant: is the signed immediate byte offset, a multiple of 8 in the range -512 to 504, encoded in the "imm7" field as `<imm>/8.

  For the 64-bit signed offset variant: is the optional signed immediate byte offset, a multiple of 8 in the range -512 to 504, defaulting to 0 and encoded in the "imm7" field as `<imm>/8.

**Shared Decode**

```plaintext
integer n = UInt(Rn);
integer t = UInt(Rt);
integer t2 = UInt(Rt2);
AccType accctype = AccType_NORMAL;
MemOp memop = if L == '1' then MemOp_LOAD else MemOp_STORE;
if L:opc<0> == '01' || opc == '11' then UNDEFINED;
boolean signed = (opc<0> != '0');
integer scale = 2 +
  if L:opc<0> == '01' || opc == '11' then UnallocatedEncoding();
  boolean signed = (opc<0> != '0');
integer datasize = 8 << scale;
bits(64) offset = LSL(SignExtend(imm7, 64), scale);
```

LDP
bits(64) address;
bits(datasize) data1;
bits(datasize) data2;
constant integer dbytes = datasize DIV 8;
boolean rt_unknown = FALSE;
boolean wb_unknown = FALSE;
boolean is_load_store = memop IN {MemOp_STORE, MemOp_LOAD};
SetNotTagCheckedInstruction(is_load_store && n == 31 && !wback);

if memop == HaveMTEExt() then
    boolean is_load_store = memop IN {MemOp_STORE, MemOp_LOAD};
    SetNotTagCheckedInstruction(is_load_store && n == 31 && !wback);

if memop == MemOp_STORE && wback && (t == n || t2 == n) && n != 31 then
    Constraint c = ConstrainUnpredictable(Unpredictable_WBOVERLAPST);
    assert c IN {Constraint_NONE, Constraint_UNKNOWN, Constraint_UNDEF, Constraint_NOP};
    case c of
        when Constraint_NONE rt_unknown = FALSE;    // value stored is pre-writeback
        when Constraint_UNKNOWN rt_unknown = TRUE;   // value stored is UNKNOWN
        when Constraint_UNDEF UNDEFINED;
        when UnallocatedEncoding();
        when Constraint_NOP EndOfInstruction();
    if memop == MemOp_LOAD && t == t2 then
        Constraint c = ConstrainUnpredictable(Unpredictable_LDPOVERLAP);
        assert c IN {Constraint_UNKNOWN, Constraint_UNDEF, Constraint_NOP};
        case c of
            when Constraint_UNKNOWN rt_unknown = TRUE;   // result is UNKNOWN
            when Constraint_UNDEF UnallocatedEncoding() UNDEFINED;
            when Constraint_NOP EndOfInstruction();
    if n == 31 then
        CheckSPAlignment();
        address = SP[];
    else
        address = X[n];

    if ! postindex then
        address = address + offset;

    case memop of
        when MemOp_STORE
            if rt_unknown && t == n then
                data1 = bits(datasize) UNKNOWN;
            else
                data1 = X[t];
            if rt_unknown && t2 == n then
                data2 = bits(datasize) UNKNOWN;
            else
                data2 = X[t2];
            Mem[address + 0, dbytes, acctype] = data1;
            Mem[address + dbytes, dbytes, acctype] = data2;
        when MemOp_LOAD
            data1 = Mem[address + 0, dbytes, acctype];
            data2 = Mem[address + dbytes, dbytes, acctype];
            if rt_unknown then
                data1 = bits(datasize) UNKNOWN;
                data2 = bits(datasize) UNKNOWN;
if signed then
  \( X[t] = \text{SignExtend}(\text{data1}, 64); \)
  \( X[t2] = \text{SignExtend}(\text{data2}, 64); \)
else
  \( X[t] = \text{data1}; \)
  \( X[t2] = \text{data2}; \)

if wback then
  if wb_unknown then
    address = \text{bits}(64) \text{ UNKNOWN};
  elsif postindex then
    address = address + offset;
  if n == 31 then
    \( \text{SP}[] = \text{address}; \)
  else
    \( X[n] = \text{address}; \)

**Operational information**

If PSTATE.DIT is 1, the timing of this instruction is insensitive to the value of the data being loaded or stored.
LDPSW

Load Pair of Registers Signed Word calculates an address from a base register value and an immediate offset, loads two 32-bit words from memory, sign-extends them, and writes them to two registers. For information about memory accesses, see Load/Store addressing modes.

It has encodings from 3 classes: Post-index, Pre-index and Signed offset.

**Post-index**

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9  | 8  | 7  | 6  | 5  | 4  | 3  | 2  | 1  | 0  |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0  | 1  | 1  | 0  | 1  | 0  | 0  | 1  | 1  | imm7|   | Rt2|    | Rn |    | Rt |
| opc|    |    |    |    |    |    |    |    | L   |   |    |    |    |    |    |

**Pre-index**

LDPSW <Xt1>, <Xt2>, [<Xn|SP>], Nº<imm>

boolean wback = TRUE;
boolean postindex = TRUE;

**Signed offset**

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9  | 8  | 7  | 6  | 5  | 4  | 3  | 2  | 1  | 0  |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0  | 1  | 1  | 0  | 1  | 0  | 0  | 1  | 1  | imm7|   | Rt2|    | Rn |    | Rt |
| opc|    |    |    |    |    |    |    |    | L   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |

**Signed offset**

LDPSW <Xt1>, <Xt2>, [<Xn|SP>{, Nº<imm}>]

boolean wback = FALSE;
boolean postindex = FALSE;

For information about the CONstrained UNPREDICTABLE behavior of this instruction, see Architectural Constraints on UNPREDICTABLE behaviors, and particularly LDPSW.

**Assembler Symbols**

<Xt1> Is the 64-bit name of the first general-purpose register to be transferred, encoded in the "Rt" field.
<Xt2> Is the 64-bit name of the second general-purpose register to be transferred, encoded in the "Rt2" field.
<Xn|SP> Is the 64-bit name of the general-purpose base register or stack pointer, encoded in the "Rn" field.
<imm> For the post-index and pre-index variant: is the signed immediate byte offset, a multiple of 4 in the range -256 to 252, encoded in the "imm7" field as <imm>/4.
For the signed offset variant: is the optional signed immediate byte offset, a multiple of 4 in the range -256 to 252, defaulting to 0 and encoded in the "imm7" field as \(<imm>/4\).

Shared Decode

```plaintext
integer n = UInt(Rn);
exteger t = UInt(Rt);
exteger t2 = UInt(Rt2);
AccType acctype = AccType_NORMAL;
MemOp memop = if L == '1' then MemOp_LOAD else MemOp_STORE;
if L:opc<0> == '01' || opc == '11' then UNDEFINED;
boolean signed = (opc<0> != '0');
integer scale = 2 + if L:opc<0> == '01' || opc == '11' then UnallocatedEncoding();
boolean signed = (opc<0> != '0');
exteger scale = 2 + UInt(opc<1>);
exteger datasize = 8 << scale;
bits(64) offset = LSL(SignExtend(imm7, 64), scale);
```
bits(64) address;
bits(datasize) data1;
bits(datasize) data2;
constant integer dbytes = datasize DIV 8;
boolean rt_unknown = FALSE;
boolean wb_unknown = FALSE;

if memop == HaveMTEx() then
    if memop == MemOp_STORE && wback && (t == n || t2 == n) && n != 31 then
        Constraint c = ConstrainUnpredictable(Unpredictable_WBOVERLAPST);
        assert c IN (Constraint_NONE, Constraint_UNDEFINED, Constraint_NOP);
        case c of
            when Constraint_UNDEFINED rt_unknown = FALSE;
            when Constraint_UNKNOWN rt_unknown = TRUE;
            when UnallocatedEncoding();
            when Constraint_NOP EndOfInstruction();
    if memop == MemOp_LOAD && t == t2 then
        Constraint c = ConstrainUnpredictable(Unpredictable_LDPOVERLAP);
        assert c IN (Constraint_UNKNOWN, Constraint_UNDEFINED, Constraint_NOP);
        case c of
            when Constraint_UNDEFINED rt_unknown = FALSE;
            when Constraint_UNKNOWN rt_unknown = TRUE;
            when UnallocatedEncoding();
            when Constraint_NOP EndOfInstruction();
    if n == 31 then
        CheckSPAlignment();
        address = SP[];
    else
        address = X[n];
    if ! postindex then
        address = address + offset;
    case memop of
        when MemOp_STORE
            if rt_unknown && t == n then
                data1 = bits(datasize) UNKNOWN;
            else
                data1 = X[t];
                if rt_unknown && t2 == n then
                    data2 = bits(datasize) UNKNOWN;
                else
                    data2 = X[t2];
                    Mem[address + 0, dbytes, acctype] = data1;
                    Mem[address + dbytes, dbytes, acctype] = data2;
            when MemOp_LOAD
                data1 = Mem[address + 0, dbytes, acctype];
                data2 = Mem[address + dbytes, dbytes, acctype];
                if rt_unknown then
                    data1 = bits(datasize) UNKNOWN;
                    data2 = bits(datasize) UNKNOWN;
if signed then
  \texttt{\[t\]} = \texttt{SignExtend}(\texttt{data1}, 64);
  \texttt{\[t2\]} = \texttt{SignExtend}(\texttt{data2}, 64);
else
  \texttt{\[t\]} = \texttt{data1};
  \texttt{\[t2\]} = \texttt{data2};

if \texttt{wback} then
  if \texttt{wb\_unknown} then
    \texttt{address} = \texttt{bits(64) UNKNOWN};
  elseif \texttt{postindex} then
    \texttt{address} = \texttt{address + offset};
  if n == 31 then
    \texttt{SP}[] = \texttt{address};
  else
    \texttt{\[n\]} = \texttt{address};

\underline{Operational information}

If PSTATE.DIT is 1, the timing of this instruction is insensitive to the value of the data being loaded or stored.
LDR (immediate, SIMD&FP)

Load SIMD&FP Register (immediate offset). This instruction loads an element from memory, and writes the result as a scalar to the SIMD&FP register. The address that is used for the load is calculated from a base register value, a signed immediate offset, and an optional offset that is a multiple of the element size.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

It has encodings from 3 classes: Post-index, Pre-index and Unsigned offset

Post-index

```
| size | 1 | 1 | 1 | 1 | 0 | 0 | x | 1 | 0 | imm9 | 0 | 1 | Rn | Rt |
```

- **8-bit (size == 00 & opc == 01)**
  - LDR <Bt>, [<Xn|SP>], #<simm>

- **16-bit (size == 01 & opc == 01)**
  - LDR <Ht>, [<Xn|SP>], #<simm>

- **32-bit (size == 10 & opc == 01)**
  - LDR <St>, [<Xn|SP>], #<simm>

- **64-bit (size == 11 & opc == 01)**
  - LDR <Dt>, [<Xn|SP>], #<simm>

- **128-bit (size == 00 & opc == 11)**
  - LDR <Qt>, [<Xn|SP>], #<simm>

```plaintext
boolean wback = TRUE;
boolean postindex = TRUE;
integer scale = UInt(opc<1>:size);
if scale > 4 then UNDEFINED;
bits(64) offset = if scale > 1 then AllocatingEncoding() else SignExtend(imm9, 64);
```

Pre-index

```
| size | 1 | 1 | 1 | 1 | 0 | 0 | x | 1 | 0 | imm9 | 1 | 1 | Rn | Rt |
```

```plaintext
LDR (immediate, SIMD&FP)
```
8-bit (size == 00 && opc == 01)
LDR <Bt>, [<Xn|SP>, #<simm>]

16-bit (size == 01 && opc == 01)
LDR <Ht>, [<Xn|SP>, #<simm>]

32-bit (size == 10 && opc == 01)
LDR <St>, [<Xn|SP>, #<simm>]

64-bit (size == 11 && opc == 01)
LDR <Dt>, [<Xn|SP>, #<simm>]

128-bit (size == 00 && opc == 11)
LDR <Qt>, [<Xn|SP>, #<simm>]

boolean wback = TRUE;
boolean postindex = FALSE;
integer scale = UInt(opc<1>:size);
if scale > 4 then UNDEFINED;
bits(64) offset = if scale > 4 then UnallocatedEncoding()::
bits(64) offset = SignExtend(imm9, 64);

Unsigned offset

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<th>1</th>
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</tr>
</tbody>
</table>

8-bit (size == 00 && opc == 01)
LDR <Bt>, [<Xn|SP>{, #<pimm}]}

16-bit (size == 01 && opc == 01)
LDR <Ht>, [<Xn|SP>{, #<pimm}]}

32-bit (size == 10 && opc == 01)
LDR <St>, [<Xn|SP>{, #<pimm}]}

64-bit (size == 11 && opc == 01)
LDR <Dt>, [<Xn|SP>{, #<pimm}]}

128-bit (size == 00 && opc == 11)
LDR <Qt>, [<Xn|SP>{, #<pimm}]}

boolean wback = FALSE;
boolean postindex = FALSE;
integer scale = UInt(opc<1>:size);
if scale > 4 then UNDEFINED;
bits(64) offset = if scale > 4 then UnallocatedEncoding()::
bits(64) offset = LSL(ZeroExtend(imm9, 64), scale);
Assembler Symbols

<Bt> Is the 8-bit name of the SIMD&FP register to be transferred, encoded in the "Rt" field.

<Dt> Is the 64-bit name of the SIMD&FP register to be transferred, encoded in the "Rt" field.

<It> Is the 16-bit name of the SIMD&FP register to be transferred, encoded in the "Rt" field.

<Qt> Is the 128-bit name of the SIMD&FP register to be transferred, encoded in the "Rt" field.

<St> Is the 32-bit name of the SIMD&FP register to be transferred, encoded in the "Rt" field.

<Xn|SP> Is the 64-bit name of the general-purpose base register or stack pointer, encoded in the "Rn" field.

<simm> Is the signed immediate byte offset, in the range -256 to 255, encoded in the "imm9" field.

<pimm> For the 8-bit variant: is the optional positive immediate byte offset, in the range 0 to 4095, defaulting to 0 and encoded in the "imm12" field.

For the 16-bit variant: is the optional positive immediate byte offset, a multiple of 2 in the range 0 to 8190, defaulting to 0 and encoded in the "imm12" field as <pimm>/2.

For the 32-bit variant: is the optional positive immediate byte offset, a multiple of 4 in the range 0 to 16380, defaulting to 0 and encoded in the "imm12" field as <pimm>/4.

For the 64-bit variant: is the optional positive immediate byte offset, a multiple of 8 in the range 0 to 32760, defaulting to 0 and encoded in the "imm12" field as <pimm>/8.

For the 128-bit variant: is the optional positive immediate byte offset, a multiple of 16 in the range 0 to 65520, defaulting to 0 and encoded in the "imm12" field as <pimm>/16.

Shared Decode

```
integer n = UInt(Rn);
integer t = UInt(Rt);
AccType accType = AccType_VEC;
MemOp memop = if opc<0> == '1' then MemOp_LOAD else MemOp_STORE;
integer datasize = 8 << scale;
```
Operation

if HaveMTEExt() then
    boolean is_load_store = memop IN {MemOp_STORE, MemOp_LOAD};
    SetNotTagCheckedInstruction(is_load_store && n == 31 && !wback);

    CheckFPAdvSIMDEnabled64();
    bits(64) address;
    bits(datasize) data;

    if n == 31 then
        CheckSPAlignment();
        address = SP[];
    else
        address = X[n];

    if ! postindex then
        address = address + offset;

    case memop of
        when MemOp_STORE
            data = V[t];
            Mem[address, datasize DIV 8, acctype] = data;
        when MemOp_LOAD
            data = Mem[address, datasize DIV 8, acctype];
            V[t] = data;

    if wback then
        if postindex then
            address = address + offset;
        if n == 31 then
            SP[] = address;
        else
            X[n] = address;

Operational information

If PSTATE.DIT is 1, the timing of this instruction is insensitive to the value of the data being loaded or stored.
LDR (immediate)

Load Register (immediate) loads a word or doubleword from memory and writes it to a register. The address that is used for the load is calculated from a base register and an immediate offset. For information about memory accesses, see Load/Store addressing modes. The Unsigned offset variant scales the immediate offset value by the size of the value accessed before adding it to the base register value.

It has encodings from 3 classes: Post-index, Pre-index and Unsigned offset.

**Post-index**

|   | 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9  | 8  | 7  | 6  | 5  | 4  | 3  | 2  | 1  | 0  |
|---|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| size | size |    |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| opc | opc |    |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |

32-bit (size == 10)

LDR <Wt>, [<Xn|SP>], #<simm>

64-bit (size == 11)

LDR <Xt>, [<Xn|SP>], #<simm>

```java
boolean wback = TRUE;
boolean postindex = TRUE;
integer scale = UInt(size);
bits(64) offset = SignExtend(imm9, 64);
```

**Pre-index**

|   | 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9  | 8  | 7  | 6  | 5  | 4  | 3  | 2  | 1  | 0  |
|---|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| size | size |    |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| opc | opc |    |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |

32-bit (size == 10)

LDR <Wt>, [<Xn|SP>], #<simm>!

64-bit (size == 11)

LDR <Xt>, [<Xn|SP>], #<simm>!

```java
boolean wback = TRUE;
boolean postindex = FALSE;
integer scale = UInt(size);
bits(64) offset = SignExtend(imm9, 64);
```

**Unsigned offset**

|   | 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9  | 8  | 7  | 6  | 5  | 4  | 3  | 2  | 1  | 0  |
|---|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| size | size |    |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| opc | opc |    |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |

LDR (immediate)
32-bit (size == 10)

LDR <Wt>, [<Xn|SP>{, #<pimm>}

64-bit (size == 11)

LDR <Xt>, [<Xn|SP>{, #<pimm>]

boolean wback = FALSE;
boolean postindex = FALSE;
integer scale = UInt(size);
bits(64) offset = LSL(ZeroExtend(imm12, 64), scale);

For information about the CONSTRAINED UNPREDICTABLE behavior of this instruction, see Architectural Constraints on UNPREDICTABLE behaviors, and particularly LDR (immediate).

Assembler Symbols

<Wt> Is the 32-bit name of the general-purpose register to be transferred, encoded in the "Rt" field.
<Xt> Is the 64-bit name of the general-purpose register to be transferred, encoded in the "Rt" field.
<Xn|SP> Is the 64-bit name of the general-purpose base register or stack pointer, encoded in the "Rn" field.
<simm> Is the signed immediate byte offset, in the range -256 to 255, encoded in the "imm9" field.
<pimm> For the 32-bit variant: is the optional positive immediate byte offset, a multiple of 4 in the range 0 to 16380, defaulting to 0 and encoded in the "imm12" field as <pimm>/4.
For the 64-bit variant: is the optional positive immediate byte offset, a multiple of 8 in the range 0 to 32760, defaulting to 0 and encoded in the "imm12" field as <pimm>/8.

Shared Decode

integer n = UInt(Rn);
integer t = UInt(Rt);
AccType acctype = AccType_NORMAL;
MemOp memop;
boolean signed;
integer regsize;
if opc<1> == '0' then
  // store or zero-extending load
  memop = if opc<0> == '1' then MemOp_LOAD else MemOp_STORE;
  regsize = if size == '11' then 64 else 32;
  signed = FALSE;
else
  if size == '11' then UNDEFINED;
  else
    // sign-extending load
    memop = if size == '11' then UnallocatedEncoding;
    else
      // sign-extending load
      memop = MemOp_LOAD;
      if size == '10' && opc<0> == '1' then UnallocatedEncoding;
      if size == '10' && opc<0> == '1' then UNDEFINED;
      regsize = if opc<0> == '1' then 32 else 64;
      signed = TRUE;
    integer datasize = 8 << scale;
if bits(64) address;
bits(datasize) data;
boolean wb_unknown = FALSE;
boolean rt_unknown = FALSE;

if memop == HaveMTEExt() then
    boolean is_load_store = memop IN {MemOp_STORE, MemOp_LOAD};
    SetNotTagCheckedInstruction(is_load_store && n == 31 && !wback);

bits(64) address;
bits(datasize) data;
boolean wb_unknown = FALSE;
boolean rt_unknown = FALSE;

if memop == 0x0 && wback && n == t && n != 31 then
    c = ConstrainUnpredictable(Unpredictable_WBOVERLAPLD);
    assert c IN {Constraint_WBSUPPRESS, Constraint_UNKNOWN, Constraint_UNDEF, Constraint_NOP};
    case c of
        when Constraint_WBSUPPRESS wback = FALSE; // writeback is suppressed
        when Constraint_UNKNOWN wb_unknown = TRUE; // writeback is UNKNOWN
        when Constraint_UNDEF rt_unknown = FALSE;  // value stored is original value
        when UnallocatedEncoding() rt_unknown = TRUE; // value stored is UNKNOWN
        when Constraint_NOP EndOfInstruction();

if memop == MemOp_STORE && wback && n == t && n != 31 then
    c = ConstrainUnpredictable(Unpredictable_WBOVERLAPST);
    assert c IN {Constraint_NONE, Constraint_UNKNOWN, Constraint_UNDEF, Constraint_NOP};
    case c of
        when Constraint_NONE rt_unknown = FALSE; // value stored is original value
        when Constraint_UNKNOWN rt_unknown = TRUE; // value stored is UNKNOWN
        when Constraint_NOP EndOfInstruction();
        when Constraint_UNDEF UnallocatedEncoding() UNDEFINED;
        else
            when Constraint_NOP EndOfInstruction();

if n == 31 then
    if memop != MemOp_PREFETCH then CheckSPAlignment();
    address = SP[];
else
    address = X[n];

if ! postindex then
    address = address + offset;

case memop of
    when MemOp_STORE
        if rt_unknown then
            data = bits(datasize) UNKNOWN;
        else
            data = X[t];
            Mem[address, datasize DIV 8, acctype] = data;
        when MemOp_LOAD
            data = Mem[address, datasize DIV 8, acctype];
            if signed then
                X[t] = SignExtend(data, regsize);
            else
                X[t] = ZeroExtend(data, regsize);
        when MemOp_PREFETCHPrefetch(address, t<4:0>);

if wback then
    if wb_unknown then
        address = bits(64) UNKNOWN;
    elsif postindex then
        address = address + offset;
    if n == 31 then
        SP[] = address;
else
    X[n] = address;

Operational information

If PSTATE.DIT is 1, the timing of this instruction is insensitive to the value of the data being loaded or stored.
LDR (literal, SIMD&FP)

Load SIMD&FP Register (PC-relative literal). This instruction loads a SIMD&FP register from memory. The address that is used for the load is calculated from the PC value and an immediate offset.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

<table>
<thead>
<tr>
<th>opc</th>
<th>imm19</th>
<th>Rt</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

32-bit (opc == 00)

LDR <St>, <label>

64-bit (opc == 01)

LDR <Dt>, <label>

128-bit (opc == 10)

LDR <Qt>, <label>

```java
integer t = UInt(Rt);
integer size;
bits(64) offset;

case opc of
  when '00' 
    size = 4;
  when '01' 
    size = 8;
  when '10' 
    size = 16;
  when '11' 
    UNDEFINED;

offset = when '11' UnallocatedEncoding();
offset = SignExtend(imm19:'00', 64);
```

Assembler Symbols

- `<Dt>` Is the 64-bit name of the SIMD&FP register to be loaded, encoded in the "Rt" field.
- `<Qt>` Is the 128-bit name of the SIMD&FP register to be loaded, encoded in the "Rt" field.
- `<St>` Is the 32-bit name of the SIMD&FP register to be loaded, encoded in the "Rt" field.
- `<label>` Is the program label from which the data is to be loaded. Its offset from the address of this instruction, in the range +/-1MB, is encoded as "imm19" times 4.

Operation

```java
bits(64) address = PC[] + offset;
bits(size*8) data;
CheckFPAdvSIMDEnabled64();

data = Mem[address, size, AccType_VEC];
V[t] = data;
```
Operational information

If PSTATE.DIT is 1, the timing of this instruction is insensitive to the value of the data being loaded or stored.
LDR (register, SIMD&FP)

Load SIMD&FP Register (register offset). This instruction loads a SIMD&FP register from memory. The address that is used for the load is calculated from a base register value and an offset register value. The offset can be optionally shifted and extended.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

<table>
<thead>
<tr>
<th>size</th>
<th>1</th>
<th>1</th>
<th>1</th>
<th>0</th>
<th>0</th>
<th>x</th>
<th>1</th>
<th>1</th>
</tr>
</thead>
<tbody>
<tr>
<td>opc</td>
<td></td>
<td></td>
<td></td>
<td>Rm</td>
<td></td>
<td>option</td>
<td>S</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

8-fsreg,LDR-8-fsreg (size == 00 & opc == 01 & option != 011)
LDR <Bt>, [<Xn|SP>, (<Wm>|<Xm>), <extend> {<amount>}]

8-fsreg,LDR-8-fsreg (size == 00 & opc == 01 & option == 011)
LDR <Bt>, [<Xn|SP>, <Xm>[], LSL <amount>]]

16-fsreg,LDR-16-fsreg (size == 01 & opc == 01)
LDR <Ht>, [<Xn|SP>, (<Wm>|<Xm>){, <extend> {<amount>}}]

32-fsreg,LDR-32-fsreg (size == 10 & opc == 01)
LDR <St>, [<Xn|SP>, (<Wm>|<Xm>){, <extend> {<amount>}}]

64-fsreg,LDR-64-fsreg (size == 11 & opc == 01)
LDR <Dt>, [<Xn|SP>, (<Wm>|<Xm>){, <extend> {<amount>}}]

128-fsreg,LDR-128-fsreg (size == 00 & opc == 11)
LDR <Qt>, [<Xn|SP>, (<Wm>|<Xm>){, <extend> {<amount>}}]

boolean wback = FALSE;
boolean postindex = FALSE;
integer scale = UInt(opc<1>:size);
if scale > 4 then UNDEFINED;
if option<1> == '0' then UNDEFINED; // sub-word index
if scale > 4 then UnallocatedEncoding();
if option<1> == '0' then UnallocatedEncoding(); // sub-word index
ExtendType extend_type = DecodeRegExtend(option);
Integer shift = if S == '1' then scale else 0;

Assembler Symbols

<Bt> Is the 8-bit name of the SIMD&FP register to be transferred, encoded in the "Rt" field.
<Dt> Is the 64-bit name of the SIMD&FP register to be transferred, encoded in the "Rt" field.
<Ht> Is the 16-bit name of the SIMD&FP register to be transferred, encoded in the "Rt" field.
<Qt> Is the 128-bit name of the SIMD&FP register to be transferred, encoded in the "Rt" field.
<St> Is the 32-bit name of the SIMD&FP register to be transferred, encoded in the "Rt" field.
<Xn|SP> Is the 64-bit name of the general-purpose base register or stack pointer, encoded in the "Rn" field.
<Wm> When option<0> is set to 0, is the 32-bit name of the general-purpose index register, encoded in the "Rm" field.
When option<0> is set to 1, is the 64-bit name of the general-purpose index register, encoded in the "Rm" field.

For the 8-bit variant: is the index extend specifier, encoded in “option”:

<table>
<thead>
<tr>
<th>option</th>
<th>extend</th>
</tr>
</thead>
<tbody>
<tr>
<td>010</td>
<td>UXTW</td>
</tr>
<tr>
<td>110</td>
<td>SXTW</td>
</tr>
<tr>
<td>111</td>
<td>SXTX</td>
</tr>
</tbody>
</table>

For the 128-bit, 16-bit, 32-bit and 64-bit variant: is the index extend/shift specifier, defaulting to LSL, and which must be omitted for the LSL option when <amount> is omitted. encoded in “option”:

<table>
<thead>
<tr>
<th>option</th>
<th>extend</th>
</tr>
</thead>
<tbody>
<tr>
<td>010</td>
<td>UXTW</td>
</tr>
<tr>
<td>011</td>
<td>LSL</td>
</tr>
<tr>
<td>110</td>
<td>SXTW</td>
</tr>
<tr>
<td>111</td>
<td>SXTX</td>
</tr>
</tbody>
</table>

For the 8-bit variant: is the index amount, it must be #0, encoded in "S" as 0 if omitted, or as 1 if present.

For the 16-bit variant: is the index shift amount, optional only when <extend> is not LSL. Where it is permitted to be optional, it defaults to #0. It is encoded in “S”:

<table>
<thead>
<tr>
<th>S</th>
<th>amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>#0</td>
</tr>
<tr>
<td>1</td>
<td>#1</td>
</tr>
</tbody>
</table>

For the 32-bit variant: is the index shift amount, optional only when <extend> is not LSL. Where it is permitted to be optional, it defaults to #0. It is encoded in “S”:

<table>
<thead>
<tr>
<th>S</th>
<th>amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>#0</td>
</tr>
<tr>
<td>1</td>
<td>#2</td>
</tr>
</tbody>
</table>

For the 64-bit variant: is the index shift amount, optional only when <extend> is not LSL. Where it is permitted to be optional, it defaults to #0. It is encoded in “S”:

<table>
<thead>
<tr>
<th>S</th>
<th>amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>#0</td>
</tr>
<tr>
<td>1</td>
<td>#3</td>
</tr>
</tbody>
</table>

For the 128-bit variant: is the index shift amount, optional only when <extend> is not LSL. Where it is permitted to be optional, it defaults to #0. It is encoded in “S”:

<table>
<thead>
<tr>
<th>S</th>
<th>amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>#0</td>
</tr>
<tr>
<td>1</td>
<td>#4</td>
</tr>
</tbody>
</table>

Shared Decode

```
integer n = UInt(Rn);
integer t = UInt(Rt);
integer m = UInt(Rm);
AccType accType = AccType_VEC;
MemOp memop = if opc<0> == 'I' then MemOp_LOAD else MemOp_STORE;
integer datasize = 8 << scale;
```
Operation

bits(64) offset = \texttt{ExtendReg}(m, \texttt{extend\_type}, \texttt{shift});
\textbf{if} \; m, \texttt{extend\_type}, \texttt{shift}; \texttt{HaveMTEExt}() \; \textbf{then}
\begin{align*}
\text{boolean is\_load\_store} & = \text{memop IN} \{\text{MemOp\_STORE, MemOp\_LOAD}\}; \\
\text{SetNotTagCheckedInstruction} & (\text{is\_load\_store} \&\& \; n == 31 \&\& \neg \text{!wback});
\end{align*}
\text{CheckFPAdvSIMDEnabled64}();
bits(64) \text{address};
bits(datasize) \text{data};
\textbf{if} \; n == 31 \; \textbf{then}
\text{CheckSPAlignment}();
\text{else}
\text{address} = \text{X}[n];
\textbf{if} \; \neg \text{postindex} \; \textbf{then}
\text{address} = \text{address} + \text{offset};
\textbf{case} \; \text{memop} \; \textbf{of}
\begin{align*}
\text{when MemOp\_STORE} & \; \text{data} = \text{V}[t]; \\
& \; \text{Mem}[\text{address}, \text{datasize DIV 8, acctype}] = \text{data}; \\
\text{when MemOp\_LOAD} & \; \text{data} = \text{Mem}[\text{address}, \text{datasize DIV 8, acctype}]; \\
& \; \text{V}[t] = \text{data};
\end{align*}
\textbf{if} \; \neg \text{wback} \; \textbf{then}
\textbf{if} \; \text{postindex} \; \textbf{then}
\text{address} = \text{address} + \text{offset};
\textbf{if} \; n == 31 \; \textbf{then}
\text{SP}[] = \text{address};
\textbf{else}
\text{X}[n] = \text{address};

Operational information

If PSTATE.DIT is 1, the timing of this instruction is insensitive to the value of the data being loaded or stored.
LDR (register)

Load Register (register) calculates an address from a base register value and an offset register value, loads a word from memory, and writes it to a register. The offset register value can optionally be shifted and extended. For information about memory accesses, see Load/Store addressing modes.

| 31  | 30  | 29  | 28  | 27  | 26  | 25  | 24  | 23  | 22  | 21  | 20  | 19  | 18  | 17  | 16  | 15  | 14  | 13  | 12  | 11  | 10  | 9   | 8   | 7   | 6   | 5   | 4   | 3   | 2   | 1   | 0   |
|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| x   | 1   | 1   | 1   | 0   | 0   | 0   | 0   | 1   | 1   | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0   |

size  opc

32-bit (size = 10)

LDR <Wt>, [<Xn|SP>, (<Wm>|<Xm>)], <extend> {<amount>}

64-bit (size = 11)

LDR <Xt>, [<Xn|SP>, (<Wm>|<Xm>), <extend> {<amount>}]

boolean wback = FALSE;
boolean postindex = FALSE;
integer scale = UInt(size);
if option<1> == '0' then UNDEFINED;             // sub-word index
if option<1> == '0' then
UnallocatedEncoding(); // sub-word index
ExtendType extend_type = DecodeRegExtend(option);
integer shift = if S == '1' then scale else 0;

Assembler Symbols

<Wt> Is the 32-bit name of the general-purpose register to be transferred, encoded in the "Rt" field.

<Xt> Is the 64-bit name of the general-purpose register to be transferred, encoded in the "Rt" field.

<Xn|SP> Is the 64-bit name of the general-purpose base register or stack pointer, encoded in the "Rn" field.

<Wm> When option<0> is set to 0, is the 32-bit name of the general-purpose index register, encoded in the "Rm" field.

<Xm> When option<0> is set to 1, is the 64-bit name of the general-purpose index register, encoded in the "Rm" field.

<extend> Is the index extend/shift specifier, defaulting to LSL, and which must be omitted for the LSL option when <amount> is omitted. encoded in "option":

<table>
<thead>
<tr>
<th>option</th>
<th>&lt;extend&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>010</td>
<td>UXTW</td>
</tr>
<tr>
<td>011</td>
<td>LSL</td>
</tr>
<tr>
<td>110</td>
<td>SXTW</td>
</tr>
<tr>
<td>111</td>
<td>SXTX</td>
</tr>
</tbody>
</table>

<amount> For the 32-bit variant: is the index shift amount, optional only when <extend> is not LSL. Where it is permitted to be optional, it defaults to #0. It is encoded in “S”:

<table>
<thead>
<tr>
<th>S</th>
<th>&lt;amount&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>#0</td>
</tr>
<tr>
<td>1</td>
<td>#2</td>
</tr>
</tbody>
</table>

For the 64-bit variant: is the index shift amount, optional only when <extend> is not LSL. Where it is permitted to be optional, it defaults to #0. It is encoded in “S”:

<table>
<thead>
<tr>
<th>S</th>
<th>&lt;amount&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>#0</td>
</tr>
<tr>
<td>1</td>
<td>#3</td>
</tr>
</tbody>
</table>
integer n = UInt(Rn);
integer t = UInt(Rt);
integer m = UInt(Rm);
AccType acc_type = AccType_NORMAL;
MemOp memop;
boolean signed;
integer regsize;

if opc<1> == '0' then
  // store or zero-extending load
  memop = if opc<0> == '1' then MemOp_LOAD else MemOp_STORE;
  regsize = if size == '11' then 64 else 32;
  signed = FALSE;
else
  if size == '11' then
    memop = MemOp_PREFETCH;
    if opc<0> == '1' then UNDEFINED;
  else
    // sign-extending load
    memop = if opc<0> == '1' then UnallocatedEncoding();
    if size == '10' && opc<0> == '1' then UNDEFINED;
    regsize = if opc<0> == '1' then 32 else 64;
    signed = TRUE;

integer datasize = 8 << scale;
bits(64) offset = ExtendReg(m, extend_type, shift);
if bits(64) address;
bits(datasize) data;
boolean wb_unknown = FALSE;
boolean rt_unknown = FALSE;

if memop == MemOp_PREFETCH then
    SetNotTagCheckedInstruction(is_load_store & n == 31 & !wback);

bits(64) address;
bits(datasize) data;
boolean wb_unknown = FALSE;
boolean rt_unknown = FALSE;

if memop == MemOp_STORE & wback & n == t & n != 31 then
    assert c IN {Constraint_NONE, Constraint_UNKNOWN, Constraint_UNDEF, Constraint_NOP};
    case c of
        when Constraint_NONE rt_unknown = FALSE; // value stored is original value
        when Constraint_UNKNOWN rt_unknown = TRUE; // value stored is UNKNOWN
        when Constraint_UNDEF rt_unknown = TRUE; // value stored is UNDEFINED;
        when Constraint_NOP EndOfInstruction();

if n == 31 then
    if memop != MemOp_PREFETCH then CheckSPAlignment();
    address = SP[];
else
    address = X[n];

if ! postindex then
    address = address + offset;

case memop of
    when MemOp_STORE
        if rt_unknown then
            data = bits(datasize) UNKNOWN;
        else
            data = X[t];
            Mem[address, datasize DIV 8, acctype] = data;
    when MemOp_LOAD
        data = Mem[address, datasize DIV 8, acctype];
        if signed then
            X[t] = SignExtend(data, regsize);
        else
            X[t] = ZeroExtend(data, regsize);
    when MemOp_PREFETCH
        if wb unknown then
            address = bits(64) UNKNOWN;
        else if postindex then
            address = address + offset;
        if n == 31 then
            SP[] = address;
else

X[n] = address;

Operational information

If PSTATE.DIT is 1, the timing of this instruction is insensitive to the value of the data being loaded or stored.
LDRAA, LDRAB

Load Register, with pointer authentication. This instruction authenticates an address from a base register using a modifier of zero and the specified key, adds an immediate offset to the authenticated address, and loads a 64-bit doubleword from memory at this resulting address into a register.

Key A is used for LDRAA, and key B is used for LDRAB.

If the authentication passes, the PE behaves the same as for an LDR instruction. If the authentication fails, a Translation fault is generated.

The authenticated address is not written back to the base register, unless the pre-indexed variant of the instruction is used. In this case, the address that is written back to the base register does not include the pointer authentication code.

For information about memory accesses, see Load/Store addressing modes.

Unscaled offset (ARMv8.3)

|   |   |   |   |   |   |   |   | S |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 |  9 |  8 |  7 |  6 |  5 |  4 |  3 |  2 |  1 |  0 |
| 1  | 1  | 1  | 1  | 1  | 1  | 0  | 0  | 0  | M | S |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |

Key A, offset (M == 0 && W == 0)

LDRAA <Xt>, [<Xn|SP>{, #<simm>}]!

Key A, pre-indexed (M == 0 && W == 1)

LDRAA <Xt>, [<Xn|SP>{, #<simm>}]!

Key B, offset (M == 1 && W == 0)

LDRAB <Xt>, [<Xn|SP>{, #<simm>}]!

Key B, pre-indexed (M == 1 && W == 1)

LDRAB <Xt>, [<Xn|SP>{, #<simm>}]!

Assembler Symbols

<Xt> is the 64-bit name of the general-purpose register to be transferred, encoded in the "Rt" field.

<Xn|SP> is the 64-bit name of the general-purpose base register or stack pointer, encoded in the "Rn" field.

<simm> is the optional signed immediate byte offset, a multiple of 8 in the range -4096 to 4088, defaulting to 0 and encoded in the "S:imm9" field as <simm>/8.

Assembler Symbols

If !HavePACExt() || size != '11' then UNDEFINED;
integer t = 0 || size != '11' then UnallocatedEncoding();
integer n = UInt(Rn);
boolean wback = (W == '1');
boolean use_key_a = (M == '0');
bv<10> S10 = S:imm9;
integer scale = 3;
bv<64> offset = LSL(SignExtend(S10, 64), scale);
Operation

bits(64) address;
bits(64) data;
boolean wb_unknown = FALSE;

if wback && n == t && n != 31 then
    c = ConstrainUnpredictable(Unpredictable_WBOVERLAPLD);
    assert c IN {Constraint_WBSUPPRESS, Constraint_UNKNOWN, Constraint_UNDEF, Constraint_NOP};
    case c of
        when Constraint_WBSUPPRESS wback = FALSE; // writeback is suppressed
        when Constraint_UNKNOWN wb_unknown = TRUE; // writeback is UNKNOWN
        when Constraint_UNDEF UNDEFINED;
        when UnallocatedEncoding();
        when Constraint_NOP EndOfInstruction();

if n == 31 then
    CheckSPAlignment();
else
    address = X[n];

if use_key_a then
    address = AuthDA(address, X[31]);
else
    address = AuthDB(address, X[31]);

address = address + offset;
data = Mem[address, 8, AccType_NORMAL];
X[t] = data;

if wback then
    if wb_unknown then
        address = bits(64) UNKNOWN;
    if n == 31 then
        SP[] = address;
    else
        X[n] = address;

Operational information

If PSTATE.DIT is 1, the timing of this instruction is insensitive to the value of the data being loaded or stored.
**LDRB (immediate)**

Load Register Byte (immediate) loads a byte from memory, zero-extends it, and writes the result to a register. The address that is used for the load is calculated from a base register and an immediate offset. For information about memory accesses, see *Load/Store addressing modes*.

It has encodings from 3 classes: **Post-index**, **Pre-index** and **Unsigned offset**.

### Post-index

<table>
<thead>
<tr>
<th>0</th>
<th>0</th>
<th>1</th>
<th>1</th>
<th>0</th>
<th>0</th>
<th>0</th>
<th>1</th>
<th>0</th>
<th>imm9</th>
<th>0</th>
<th>1</th>
<th>Rn</th>
<th>Rt</th>
</tr>
</thead>
<tbody>
<tr>
<td>size</td>
<td>opc</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### Post-index

$LDRB \langle Wt \rangle, [<Xn]\|SP>, #<simm>

```java
boolean wback = TRUE;
boolean postindex = TRUE;
integer scale = UInt(size);
bits(64) offset = SignExtend(imm9, 64);
```

### Pre-index

<table>
<thead>
<tr>
<th>0</th>
<th>0</th>
<th>1</th>
<th>1</th>
<th>0</th>
<th>0</th>
<th>0</th>
<th>1</th>
<th>0</th>
<th>imm9</th>
<th>1</th>
<th>1</th>
<th>Rn</th>
<th>Rt</th>
</tr>
</thead>
<tbody>
<tr>
<td>size</td>
<td>opc</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### Pre-index

$LDRB \langle Wt \rangle, [<Xn]\|SP>, #<imm>

```java
boolean wback = TRUE;
boolean postindex = FALSE;
integer scale = UInt(size);
bits(64) offset = SignExtend(imm9, 64);
```

### Unsigned offset

<table>
<thead>
<tr>
<th>0</th>
<th>0</th>
<th>1</th>
<th>1</th>
<th>0</th>
<th>0</th>
<th>1</th>
<th>0</th>
<th>imm12</th>
<th>Rn</th>
<th>Rt</th>
</tr>
</thead>
<tbody>
<tr>
<td>size</td>
<td>opc</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### Unsigned offset

$LDRB \langle Wt \rangle, [<Xn]\|SP>, #<imm>

```java
boolean wback = FALSE;
boolean postindex = FALSE;
integer scale = UInt(size);
bits(64) offset = LSL(ZeroExtend(imm12, 64), scale);
```

For information about the CONSTRAINED UNPREDICTABLE behavior of this instruction, see *Architectural Constraints on UNPREDICTABLE behaviors*, and particularly *LDRH (immediate)*.

**Assembler Symbols**

<\(Wt\)> Is the 32-bit name of the general-purpose register to be transferred, encoded in the "Rt" field.
Is the 64-bit name of the general-purpose base register or stack pointer, encoded in the "Rn" field.

<simm> Is the signed immediate byte offset, in the range -256 to 255, encoded in the "imm9" field.

<pimm> Is the optional positive immediate byte offset, in the range 0 to 4095, defaulting to 0 and encoded in the "imm12" field.

Shared Decode

```plaintext
integer n = Uint(Rn);
integer t = Uint(Rt);
AccType acctype = AccType_NORMAL;
MemOp memop;
boolean signed;
integer regsize;

if opc<1> == '0' then
    // store or zero-extending load
    memop = if opc<0> == '1' then MemOp_LOAD else MemOp_STORE;
    regsize = if size == '11' then 64 else 32;
    signed = FALSE;
else
    if size == '11' then UNDEFINED;
    else
        // sign-extending load
        memop = if size == '11' then UnallocatedEncoding else MemOp_LOAD;
        regsize = if size == '10' && opc<0> == '1' then UNDEFINED;
        if size == '10' && opc<0> == '1' then UnallocatedEncoding
        else
            regsize = if opc<0> == '1' then 32 else 64;
            signed = TRUE;

integer datasize = 8 << scale;
```
Operation

LDRB (immediate)
if bits(64) address;
bits(datasize) data;
boolean wb_unknown = FALSE;
boolean rt_unknown = FALSE;
if memop == HaveMTEExt() then
    boolean is_load_store = memop IN {MemOp STORE, MemOp LOAD};
    SetNotTagCheckedInstruction(is_load_store && n == 31 && !wback);

bits(64) address;
bits(datasize) data;
boolean wb_unknown = FALSE;
boolean rt_unknown = FALSE;
if memop == MemOp LOAD && wback && n == t && n != 31 then
    c = ConstrainUnpredictable(Unpredictable_WBOVERLAPLD);
    assert c IN {Constraint_WBSUPPRESS, Constraint_UNKNOWN, Constraint_UNDEF, Constraint_NOP};
case c of
    when Constraint_WBSUPPRESS wback = FALSE;       // writeback is suppressed
    when Constraint_UNKNOWN  wb_unknown = TRUE;   // writeback is UNKNOWN
    when Constraint_UNDEF rt_unknown = TRUE;      // value stored is UNKNOWN
    when UnallocatedEncoding();
    when Constraint_NOP EndOfInstruction();
fi

if memop == MemOp STORE && wback && n == t && n != 31 then
    c = ConstrainUnpredictable(Unpredictable_WBOVERLAPST);
    assert c IN {Constraint_NONE, Constraint_UNKNOWN, Constraint_UNDEF, Constraint_NOP};
case c of
    when Constraint_NONE rt_unknown = FALSE; // value stored is original value
    when Constraint_UNKNOWN rt_unknown = TRUE; // value stored is UNKNOWN
    when Constraint_UNDEF rt_unknown = TRUE; // value stored is UNKNOWN
    when UnallocatedEncoding();
    when Constraint_NOP EndOfInstruction();
fi

if n == 31 then
    if memop != MemOp_PREFETCH then CheckSPAlignment();
    address = SP[];
else
    address = X[n];

if ! postindex then
    address = address + offset;

case memop of
    when MemOp STORE
        if rt_unknown then
            data = bits(datasize) UNKNOWN;
        else
            data = X[t];
        Mem[address, datasize DIV 8, acctype] = data;
    when MemOp LOAD
        data = Mem[address, datasize DIV 8, acctype];
        if signed then
            X[t] = SignExtend(data, regsize);
        else
            X[t] = ZeroExtend(data, regsize);
    when MemOp_PREFETCH Prefetch(address, t<4:0>);

if wback then
    if wb_unknown then
        address = bits(64) UNKNOWN;
    elsif postindex then
        address = address + offset;
    if n == 31 then
        SP[] = address;
else
  \texttt{X[n] = address;}

Operational information

If \textsc{PSTATE.DIT} is 1, the timing of this instruction is insensitive to the value of the data being loaded or stored.
LDRB (register)

Load Register Byte (register) calculates an address from a base register value and an offset register value, loads a byte from memory, zero-extends it, and writes it to a register. For information about memory accesses, see Load/Store addressing modes.

LDRB (register)

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9  | 8  | 7  | 6  | 5  | 4  | 3  | 2  | 1  | 0  |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0  | 0  | 1  | 1  | 1  | 0  | 0  | 0  | 1  | 1  | 0  | 0  | 0  | 1  | 1  | 0  | 1  | 0  | 0  | 1  | 1  | 0  | 1  | 0  | 0  | 0  | 1  | 1  | 0  | 1  |

Extended register (option != 011)

LDRB <Wt>, [<Xn|SP>, (<Wm>|<Xm>), <extend> {<amount>}}]

Shifted register (option == 011)

LDRB <Wt>, [<Xn|SP>, <Xm>{, LSL <amount>}}]

boolean wback = FALSE;
boolean postindex = FALSE;
integer scale = UInt(size);
if option<1> == '0' then UNDEFINED;             // sub-word index
UnallocatedEncoding(); // sub-word index
ExtendType extend_type = DecodeRegExtend(option);
integer shift = if S == '1' then scale else 0;

Assembler Symbols

<Wt> Is the 32-bit name of the general-purpose register to be transferred, encoded in the "Rt" field.
<Xn|SP> Is the 64-bit name of the general-purpose base register or stack pointer, encoded in the "Rn" field.
<Wm> When option<0> is set to 0, is the 32-bit name of the general-purpose index register, encoded in the "Rm" field.
<Xm> When option<0> is set to 1, is the 64-bit name of the general-purpose index register, encoded in the "Rm" field.
<extend> Is the index extend specifier, encoded in “option”:

<table>
<thead>
<tr>
<th>option</th>
<th>&lt;extend&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>010</td>
<td>UXTW</td>
</tr>
<tr>
<td>110</td>
<td>SXTW</td>
</tr>
<tr>
<td>111</td>
<td>SXTX</td>
</tr>
</tbody>
</table>

<amount> Is the index shift amount, it must be #0, encoded in "S" as 0 if omitted, or as 1 if present.
integer n = UInt(Rn);
integer t = UInt(Rt);
integer m = UInt(Rm);
AccType acctype = AccType_NORMAL;
MemOp memop;
boolean signed;
integer regsize;

if opc<1> == '0' then
    // store or zero-extending load
    memop = if opc<0> == '1' then MemOp_LOAD else MemOp_STORE;
    regsize = if size == '11' then 64 else 32;
    signed = FALSE;
else
    if size == '11' then
        memop = MemOp_PREFETCH;
        if opc<0> == '1' then UNDEFINED;
    else
        // sign-extending load
        memop = if opc<0> == '1' then UnallocatedEncoding();
        else
            // sign-extending load
            memop = MemOp_LOAD;
            if size == '10' && opc<0> == '1' then UnallocatedEncoding;
            if size == '10' && opc<0> == '1' then UNDEFINED;
    else
        regsize = if opc<0> == '1' then 32 else 64;
        signed = TRUE;

integer datasize = 8 << scale;
Operation

LDRB (register)
bits(64) offset = ExtendReg(m, extend_type, shift);
if memop == MemOp PREFETCH then
    if wback then
        address = bits(64) UNKNOWN;
        elsif postindex then
            address = address + offset;
if n == 31 then
    if memop != MemOp_PREFETCH then
        CheckSPAlignment();
    address = SP[7];
else
    address = X[n];
if ! postindex then
    address = address + offset;
case memop of
    when MemOp STORE
        if rt_unknown then
            data = bits(datasize) UNKNOWN;
        else
            data = X[t];
            Mem[address, datasize DIV 8, acctype] = data;
    when MemOp LOAD
        data = Mem[address, datasize DIV 8, acctype];
        if signed then
            X[t] = SignExtend(data, regsize);
        else
            X[t] = ZeroExtend(data, regsize);
    when MemOp_PREFETCH
        Prefetch(address, t<4:0>);
if wback then
    if wb unknown then
        address = bits(64) UNKNOWN;
    elsif postindex then
        address = address + offset;
if n == 31 then
    SP[] = address;
else

X[n] = address;

Operational information

If PSTATE.DIT is 1, the timing of this instruction is insensitive to the value of the data being loaded or stored.
LDRH (immediate)

Load Register Halfword (immediate) loads a halfword from memory, zero-extends it, and writes the result to a register. The address that is used for the load is calculated from a base register and an immediate offset. For information about memory accesses, see Load/Store addressing modes.

It has encodings from 3 classes: Post-index, Pre-index and Unsigned offset

Post-index

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0  | 1  | 1  | 1  | 0  | 0  | 0  | 1  | 0  | imm9 | 0  | 1  | Rn | Rt |

size           opc

LDRH <Wt>, [<Xn|SP>], #<simm>

boolean wback = TRUE;
boolean postindex = TRUE;
integer scale = UInt(size);
bits(64) offset = SignExtend(imm9, 64);

Pre-index

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0  | 1  | 1  | 1  | 0  | 0  | 0  | 1  | 0  | imm9 | 1  | 1  | Rn | Rt |

size           opc

LDRH <Wt>, [<Xn|SP>], #<simm>!

boolean wback = TRUE;
boolean postindex = FALSE;
integer scale = UInt(size);
bits(64) offset = SignExtend(imm9, 64);

Unsigned offset

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0  | 1  | 1  | 1  | 0  | 0  | 1  | 0  | 1  | imm12 |  Rn | Rt |

size           opc

LDRH <Wt>, [<Xn|SP>{, #<pimm}>]

boolean wback = FALSE;
boolean postindex = FALSE;
integer scale = UInt(size);
bits(64) offset = LSL(ZeroExtend(imm12, 64), scale);

For information about the CONSTRAINED UNPREDICTABLE behavior of this instruction, see Architectural Constraints on UNPREDICTABLE behaviors, and particularly LDRH (immediate).

Assembler Symbols

<Wt> Is the 32-bit name of the general-purpose register to be transferred, encoded in the "Rt" field.
Is the 64-bit name of the general-purpose base register or stack pointer, encoded in the "Rn" field.

Is the signed immediate byte offset, in the range -256 to 255, encoded in the "imm9" field.

Is the optional positive immediate byte offset, a multiple of 2 in the range 0 to 8190, defaulting to 0 and encoded in the "imm12" field as <pimm>/2.

**Shared Decode**

```python
integer n = UInt(Rn);
integer t = UInt(Rt);
AccType acctype = AccType_NORMAL;
MemOp memop;
boolean signed;
integer regsize;

if opc<1> == '0' then
    // store or zero-extending load
    memop = if opc<0> == '1' then MemOp_LOAD else MemOp_STORE;
    regsize = if size == '11' then 64 else 32;
    signed = FALSE;
else
    if size == '11' then UNDEFINED;
    else
        // sign-extending load
        memop = if size == '11' then UnallocatedEncoding() else
        // sign-extending load
        memop = if size == '10' && opc<0> == '1' then UnallocatedEncoding();
        if size == '10' && opc<0> == '1' then UNDEFINED;
        regsize = if opc<0> == '1' then 32 else 64;
        signed = TRUE;

integer datasize = 8 << scale;
```
if bits(64) address;
bits(datasize) data;
boolean wb_unknown = FALSE;
boolean rt_unknown = FALSE;
if memop == HaveMTExx() then
    boolean is_load_store = memop IN {MemOp STORE, MemOp LOAD};
    SetNotTagCheckedInstruction(is_load_store && n == 31 && !wback);

bits(64) address;
bis(datasize) data;
boolean wb_unknown = FALSE;
boolean rt_unknown = FALSE;
if memop == MemOp LOAD && wback && n == t && n != 31 then
    c = ConstrainUnpredictable(Unpredictable_WBOVERLAPLD);
    assert c IN {Constraint_WBSUPPRESS, Constraint_UNKNOWN, Constraint_UNDEF, Constraint_NOP};
    case c of
        when Constraint_WBSUPPRESS wback = FALSE; // writeback is suppressed
        when Constraint_UNKNOWN wb_unknown = TRUE; // writeback is UNKNOWN
        when Constraint_UNDEF rt_unknown = TRUE; // value stored is UNKNOWN
        when UnallocatedEncoding();
        EndOfInstruction();
    case memop of
        when MemOp STORE && wback && n == t && n != 31 then
            c = ConstrainUnpredictable(Unpredictable_WBOVERLAPST);
            assert c IN {Constraint_NONE, Constraint_UNKNOWN, Constraint_UNDEF, Constraint_NOP};
            case c of
                when Constraint_NONE rt_unknown = TRUE; // value stored is original value
                when Constraint_UNKNOWN rt_unknown = TRUE; // value stored is UNKNOWN
                when Constraint_UNDEF UnallocatedEncoding();
                when Constraint_NOP EndOfInstruction();
            assert memop != MemOp_PREFETCH then CheckSPAlignment();
            address = SP[];
        else
            address = X[n];
        if ! postindex then
            address = address + offset;
        endcase memop of
            when MemOp STORE
                if rt_unknown then
                    data = bits(datasize) UNKNOWN;
                else
                    data = X[t];
                    Mem[address, datasize DIV 8, acctype] = data;
                endwhen
            when MemOp LOAD
                data = Mem[address, datasize DIV 8, acctype];
                if signed then
                    X[t] = SignExtend(data, regsize);
                else
                    X[t] = ZeroExtend(data, regsize);
                endwhen
            when MemOp_PREFETCHPrefetch(address, t<4:0>);
        if wback then
            if wb_unknown then
                address = bits(64) UNKNOWN;
            else if postindex then
                address = address + offset;
            if n == 31 then
                SP[] = address;
            endif
else
    X[n] = address;

Operational information

If PSTATE.DIT is 1, the timing of this instruction is insensitive to the value of the data being loaded or stored.


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LDRH (register)

Load Register Halfword (register) calculates an address from a base register value and an offset register value, loads a halfword from memory, zero-extends it, and writes it to a register. For information about memory accesses, see Load/Store addressing modes.

32-bit

LDRH <Wt>, [<Xn|SP>, (<Wm>|<Xm>){, <extend> {<amount>}}]

boolean wback = FALSE;
boolean postindex = FALSE;
integer scale = UInt(size);
if option<1> == '0' then UNDEFINED; // sub-word index
UnallocatedEncoding(); // sub-word index
ExtendType extend_type = DecodeRegExtend(option);
integer shift = if S == '1' then scale else 0;

For information about the CONSTRAINED UNPREDICTABLE behavior of this instruction, see Architectural Constraints on UNPREDICTABLE behaviors.

Assembler Symbols

<Wt> Is the 32-bit name of the general-purpose register to be transferred, encoded in the "Rt" field.
<Xn|SP> Is the 64-bit name of the general-purpose base register or stack pointer, encoded in the "Rn" field.
<Wm> When option<0> is set to 0, is the 32-bit name of the general-purpose index register, encoded in the "Rm" field.
<Xm> When option<0> is set to 1, is the 64-bit name of the general-purpose index register, encoded in the "Rm" field.
<extend> Is the index extend/shift specifier, defaulting to LSL, and which must be omitted for the LSL option when <amount> is omitted. encoded in “option”:

<table>
<thead>
<tr>
<th>option</th>
<th>&lt;extend&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>010</td>
<td>UXTW</td>
</tr>
<tr>
<td>011</td>
<td>LSL</td>
</tr>
<tr>
<td>110</td>
<td>SXTW</td>
</tr>
<tr>
<td>111</td>
<td>SXTX</td>
</tr>
</tbody>
</table>

<amount> Is the index shift amount, optional only when <extend> is not LSL. Where it is permitted to be optional, it defaults to #0. It is encoded in “S”:

<table>
<thead>
<tr>
<th>S</th>
<th>&lt;amount&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>#0</td>
</tr>
<tr>
<td>1</td>
<td>#1</td>
</tr>
</tbody>
</table>
integer n = UInt(Rn);
integer t = UInt(Rt);
integer m = UInt(Rm);
AccType acctype = AccType_NORMAL;
MemOp memop;
boolean signed;
integer regsize;
if opc<1> == '0' then
    // store or zero-extending load
    memop = if opc<0> == '1' then MemOp_LOAD else MemOp_STORE;
    regsize = if size == '11' then 64 else 32;
    signed = FALSE;
else
    if size == '11' then
        memop = MemOp_PREFETCH;
        if opc<0> == '1' then UNDEFINED;
    else
        // sign-extending load
        memop = if opc<0> == '1' then UnallocatedEncoding();
        else
            // sign-extending load
            memop = MemOp_LOAD;
            if size == '10' && opc<0> == '1' then UnallocatedEncoding();
            if size == '10' && opc<0> == '1' then UNDEFINED;
            regsize = if opc<0> == '1' then 32 else 64;
            signed = TRUE;

integer datasize = 8 << scale;
Operation

LDRH (register)
bits(64) offset = ExtendReg(m, extend_type, shift);
if memop == MemOp_STORE && wback && n == 31 then
  c = ConstrainUnpredictable(Unpredictable_WBOVERLAPST);
  assert c IN {Constraint_NONE, Constraint_UNKNOWN, Constraint_UNDEF, Constraint_NOP};
  case c of
    when Constraint_NONE rt_unknown = FALSE;  // value stored is original value
    when Constraint_UNKNOWN rt_unknown = TRUE;  // value stored is UNKNOWN
    when Constraint_UNDEF UNDEFINED;
    when Constraint_NOP EndOfInstruction();
  end;
if n == 31 then
  if memop != MemOp_PREFETCH then CheckSPAlignment();
  address = SP[];
else
  address = X[n];
if ! postindex then
  address = address + offset;
end;
case memop of
  when MemOp_STORE
    if rt_unknown then
      data = bits(datasize) UNKNOWN;
    else
      data = X[t];
      Mem[address, datasize DIV 8, acctype] = data;
  when MemOp_LOAD
    data = Mem[address, datasize DIV 8, acctype];
    if signed then
      X[t] = SignExtend(data, regsize);
    else
      X[t] = ZeroExtend(data, regsize);
    when MemOp_PREFETCHPrefetch(address, t<4:0>);
if wback then
  if wb unknown then
    address = bits(64) UNKNOWN;
  elsif postindex then
    address = address + offset;
  if n == 31 then
    SP[] = address;
else
    X[n] = address;

**Operational information**

If PSTATE.DIT is 1, the timing of this instruction is insensitive to the value of the data being loaded or stored.
LDRSB (immediate)

Load Register Signed Byte (immediate) loads a byte from memory, sign-extends it to either 32 bits or 64 bits, and writes the result to a register. The address that is used for the load is calculated from a base register and an immediate offset. For information about memory accesses, see Load/Store addressing modes.

It has encodings from 3 classes: Post-index, Pre-index and Unsigned offset.

Post-index

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9  | 8  | 7  | 6  | 5  | 4  | 3  | 2  | 1  | 0 |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|    |
| 0  | 0  | 1  | 1  | 1  | 0  | 0  | 0  | 1  | x  | 0  |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |

size opc

32-bit (opc == 11)

LDRSB <Wt>, [<Xn|SP>], #<simm>

64-bit (opc == 10)

LDRSB <Xt>, [<Xn|SP>], #<simm>

```java
boolean wback = TRUE;
boolean postindex = TRUE;
integer scale = UInt(size);
bits(64) offset = SignExtend(imm9, 64);
```

Pre-index

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9  | 8  | 7  | 6  | 5  | 4  | 3  | 2  | 1  | 0 |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|    |
| 0  | 0  | 1  | 1  | 1  | 0  | 0  | 0  | 1  | x  | 0  |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |

size opc

32-bit (opc == 11)

LDRSB <Wt>, [<Xn|SP>], #<simm>!

64-bit (opc == 10)

LDRSB <Xt>, [<Xn|SP>], #<simm>!

```java
boolean wback = TRUE;
boolean postindex = FALSE;
integer scale = UInt(size);
bits(64) offset = SignExtend(imm9, 64);
```

Unsigned offset

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9  | 8  | 7  | 6  | 5  | 4  | 3  | 2  | 1  | 0 |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|    |
| 0  | 0  | 1  | 1  | 1  | 0  | 0  | 1  | 0  | 1  | x  |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |

size opc

LDRSB (immediate)
32-bit (opc == 11)

LDRSB <Wt>, [<Xn|SP>{, #<pimm>}

64-bit (opc == 10)

LDRSB <Xt>, [<Xn|SP>{, #<pimm>}

boolean wback = FALSE;
boolean postindex = FALSE;
integer scale = UInt(size);
bits(64) offset = LSL(ZeroExtend(imm12, 64), scale);

For information about the CONstrained UNPREDICTABLE behavior of this instruction, see Architectural Constraints on UNPREDICTABLE behaviors, and particularly LDRSB (immediate).

Assembler Symbols

<Wt> Is the 32-bit name of the general-purpose register to be transferred, encoded in the "Rt" field.
<Xt> Is the 64-bit name of the general-purpose register to be transferred, encoded in the "Rt" field.
<Xn|SP> Is the 64-bit name of the general-purpose base register or stack pointer, encoded in the "Rn" field.
<simm> Is the signed immediate byte offset, in the range -256 to 255, encoded in the "imm9" field.
<pimm> Is the optional positive immediate byte offset, in the range 0 to 4095, defaulting to 0 and encoded in the "imm12" field.

Shared Decode

integer n = UInt(Rn);
integer t = UInt(Rt);
AccType accType = AccType_NORMAL;
MemOp memop;
boolean signed;
integer regsize;
if opc<1> == '0' then
  // store or zero-extending load
  memop = if opc<0> == '1' then MemOp_LOAD else MemOp_STORE;
  regsize = if size == '11' then 64 else 32;
  signed = FALSE;
else
  if size == '11' then UNDEFINED;
  regsize = if opc<0> == '1' then 32 else 64;
  signed = TRUE;
integer datasize = 8 << scale;
if memop == MemOp_STORE && wback && n == t && n != 31 then
    c = ConstrainUnpredictable(Unpredictable_WBOVERLAPLD);
    assert c IN {Constraint_WBSUPPRESS, Constraint_UNKNOWN, Constraint_UNDEF, Constraint_NOP};
    case c of
        when Constraint_WBSUPPRESS wback = FALSE;       // writeback is suppressed
        when Constraint_UNKNOWN rt_unknown = TRUE;       // value stored is UNKNOWN
        when Constraint_UNDEF rt_unknown = TRUE;        // value is UNDEFINED;
        when UnallocatedEncoding()
        when Constraint_NOP EndOfInstruction();
    end case;

if memop == MemOp_PREFETCH then
    CheckSPAlignment();
    address = SP[];
else
    address = X[n];
if ! postindex then
    address = address + offset;
    case memop of
        when MemOp_STORE
            if rt_unknown then
                data = bits(datasize) UNKNOWN;
            else
                data = X[t];
            Mem[address, datasize DIV 8, acctype] = data;
        when MemOp_LOAD
            data = Mem[address, datasize DIV 8, acctype];
            if signed then
                X[t] = SignExtend(data, regsize);
            else
                X[t] = ZeroExtend(data, regsize);
            end if;
        when MemOp_PREFETCH
            Prefetch(address, t<4:0>);
    end case;
    if wback then
        if wb_unknown then
            address = bits(64) UNKNOWN;
        elsif postindex then
            address = address + offset;
        if n == 31 then
            SP[] = address;
        end if;
else
    \( X[n] = \text{address}; \)

**Operational information**

If `PSTATE.DIT` is 1, the timing of this instruction is insensitive to the value of the data being loaded or stored.
LDRSB (register)

Load Register Signed Byte (register) calculates an address from a base register value and an offset register value, loads a byte from memory, sign-extends it, and writes it to a register. For information about memory accesses, see Load/Store addressing modes.

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9  | 8  | 7  | 6  | 5  | 4  | 3  | 2  | 1  | 0 |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0  | 0  | 1  | 1  | 0  | 0  | 1  | x  | 1  | Rm | option | S  | 1  | 0  | Rn | | | | | | | | | | | | | | | | | | | | | | | |

32-bit with extended register offset (opc == 11 && option != 011)

LDRSB <Wt>, [<Xn|SP>, (Wm|Xm)], {extend} {<amount>}

32-bit with shifted register offset (opc == 11 && option == 011)

LDRSB <Wt>, [<Xn|SP>, Xm], {LSL <amount>}

64-bit with extended register offset (opc == 10 && option != 011)

LDRSB <Xt>, [<Xn|SP>, (Wm|Xm)], {extend} {<amount>}

64-bit with shifted register offset (opc == 10 && option == 011)

LDRSB <Xt>, [<Xn|SP>, Xm], {LSL <amount>}

boolean wback = FALSE;
boolean postindex = FALSE;
integer scale = UInt(size);
if option<1> == '0' then UNDEFINED; // sub-word index
ExtendType extend_type = DecodeRegExtend(option);
integer shift = if S == '1' then scale else 0;

Assembler Symbols

<Wt> Is the 32-bit name of the general-purpose register to be transferred, encoded in the "Rt" field.
<Xt> Is the 64-bit name of the general-purpose register to be transferred, encoded in the "Rt" field.
<Xn|SP> Is the 64-bit name of the general-purpose base register or stack pointer, encoded in the "Rn" field.
<Wm> When option<0> is set to 0, is the 32-bit name of the general-purpose index register, encoded in the "Rm" field.
<Xm> When option<0> is set to 1, is the 64-bit name of the general-purpose index register, encoded in the "Rm" field.
<extend> Is the index extend specifier, encoded in "option":

<table>
<thead>
<tr>
<th>option</th>
<th>&lt;extend&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>010</td>
<td>UXTW</td>
</tr>
<tr>
<td>110</td>
<td>SXTW</td>
</tr>
<tr>
<td>111</td>
<td>SXTX</td>
</tr>
</tbody>
</table>

<amount> Is the index shift amount, it must be #0, encoded in "S" as 0 if omitted, or as 1 if present.
integer n = UInt(Rn);
integer t = UInt(Rt);
integer m = UInt(Rm);
AccType accType = AccType_NORMAL;
MemOp memop;
boolean signed;
integer regsize;

if opc<1> == '0' then
  // store or zero-extending load
  memop = if opc<0> == '1' then MemOp_LOAD else MemOp_STORE;
  regsize = if size == '11' then 64 else 32;
  signed = FALSE;
else
  if size == '11' then
    memop = MemOp_PREFETCH;
    if opc<0> == '1' then UNDEFINED;
  else
    // sign-extending load
    memop = if opc<0> == '1' then UnallocatedEncoding();
    else
      // sign-extending load
      memop = MemOp_LOAD;
      if size == '10' && opc<0> == '1' then UnallocatedEncoding;
      if size == '10' && opc<0> == '1' then UNDEFINED;
      regsize = if opc<0> == '1' then 32 else 64;
      signed = TRUE;

integer datasize = 8 << scale;
Operation

LDRSB (register)
bits(64) offset = ExtendReg(m, extend_type, shift);
if (bits(64) address; bits(datasize) data;
boolean wb_unknown = FALSE;
boolean rt_unknown = FALSE;
if memop == HaveMTEExt() then
    SetNotTagCheckedInstruction(is_load_store && n == 31 && !wback);

bits(64) address;
bits(datasize) data;
boolean wb_unknown = FALSE;
boolean rt_unknown = FALSE;
if memop == MemOp_LOAD && wback && n == t && n != 31 then
    c = ConstrainUnpredictable(Unpredictable_WBOVERLAPST);
assert c IN {Constraint_NONE, Constraint_UNKNOWN, Constraint_UNDEF, Constraint_NOP};
case c of
    when Constraint_NONE rt_unknown = FALSE;  // value stored is original value
    when Constraint_UNKNOWN rt_unknown = TRUE;  // value stored is original value
    when Constraint_UNDEF UNDEFINED;
    when UnallocatedEncoding();
    when Constraint_NOP EndOfInstruction();
if n == 31 then
    if memop != MemOp_PREFETCH then CheckSPAlignment();
    address = SP[];
else
    address = X[n];
if ! postindex then
    address = address + offset;

case memop of
    when MemOp_STORE
        if rt_unknown then
            data = bits(datasize) UNKNOWN;
        else
            data = X[t];
            Mem[address, datasize DIV 8, acctype] = data;
    when MemOp_LOAD
        data = Mem[address, datasize DIV 8, acctype];
        if signed then
            X[t] = SignExtend(data, regsize);
        else
            X[t] = ZeroExtend(data, regsize);
    when MemOp_PREFETCH
        Prefetch(address, t<4:0>);
if wback then
    if wb_unknown then
        address = bits(64) UNKNOWN;
    elsif postindex then
        address = address + offset;
    if n == 31 then
        SP[] = address;
else

\( X[n] = \text{address}; \)

**Operational information**

If PSTATE.DIT is 1, the timing of this instruction is insensitive to the value of the data being loaded or stored.
LDRSH (immediate)

Load Register Signed Halfword (immediate) loads a halfword from memory, sign-extends it to 32 bits or 64 bits, and writes the result to a register. The address that is used for the load is calculated from a base register and an immediate offset. For information about memory accesses, see Load/Store addressing modes.

It has encodings from 3 classes: Post-index, Pre-index and Unsigned offset

Post-index

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9  | 8  | 7  | 6  | 5  | 4  | 3  | 2  | 1  | 0  |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0  | 1  | 1  | 1  | 0  | 0  | 0  | 1  | x  | 0  | imm9| 0  | 1  | Rn |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |

size          opc

32-bit (opc == 11)

LDRSH <Wt>, [<Xn|SP>], #<simm>

64-bit (opc == 10)

LDRSH <Xt>, [<Xn|SP>], #<simm>

```
boolean wback = TRUE;
boolean postindex = TRUE;
integer scale = UInt(size);
bias(64) offset = SignExtend(imm9, 64);
```

Pre-index

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9  | 8  | 7  | 6  | 5  | 4  | 3  | 2  | 1  | 0  |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0  | 1  | 1  | 1  | 0  | 0  | 0  | 1  | x  | 0  | imm9| 1  | 1  | Rn |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |

size          opc

32-bit (opc == 11)

LDRSH <Wt>, [<Xn|SP>], #<simm>!

64-bit (opc == 10)

LDRSH <Xt>, [<Xn|SP>], #<simm>!

```
boolean wback = TRUE;
boolean postindex = FALSE;
integer scale = UInt(size);
bias(64) offset = SignExtend(imm9, 64);
```

Unsigned offset

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9  | 8  | 7  | 6  | 5  | 4  | 3  | 2  | 1  | 0  |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0  | 1  | 1  | 1  | 0  | 0  | 1  | 1  | x  | 0  | imm12|   | Rn |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |

size          opc

boolean wback = TRUE;
boolean postindex = FALSE;
integer scale = UInt(size);
bias(64) offset = SignExtend(imm9, 64);
32-bit (opc == 11)

LDRSH <Wt>, [<Xn|SP>{, #<pimm}]

64-bit (opc == 10)

LDRSH <Xt>, [<Xn|SP>{, #<pimm}]

boolean wback = FALSE;
boolean postindex = FALSE;
integer scale = UInt(size);
bits(64) offset = LSL(ZeroExtend(imm12, 64), scale);

For information about the CONSTRAINED UNPREDICTABLE behavior of this instruction, see Architectural Constraints on UNPREDICTABLE behaviors, and particularly LDRSH (immediate).

Assembler Symbols

<Wt> Is the 32-bit name of the general-purpose register to be transferred, encoded in the "Rt" field.
<Xt> Is the 64-bit name of the general-purpose register to be transferred, encoded in the "Rt" field.
<Xn|SP> Is the 64-bit name of the general-purpose base register or stack pointer, encoded in the "Rn" field.
<simm> Is the signed immediate byte offset, in the range -256 to 255, encoded in the "imm9" field.
<pimm> Is the optional positive immediate byte offset, a multiple of 2 in the range 0 to 8190, defaulting to 0 and encoded in the "imm12" field as <pimm>/2.

Shared Decode

integer n = UInt(Rn);
integer t = UInt(Rt);
AccType accType = AccType_NORMAL;
MemOp memop;
boolean signed;
integer regsize;
if opc<1> == '0' then
  // store or zero-extending load
  memop = if opc<0> == '1' then MemOp_LOAD else MemOp_STORE;
  regsize = if size == '11' then 64 else 32;
  signed = FALSE;
else
  if size == '11' then
    UNDEFINED;
  else
    // sign-extending load
    memop = if size == '11' then UnallocatedEncoding() else
    if size == '10' && opc<0> == '1' then UnallocatedEncoding();
    regsize = if opc<0> == '1' then 32 else 64;
    signed = TRUE;
else
  integer datasize = 8 << scale;
if bits(64) address;
bits(datasize) data;
boolean wb_unknown = FALSE;
boolean rt_unknown = FALSE;

if memop == HaveMTEExt() then
    boolean is_load_store = memop IN {MemOp_STORE, MemOp_LOAD};
    SetNotTagCheckedInstruction(is_load_store && n == 31 & wback);

bits(64) address;
bits(datasize) data;
boolean wb_unknown = FALSE;
boolean rt_unknown = FALSE;

if memop == MemOp_LOAD && wback && n == t && n != 31 then
    c = ConstrainUnpredictable(Unpredictable_WBOVERLAPLD);
    assert c IN {Constraint_WBSUPPRESS, Constraint_UNKNOWN, Constraint_UNDEF, Constraint_NOP};
    case c of
        when Constraint_WBSUPPRESS wbback = FALSE;       // writeback is suppressed
        when Constraint_UNKNOWN wb_unknown = TRUE;        // writeback is UNKNOWN
        when Constraint_UNDEF rt_unknown = FALSE;        // value stored is original value
        when UnallocatedEncoding() rt_unknown = TRUE;    // value stored is UNKNOWN
        when Constraint_NOP EndOfInstruction();

if memop == MemOp_STORE && wback && n == t && n != 31 then
    c = ConstrainUnpredictable(Unpredictable_WBOVERLAPST);
    assert c IN {Constraint_NONE, Constraint_UNKNOWN, Constraint_UNDEF, Constraint_NOP};
    case c of
        when Constraint_NONE rt_unknown = FALSE;        // value stored is original value
        when Constraint_UNKNOWN rt_unknown = TRUE;       // value stored is UNKNOWN
        when Constraint_UNDEF UNDEFINED;
        when UnallocatedEncoding() UNDEFINED;
        when Constraint_NOP EndOfInstruction();

if n == 31 then
    if memop != MemOp_PREFETCH then CheckSPAlignment();
    address = SP[];
else
    address = X[n];
if ! postindex then
    address = address + offset;

case memop of
    when MemOp_STORE
        if rt_unknown then
            data = bits(datasize) UNKNOWN;
        else
            data = X[t];
            Mem[address, datasize DIV 8, acctype] = data;
    when MemOp_LOAD
        data = Mem[address, datasize DIV 8, acctype];
        if signed then
            X[t] = SignExtend(data, regsize);
        else
            X[t] = ZeroExtend(data, regsize);
    when MemOp_PREFETCH Prefetch(address, t<4:0>);
if wback then
    if wb_unknown then
        address = bits(64) UNKNOWN;
    elsif postindex then
        address = address + offset;
    if n == 31 then
        SP[] = address;
else
    $X[n] = \text{address}$;

**Operational information**

If PSTATE.DIT is 1, the timing of this instruction is insensitive to the value of the data being loaded or stored.
LDRSH (register)

Load Register Signed Halfword (register) calculates an address from a base register value and an offset register value, loads a halfword from memory, sign-extends it, and writes it to a register. For information about memory accesses see [Load/Store addressing modes](#).

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9  | 8  | 7  | 6  | 5  | 4  | 3  | 2  | 1  | 0  |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0  | 1  | 1  | 1  | 1  | 0  | 0  | 0  | 1  | x  | 1  | Rm | option | S  | 1  | 0  | Rn |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| size | opc |

32-bit (opc == 11)

LDRSH <Wt>, [<Xn|SP>, (<Wm>|<Xm>){, <extend> [<amount>]}]

64-bit (opc == 10)

LDRSH <Xt>, [<Xn|SP>, (<Wm>|<Xm>){, <extend> [<amount>]}]

```java
boolean wback = FALSE;
boolean postindex = FALSE;
integer scale = UInt(size);
if option<1> == '0' then UNDEFINED; // sub-word index
if option<1> == '0' then UnallocatedEncoding(); // sub-word index
ExtendType extend_type = DecodeRegExtend(option);
integer shift = if S == '1' then scale else 0;
```

Assembler Symbols

- `<Wt>`: Is the 32-bit name of the general-purpose register to be transferred, encoded in the "Rt" field.
- `<Xt>`: Is the 64-bit name of the general-purpose register to be transferred, encoded in the "Rt" field.
- `<Xn|SP>`: Is the 64-bit name of the general-purpose base register or stack pointer, encoded in the "Rn" field.
- `<Wm>`: When option<0> is set to 0, is the 32-bit name of the general-purpose index register, encoded in the "Rm" field.
- `<Xm>`: When option<0> is set to 1, is the 64-bit name of the general-purpose index register, encoded in the "Rm" field.
- `<extend>`: Is the index extend/shift specifier, defaulting to LSL, and which must be omitted for the LSL option when `<amount>` is omitted. encoded in “option”:

<table>
<thead>
<tr>
<th>option</th>
<th>&lt;extend&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>010</td>
<td>UXTW</td>
</tr>
<tr>
<td>011</td>
<td>LSL</td>
</tr>
<tr>
<td>110</td>
<td>SXTW</td>
</tr>
<tr>
<td>111</td>
<td>SXTX</td>
</tr>
</tbody>
</table>

- `<amount>`: Is the index shift amount, optional only when `<extend>` is not LSL. Where it is permitted to be optional, it defaults to #0. It is encoded in “S”:

<table>
<thead>
<tr>
<th>S</th>
<th>&lt;amount&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>#0</td>
</tr>
<tr>
<td>1</td>
<td>#1</td>
</tr>
</tbody>
</table>
integer n = UInt(Rn);
integer t = UInt(Rt);
integer m = UInt(Rm);
AccType acctype = AccType_NORMAL;
MemOp memop;
boolean signed;
integer regsize;

if opc<1> == '0' then
  // store or zero-extending load
  memop = if opc<0> == '1' then MemOp_LOAD else MemOp_STORE;
  regsize = if size == '11' then 64 else 32;
  signed = FALSE;
else
  if size == '11' then
    memop = MemOp_PREFETCH;
  if opc<0> == '1' then UNDEFINED;
else
  // sign-extending load
  memop = if opc<0> == '1' then UnallocatedEncoding();
  else
    regsize = if opc<0> == '1' then 32 else 64;
    signed = TRUE;

integer datasize = 8 << scale;
bits(64) offset = ExtendReg(m, extend_type, shift);
if (bits(64) address)
  bits(datasize) data;
boolean wb_unknown = FALSE;
boolean rt_unknown = FALSE;
if memop == HaveMTEExt() then
  boolean is_load_store = memop IN {MemOp STORE, MemOp LOAD};
  SetNotTagCheckedInstruction(is_load_store && n == 31 && !wback);
bits(64) address;
bits(datasize) data;
boolean wb_unknown = FALSE;
boolean rt_unknown = FALSE;
if memop == MemOp LOAD && wback && n == t && n != 31 then
  c = ConstrainUnpredictable(Unpredictable_WBOVERLAPLD);
  assert c IN {Constraint_WBSUPPRESS, Constraint_UNKNOWN, Constraint_UNDEF, Constraint_NOP};
  case c of
    when Constraint_WBSUPPRESS
      wbback = FALSE; // writeback is suppressed
    when Constraint_UNKNOWN
      wb_unknown = TRUE; // writeback is UNKNOWN
    when Constraint_UNDEF
      UNDEFINED;
    when UnallocatedEncoding();
    when Constraint_NOP
      EndOfInstruction();
  end;
if memop == MemOp STORE && wback && n == t && n != 31 then
  c = ConstrainUnpredictable(Unpredictable_WBOVERLAPST);
  assert c IN {Constraint_NONE, Constraint_UNKNOWN, Constraint_UNDEF, Constraint_NOP};
  case c of
    when Constraint_NONE
      rt_unknown = FALSE; // value stored is original value
    when Constraint_UNKNOWN
      rt_unknown = TRUE; // value stored is UNKNOWN
    when Constraint_UNDEF
      UNDEFINED;
    when Constraint_NOP
      EndOfInstruction();
  end;
if n == 31 then
  if memop != MemOp_PREFETCH then CheckSPAlignment();
  address = SP[];
else
  address = X[n];
if ! postindex then
  address = address + offset;
case memop of
  when MemOp_STORE
    if rt_unknown then
      data = bits(datasize) UNKNOWN;
    else
      data = X[t];
      Mem[address, datasize DIV 8, acctype] = data;
    when MemOp_LOAD
      data = Mem[address, datasize DIV 8, acctype];
    if signed then
      X[t] = SignExtend(data, regsize);
    else
      X[t] = ZeroExtend(data, regsize);
    when MemOp_PREFETCH
      Prefetch(address, t<4:0>);
if wbback then
  if wb_unknown then
    address = bits(64) UNKNOWN;
  elsif postindex then
    address = address + offset;
  if n == 31 then
    SP[] = address;
```c
else
    X[n] = address;
```

**Operational information**

If PSTATE.DIT is 1, the timing of this instruction is insensitive to the value of the data being loaded or stored.

---

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LDRSW (immediate)

Load Register Signed Word (immediate) loads a word from memory, sign-extends it to 64 bits, and writes the result to a register. The address that is used for the load is calculated from a base register and an immediate offset. For information about memory accesses, see Load/Store addressing modes.

It has encodings from 3 classes: Post-index, Pre-index and Unsigned offset.

Post-index

<table>
<thead>
<tr>
<th>31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 0 1 1 1 0 0 0 1 0 0</td>
</tr>
</tbody>
</table>

size         opc

Post-index

LDRSW <Xt>, [<Xn|SP>], #<simm>

```java
boolean wback = TRUE;
boolean postindex = TRUE;
integer scale = UInt(size);
bounds(64) offset = SignExtend(imm9, 64);
```

Pre-index

<table>
<thead>
<tr>
<th>31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 0 1 1 1 0 0 0 1 0 0</td>
</tr>
</tbody>
</table>

size         opc

Pre-index

LDRSW <Xt>, [<Xn|SP>], #<simm>

```java
boolean wback = TRUE;
boolean postindex = FALSE;
integer scale = UInt(size);
bounds(64) offset = SignExtend(imm9, 64);
```

Unsigned offset

<table>
<thead>
<tr>
<th>31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 0 1 1 1 0 0 1 1 0</td>
</tr>
</tbody>
</table>

size         opc

Unsigned offset

LDRSW <Xt>, [<Xn|SP>{, #<pimm>}

```java
boolean wback = FALSE;
boolean postindex = FALSE;
integer scale = UInt(size);
bounds(64) offset = LSL(ZeroExtend(imm12, 64), scale);
```

For information about the CONSTRAINED UNPREDICTABLE behavior of this instruction, see Architectural Constraints on UNPREDICTABLE behaviors, and particularly LDRSW (immediate).

Assembler Symbols

<Xt> Is the 64-bit name of the general-purpose register to be transferred, encoded in the "Rt" field.
Is the 64-bit name of the general-purpose base register or stack pointer, encoded in the "Rn" field.

Is the signed immediate byte offset, in the range -256 to 255, encoded in the "imm9" field.

Is the optional positive immediate byte offset, a multiple of 4 in the range 0 to 16380, defaulting to 0 and encoded in the "imm12" field as \(<\text{pimm}\>/4\).

**Shared Decode**

```plaintext
integer n = UInt(Rn);
integer t = UInt(Rt);
AccType acctype = AccType_NORMAL;
MemOp memop;
boolean signed;
integer regsize;

if opc<1> == '0' then
  // store or zero-extending load
  memop = if opc<0> == '1' then MemOp_LOAD else MemOp_STORE;
  regsize = if size == '11' then 64 else 32;
  signed = FALSE;
else
  if size == '11' then
    UNDEFINED;
  else
    // sign-extending load
    memop = if size == '11' then UnallocatedEncoding();
    else
    // sign-extending load
    memop = MemOp_LOAD;
    if size == '10' & opc<0> == '1' then UnallocatedEncoding();
    if size == '10' && opc<0> == '1' then UNDEFINED;
  
  regsize = if opc<0> == '1' then 32 else 64;
  signed = TRUE;

integer datasize = 8 << scale;
```

LDRSW (immediate)
if memop == MemOp_STORE & wback & & n == t & & n != 31 then
    c = ConstrualUnpredictable(Unpredictable_WBOVERLAPST);
    assert c IN {Constraint_NONE, Constraint_UNKNOWN, Constraint_UNDEF, Constraint_NOP};
    case c of
        when Constraint_NONE rt_unknown = FALSE; // value stored is original value
        when Constraint_UNKNOWN rt_unknown = TRUE; // value stored is UNKNOWN
        when Constraint_UNDEF UnallocatedEncoding UNDEFINED;
        when Constraint_NOP EndOfInstruction();
if n == 31 then
    if memop != MemOp_PREFETCH then CheckSPAlignment();
    address = SP[];
else
    address = X[n];
if ! postindex then
    address = address + offset;
case memop of
    when MemOp_STORE
        if rt_unknown then
            data = bits(datasize) UNKNOWN;
        else
            data = X[t];
            Mem[address, datasize DIV 8, acctype] = data;
        when MemOp_LOAD
            data = Mem[address, datasize DIV 8, acctype];
            if signed then
                X[t] = SignExtend(data, regsize);
            else
                X[t] = ZeroExtend(data, regsize);
        when MemOp_PREFETCHPrefetch(address, t<4:0>);
if wback then
    if wb_unknown then
        address = bits(64) UNKNOWN;
    elsif postindex then
        address = address + offset;
    if n == 31 then
        SP[] = address;
else
  x[n] = address;

Operational information

If PSTATE.DIT is 1, the timing of this instruction is insensitive to the value of the data being loaded or stored.
LDRSW (register)

Load Register Signed Word (register) calculates an address from a base register value and an offset register value, loads a word from memory, sign-extends it to form a 64-bit value, and writes it to a register. The offset register value can be shifted left by 0 or 2 bits. For information about memory accesses, see Load/Store addressing modes.

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 1  | 0  | 1  | 1  | 0  | 0  | 0  | 1  | 0  | 1  | Rm | option | S | 1 | 0 | Rn | Rt |

64-bit

LDRSW <Xt>, [<Xn|SP>, (Rm|x<Xm>{, <extend> [<amount>}])]

boolean wback = FALSE;
boolean postindex = FALSE;
integer scale = UInt(size);
if option<1> == '0' then UNDEFINED; // sub-word index
ExtendType extend_type = DecodeRegExtend(option);
integer shift = if S == '1' then scale else 0;

Assembler Symbols

<Xt> Is the 64-bit name of the general-purpose register to be transferred, encoded in the "Rt" field.
<Xn|SP> Is the 64-bit name of the general-purpose base register or stack pointer, encoded in the "Rn" field.
<Wm> When option<0> is set to 0, is the 32-bit name of the general-purpose index register, encoded in the "Rm" field.
<Xm> When option<0> is set to 1, is the 64-bit name of the general-purpose index register, encoded in the "Rm" field.
<extend> Is the index extend/shift specifier, defaulting to LSL, and which must be omitted for the LSL option when <amount> is omitted. encoded in "option":

<table>
<thead>
<tr>
<th>option</th>
<th>&lt;extend&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>010</td>
<td>UXTW</td>
</tr>
<tr>
<td>011</td>
<td>LSL</td>
</tr>
<tr>
<td>110</td>
<td>SXTW</td>
</tr>
<tr>
<td>111</td>
<td>SXTX</td>
</tr>
</tbody>
</table>

<amount> Is the index shift amount, optional only when <extend> is not LSL. Where it is permitted to be optional, it defaults to #0. It is encoded in "S":

<table>
<thead>
<tr>
<th>S</th>
<th>&lt;amount&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>#0</td>
</tr>
<tr>
<td>1</td>
<td>#2</td>
</tr>
</tbody>
</table>
integer n = UInt(Rn);
integer t = UInt(Rt);
integer m = UInt(Rm);
AccType acctype = AccType_NORMAL;
MemOp memop;
boolean signed;
integer regsize;
if opc<1> == '0' then // store or zero-extending load
    memop = if opc<0> == '1' then MemOp_LOAD else MemOp_STORE;
    regsize = if size == '11' then 64 else 32;
    signed = FALSE;
else
    if size == '11' then
        memop = MemOp_PREFETCH;
        if opc<0> == '1' then UNDEFINED;
    else
        // sign-extending load
        memop = MemOp_LOAD;
        if opc<0> == '1' then UnallocatedEncoding();
    else
        // sign-extending load
        memop = MemOp_LOAD;
        if size == '10' && opc<0> == '1' then UnallocatedEncoding();
        if size == '10' && opc<0> == '1' then UNDEFINED;
    end
    regsize = if opc<0> == '1' then 32 else 64;
    signed = TRUE;

integer datasize = 8 << scale;
bits(64) offset = ExtendReg(m, extend_type, shift);
if bits(64) address;
bits(datasize) data;
boolean wb_unknown = FALSE;
boolean rt_unknown = FALSE;
if memop == HaveMTEExt() then
  boolean is_load_store = memop IN {MemOp STORE, MemOp LOAD};
  SetNotTagCheckedInstruction(is_load_store && n == 31 && !wback);
bits(64) address;
bits(datasize) data;
boolean wb_unknown = FALSE;
boolean rt_unknown = FALSE;
if memop == MemOp STORE && wback && n == t && n != 31 then
  c = ConstrainUnpredictable(Unpredictable_WBOVERLAPST);
  assert c IN {Constraint_NONE, Constraint_UNKNOWN, Constraint_UNDEF, Constraint_NOP};
case c of
  when Constraint_NONE rt_unknown = FALSE;  // value stored is original value
  when Constraint_UNKNOWN rt_unknown = TRUE;  // value stored is UNKNOWN
  when Constraint_UNDEF rt_unknown = UNDEFINED;
  when Constraint_NOP EndOfInstruction();

if n == 31 then
  if memop != MemOp_PREFETCH then CheckSPAlignment();
  address = SP[];
else
  address = X[n];
if ! postindex then
  address = address + offset;

case memop of
  when MemOp_STORE
    if rt_unknown then
      data = bits(datasize) UNKNOWN;
    else
      data = X[t];
      Mem[address, datasize DIV 8, acctype] = data;
  when MemOp_LOAD
    data = Mem[address, datasize DIV 8, acctype];
    if signed then
      X[t] = SignExtend(data, regsize);
    else
      X[t] = ZeroExtend(data, regsize);
    when MemOp_PREFETCHPrefetch(address, t<4:0>);

  if wback then
    if wb unknown then
      address = bits(64) UNKNOWN;
    elseif postindex then
      address = address + offset;
    if n == 31 then
      SP[] = address;
else
  \( X[n] = \text{address}; \)

### Operational information

If PSTATE.DIT is 1, the timing of this instruction is insensitive to the value of the data being loaded or stored.
LDSET, LDSETA, LDSETAL, LDSETL

Atomic bit set on word or doubleword in memory atomically loads a 32-bit word or 64-bit doubleword from memory, performs a bitwise OR with the value held in a register on it, and stores the result back to memory. The value initially loaded from memory is returned in the destination register.

- If the destination register is not one of WZR or XZR, LDSETA and LDSETAL load from memory with acquire semantics.
- LDSETL and LDSETAL store to memory with release semantics.
- LDSET has no memory ordering requirements.

For more information about memory ordering semantics see Load-Acquire, Store-Release.
For information about memory accesses see Load/Store addressing modes.

This instruction is used by the alias STSET, STSETL.

### Integer
(ARMv8.1)

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9  | 8  | 7  | 6  | 5  | 4  | 3  | 2  | 1  | 0  |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 1  | x  | 1  | 1  | 1  | 0  | 0  | 0  | A  | R  | 1  | Rs | 0  | 0  | 1  | 1  | 0  | 0  | Rn |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |

**Size**

<table>
<thead>
<tr>
<th>size</th>
<th>opc</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>
32-bit LDSET (size == 10 && A == 0 && R == 0)

LDSET <Ws>, <Wt>, [Xn|SP]

32-bit LDSETA (size == 10 && A == 1 && R == 0)

LDSETA <Ws>, <Wt>, [Xn|SP]

32-bit LDSETAL (size == 10 && A == 1 && R == 1)

LDSETAL <Ws>, <Wt>, [Xn|SP]

32-bit LDSETL (size == 10 && A == 0 && R == 1)

LDSETL <Ws>, <Wt>, [Xn|SP]

64-bit LDSET (size == 11 && A == 0 && R == 0)

LDSET <Xs>, <Xt>, [Xn|SP]

64-bit LDSETA (size == 11 && A == 1 && R == 0)

LDSETA <Xs>, <Xt>, [Xn|SP]

64-bit LDSETAL (size == 11 && A == 1 && R == 1)

LDSETAL <Xs>, <Xt>, [Xn|SP]

64-bit LDSETL (size == 11 && A == 0 && R == 1)

LDSETL <Xs>, <Xt>, [Xn|SP]

if !HaveAtomicExt() then UNDEFINED;
integer t = UInt(Rt);
integer n = UInt(Rn);
integer s = UInt(Rs);
integer datasize = 8 << UInt(size);
integer regsize = if datasize == 64 then 64 else 32;

AccType ldacctype = if A == '1' && Rt != '11111' then AccType_ORDEREDATOMICRW else AccType_ATOMICRW;
AccType stacctype = if R == '1' then AccType_ORDEREDATOMICRW else AccType_ATOMICRW;

MemAtomicOp op;
case opc of
  when '000' op = MemAtomicOp_ADD;
  when '001' op = MemAtomicOp_BIC;
  when '010' op = MemAtomicOp_EOR;
  when '011' op = MemAtomicOp_ORR;
  when '100' op = MemAtomicOp_SMAX;
  when '101' op = MemAtomicOp_SMIN;
  when '110' op = MemAtomicOp_UMAX;
  when '111' op = MemAtomicOp_UMIN;

Assembler Symbols

Ws> Is the 32-bit name of the general-purpose register holding the data value to be operated on with the contents of the memory location, encoded in the "Rs" field.

Wt> Is the 32-bit name of the general-purpose register to be loaded, encoded in the "Rt" field.

Xs> Is the 64-bit name of the general-purpose register holding the data value to be operated on with the contents of the memory location, encoded in the "Rs" field.
<Xn|SP> Is the 64-bit name of the general-purpose base register or stack pointer, encoded in the "Rn" field.

**Alias Conditions**

<table>
<thead>
<tr>
<th>Alias</th>
<th>Is preferred when</th>
</tr>
</thead>
<tbody>
<tr>
<td>STSET, STSETL</td>
<td>(A == '0' &amp;&amp; Rt == '11111')</td>
</tr>
</tbody>
</table>

**Operation**

```plaintext
bits(64) address;
bins(datasize) value;
bins(datasize) data;
bins(datasize) result;
if value = HaveMTEExt() then
    SetNotTagCheckedInstruction(n == 31);
value = X[s];
if n == 31 then
    CheckSPAlignment();
    address = SP[];
else
    address = X[n];
// All observers in the shareability domain observe the
// following load and store atomically.
data = Mem[address, datasize DIV 8, ldacctype];
case op of
    when MemAtomicOp_ADD result = data + value;
    when MemAtomicOp_BIC result = data AND NOT(value);
    when MemAtomicOp_EOR result = data EOR value;
    when MemAtomicOp_ORR result = data OR value;
    when MemAtomicOp_SMAX result = if SInt(data) > SInt(value) then data else value;
    when Mem AtomicOp_MIN result = if SInt(data) > SInt(value) then value else data;
    when Mem AtomicOp_UMAX result = if UInt(data) > UInt(value) then data else value;
    when Mem AtomicOp_UMIN result = if UInt(data) > UInt(value) then value else data;
Mem[address, datasize DIV 8, stacctype] = result;
if t != 31 then
    X[t] = ZeroExtend(data, regsize);
```

**Operational information**

If PSTATE.DIT is 1, the timing of this instruction is insensitive to the value of the data being loaded or stored.

---

(old)  
htmldiff from-  
(new)

LDSET, LDSETA, LDSETAL,  
LDSETL
LDSETB, LDSETAB, LDSETALB, LDSETLB

Atomic bit set on byte in memory atomically loads an 8-bit byte from memory, performs a bitwise OR with the value held in a register on it, and stores the result back to memory. The value initially loaded from memory is returned in the destination register.

- If the destination register is not WZR, LDSETAB and LDSETALB load from memory with acquire semantics.
- LDSETLB and LDSETALB store to memory with release semantics.
- LDSETB has no memory ordering requirements.

For more information about memory ordering semantics see Load-Acquire, Store-Release.
For information about memory accesses see Load/Store addressing modes.

This instruction is used by the alias STSETB, STSETLB.

<table>
<thead>
<tr>
<th>Integer</th>
<th>(ARMv8.1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0</td>
<td></td>
</tr>
<tr>
<td>0 0 1 1 1 0 0 0 A R 1 Rs 0 0 1 1 0 0 Rn Rt</td>
<td></td>
</tr>
</tbody>
</table>

**LDSETAB (A == 1 & R == 0)**

LDSETAB <Ws>, <Wt>, [<Xn|SP]>

**LDSETALB (A == 1 & R == 1)**

LDSETALB <Ws>, <Wt>, [<Xn|SP]>

**LDSETB (A == 0 & R == 0)**

LDSETB <Ws>, <Wt>, [<Xn|SP]>

**LDSETLB (A == 0 & R == 1)**

LDSETLB <Ws>, <Wt>, [<Xn|SP]>

if !HaveAtomicExt() then UNDEFINED;
integer t = 1 then UnallocatedEncoding();
integer t = UInt(Rt);
integer n = UInt(Rn);
integer s = UInt(Rs);

integer datasize = 8 << UInt(size);
integer regsize = if datasize == 64 then 64 else 32;
AccType ldacctype = if A == '1' && Rt != '11111' then AccType_ORDEREDATOMICRW else AccType_ATOMICRW;
AccType stacctype = if R == '1' then AccType_ORDEREDATOMICRW else AccType_ATOMICRW;
MemAtomicOp op;
case opc of
    when '000' op = MemAtomicOp_ADD;
    when '001' op = MemAtomicOp_BIC;
    when '010' op = MemAtomicOp_EOR;
    when '011' op = MemAtomicOp_ORR;
    when '100' op = MemAtomicOp_SMAX;
    when '101' op = MemAtomicOp_SMIN;
    when '110' op = MemAtomicOp_UMAX;
    when '111' op = MemAtomicOp_UMIN;
Assembler Symbols

<Ws> Is the 32-bit name of the general-purpose register holding the data value to be operated on with the contents of the memory location, encoded in the "Rs" field.

<Wt> Is the 32-bit name of the general-purpose register to be loaded, encoded in the "Rt" field.

<Xn|SP> Is the 64-bit name of the general-purpose base register or stack pointer, encoded in the "Rn" field.

Alias Conditions

<table>
<thead>
<tr>
<th>Alias</th>
<th>Is preferred when</th>
</tr>
</thead>
<tbody>
<tr>
<td>STSETB, STSETLB</td>
<td>A == '0' &amp;&amp; Rt == '11111'</td>
</tr>
</tbody>
</table>

Operation

```plaintext
bits(64) address;
bits(datasize) value;
bits(datasize) data;
bits(datasize) result;

if value = HaveMTEExt() then
    SetNotTagCheckedInstruction(n == 31);

value = X[s];
if n == 31 then
    CheckSPAlignment();
    address = SP[];
else
    address = X[n];

// All observers in the shareability domain observe the
// following load and store atomically.
data = Mem[address, datasize DIV 8, ldacctype];

case op of
    when MemAtomicOp_ADD result = data + value;
    when MemAtomicOp_BIC result = data AND NOT(value);
    when MemAtomicOp_EOR result = data EOR value;
    when MemAtomicOp_OR result = data OR value;
    when MemAtomicOp_SMAX result = if SInt(data) > SInt(value) then data else value;
    when MemAtomicOp_SMIN result = if SInt(data) > SInt(value) then value else data;
    when MemAtomicOp_UMAX result = if UInt(data) > UInt(value) then data else value;
    when MemAtomicOp_UMIN result = if UInt(data) > UInt(value) then value else data;

Mem[address, datasize DIV 8, stacctype] = result;

if t != 31 then
    X[t] = ZeroExtend(data, regsize);
```

Operational information

If PSTATE.DIT is 1, the timing of this instruction is insensitive to the value of the data being loaded or stored.

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LDSETH, LDSETAH, LDSETALH, LDSETLH

Atomic bit set on halfword in memory atomically loads a 16-bit halfword from memory, performs a bitwise OR with the value held in a register on it, and stores the result back to memory. The value initially loaded from memory is returned in the destination register.

- If the destination register is not WZR, LDSETAH and LDSETALH load from memory with acquire semantics.
- LDSETLH and LDSETALH store to memory with release semantics.
- LDSETH has no memory ordering requirements.

For more information about memory ordering semantics see Load-Acquire, Store-Release.
For information about memory accesses see Load/Store addressing modes.

This instruction is used by the alias STSETH, STSETLH.

Integer
(ARMv8.1)

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0  | 1  | 1  | 1  | 0  | 0  | A  | R  | 1  | Rs | 0  | 0  | 1  | 1  | 0  | 0  | Rn |  | Rt |

size opc

LDSETH (A == 1 & R == 0)

LDSETH <Ws>, <Wt>, [<Xn|SP]>

LDSETAH (A == 1 & R == 1)

LDSETALH (A == 1 & R == 1)

LDSETH (A == 0 & R == 0)

LDSETH <Ws>, <Wt>, [<Xn|SP]>

LDSETLH (A == 0 & R == 1)

LDSETLH <Ws>, <Wt>, [<Xn|SP]>

if !HaveAtomicExt() then UNDEFINED;
integer t = if !HaveAtomicExt() then UnallocatedEncoding() else UInt(Rt);
integer n = UInt(Rn);
integer s = UInt(Rs);

integer datasize = 8 << UInt(size);
integer regsize = if datasize == 64 then 64 else 32;
AccType ldacctype = if A == '1' & Rt !='1111' then AccType_ORDEREDATOMICRW else AccType_ATOMICRW;
AccType stacctype = if R == '1' then AccType_ORDEREDATOMICRW else AccType_ATOMICRW;
MemAtomicOp op;
case opc of
  when '000' op = MemAtomicOp_ADD;
  when '001' op = MemAtomicOp_BIC;
  when '010' op = MemAtomicOp_EOR;
  when '011' op = MemAtomicOp_ORR;
  when '100' op = MemAtomicOp_SMAX;
  when '101' op = MemAtomicOp_SMIN;
  when '110' op = MemAtomicOp_UMAX;
  when '111' op = MemAtomicOp_UMIN;
Assembler Symbols

<Ws> Is the 32-bit name of the general-purpose register holding the data value to be operated on with the contents of the memory location, encoded in the "Rs" field.

<Wt> Is the 32-bit name of the general-purpose register to be loaded, encoded in the "Rt" field.

<Xn|SP> Is the 64-bit name of the general-purpose base register or stack pointer, encoded in the "Rn" field.

Alias Conditions

<table>
<thead>
<tr>
<th>Alias</th>
<th>Is preferred when</th>
</tr>
</thead>
<tbody>
<tr>
<td>STSETH, STSETLH</td>
<td>A == '0' &amp; Rt == '11111'</td>
</tr>
</tbody>
</table>

Operation

```plaintext
bits(64) address;
bits(datasize) value;
bits(datasize) data;
bits(datasize) result;

if value = HaveMTEExt() then
  SetNotTagCheckedInstruction(n == 31);

value = X[s];
if n == 31 then
  CheckSPAlignment();
  address = SP[];
else
  address = X[n];

// All observers in the shareability domain observe the
// following load and store atomically.
data = Mem[address, datasize DIV 8, ldacctype];

case op of
  when MemAtomicOp_ADD result = data + value;
  when MemAtomicOp_BIC result = data AND NOT(value);
  when MemAtomicOp_EOR result = data EOR value;
  when MemAtomicOp_ORR result = data OR value;
  when MemAtomicOp_SMAX result = if SInt(data) > SInt(value) then data else value;
  when MemAtomicOp_SMIN result = if SInt(data) > SInt(value) then value else data;
  when MemAtomicOp_UMAX result = if UInt(data) > UInt(value) then value else data;
  when MemAtomicOp_UMIN result = if UInt(data) > UInt(value) then data else value;

Mem[address, datasize DIV 8, stacctype] = result;

if t != 31 then
  X[t] = ZeroExtend(data, regsize);
```

Operational information

If PSTATE.DIT is 1, the timing of this instruction is insensitive to the value of the data being loaded or stored.
LDSMAX, LDSMAXA, LDSMAXAL, LDSMAXL

Atomic signed maximum on word or doubleword in memory atomically loads a 32-bit word or 64-bit doubleword from memory, compares it against the value held in a register, and stores the larger value back to memory, treating the values as signed numbers. The value initially loaded from memory is returned in the destination register.

- If the destination register is not one of WZR or XZR, LDSMAXA and LDSMAXAL load from memory with acquire semantics.
- LDSMAXL and LDSMAXAL store to memory with release semantics.
- LDSMAX has no memory ordering requirements.

For more information about memory ordering semantics see Load-Acquire, Store-Release.
For information about memory accesses see Load/Store addressing modes.

This instruction is used by the alias STSMAX, STSMAXL.

### Integer

#### (ARMv8.1)

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9  | 8  | 7  | 6  | 5  | 4  | 3  | 2  | 1  | 0  |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 1  | x  | 1  | 1  | 1  | 0  | 0  | A  | R  | 1  |    |    | Rs | 0  | 1  | 0  | 0  | 0  | Rn |    |    |    |    |    |    |    |    |    |    |    |
|    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |

<table>
<thead>
<tr>
<th>size</th>
<th>opc</th>
</tr>
</thead>
</table>

LDSMAX, LDSMAXA, LDSMAXAL, LDSMAXL
Page 754
32-bit LDSMAX (size == 10 & A == 0 & R == 0)

LDSMAX <Ws>, <Wt>, [Xn|SP]

32-bit LDSMAXA (size == 10 & A == 1 & R == 0)

LDSMAXA <Ws>, <Wt>, [Xn|SP]

32-bit LDSMAXAL (size == 10 & A == 1 & R == 1)

LDSMAXAL <Ws>, <Wt>, [Xn|SP]

32-bit LDSMAXL (size == 10 & A == 0 & R == 1)

LDSMAXL <Ws>, <Wt>, [Xn|SP]

64-bit LDSMAX (size == 11 & A == 0 & R == 0)

LDSMAX <Xs>, <Xt>, [Xn|SP]

64-bit LDSMAXA (size == 11 & A == 1 & R == 0)

LDSMAXA <Xs>, <Xt>, [Xn|SP]

64-bit LDSMAXAL (size == 11 & A == 1 & R == 1)

LDSMAXAL <Xs>, <Xt>, [Xn|SP]

64-bit LDSMAXL (size == 11 & A == 0 & R == 1)

LDSMAXL <Xs>, <Xt>, [Xn|SP]

    if !HaveAtomicExt() then UNDEFINED;
integer t = UInt(Rt);
integer n = UInt(Rn);
integer s = UInt(Rs);

integer datasize = 8 << UInt(size);
integer regsize = if datasize == 64 then 64 else 32;
AccType ldacctype = if A == '1' & Rt != '11111' then AccType_ORDERED_ATOMIC_RW else AccType_ATOMIC_RW;
AccType stacctype = if R == '1' then AccType_ORDERED_ATOMIC_RW else AccType_ATOMIC_RW;
MemAtomicOp op;
case opc of
    when '000' op = MemAtomicOp_ADD;
    when '001' op = MemAtomicOp_BIC;
    when '010' op = MemAtomicOp_EOR;
    when '011' op = MemAtomicOp_ORR;
    when '100' op = MemAtomicOp_SMAX;
    when '101' op = MemAtomicOp_SMIN;
    when '110' op = MemAtomicOp_UMAX;
    when '111' op = MemAtomicOp_UMIN;

Assembler Symbols

<Ws> Is the 32-bit name of the general-purpose register holding the data value to be operated on with the contents of the memory location, encoded in the "Rs" field.

<Wt> Is the 32-bit name of the general-purpose register to be loaded, encoded in the "Rt" field.

<Xs> Is the 64-bit name of the general-purpose register holding the data value to be operated on with the contents of the memory location, encoded in the "Rs" field.
Is the 64-bit name of the general-purpose register to be loaded, encoded in the "Rt" field.

Is the 64-bit name of the general-purpose base register or stack pointer, encoded in the "Rn" field.

### Alias Conditions

<table>
<thead>
<tr>
<th>Alias</th>
<th>Is preferred when</th>
</tr>
</thead>
<tbody>
<tr>
<td>STSMAX, STSMAXL</td>
<td>A == '0' &amp; &amp; Rt == '11111'</td>
</tr>
</tbody>
</table>

### Operation

```plaintext
bits(64) address;
bits(datasize) value;
bits(datasize) data;
bits(datasize) result;

if value = HaveMTEExt() then
  SetNotTagCheckedInstruction(n == 31);

value = X[s];
if n == 31 then
  CheckSPAignment();
  address = SP[];
else
  address = X[n];
// All observers in the shareability domain observe the
// following load and store atomically.
data = Mem[address, datasize DIV 8, ldacctype];

case op of
  when MemAtomicOp_ADD  result = data + value;
  when MemAtomicOp_BIC  result = data AND NOT(value);
  when MemAtomicOp_EOR  result = data EOR value;
  when MemAtomicOp_ORR  result = data OR value;
  when MemAtomicOp_SMAX result = if SInt(data) > SInt(value) then data else value;
  when MemAtomicOp_SMIN result = if SInt(data) > SInt(value) then value else data;
  when MemAtomicOp_UMAX result = if UInt(data) > UInt(value) then data else value;
  when MemAtomicOp_UMIN result = if UInt(data) > UInt(value) then value else data;

Mem[address, datasize DIV 8, stacctype] = result;

if t != 31 then
  X[t] = ZeroExtend(data, regsize);
```

### Operational Information

If PSTATE.DIT is 1, the timing of this instruction is insensitive to the value of the data being loaded or stored.
LDSMAXB, LDSMAXAB, LDSMAXALB, LDSMAXLB

Atomic signed maximum on byte in memory atomically loads an 8-bit byte from memory, compares it against the value held in a register, and stores the larger value back to memory, treating the values as signed numbers. The value initially loaded from memory is returned in the destination register.

- If the destination register is not WZR, LDSMAXAB and LDSMAXALB load from memory with acquire semantics.
- LDSMAXLB and LDSMAXALB store to memory with release semantics.
- LDSMAXB has no memory ordering requirements.

For more information about memory ordering semantics see Load-Acquire, Store-Release. For information about memory accesses see Load/Store addressing modes.

This instruction is used by the alias STSMAXB, STSMAXLB.

Integer (ARMv8.1)

|   | 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9  | 8  | 7  | 6  | 5  | 4  | 3  | 2  | 1  | 0  |
|---|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| size | Rs |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| opc  | Rn |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |

LDSMAXAB (A == 1 && R == 0)

LDSMAXAB <Ws>, <Wt>, [<Xn|SP>]

LDSMAXLB (A == 1 && R == 1)

LDSMAXALB (A == 0 && R == 0)

LDSMAXB (A == 0 && R == 1)

LDSMAXLB (A == 0 && R == 1)

LDSMAXLB <Ws>, <Wt>, [<Xn|SP>]

if !HaveAtomicExt() then UNDEFINED;
integer t = 4 then UnallocatedEncoding4;
integer t = UInt(Rt);
integer n =UInt(Rn);
integer s = UInt(Rs);

integer datasize = 8 << UInt(size);
integer regsize = if datasize == 64 then 64 else 32;
AccType ldacctype = if A == '1' && Rt != '11111' then AccType_ORDEREDATOMIC | AccType_ORDERED else AccType_ATOMIC;
AccType stacctype = if R == '1' then AccType_ORDEREDATOMIC | AccType_ORDERED else AccType_ATOMIC;
MemAtomicOp op;

case opc of
  when '000' op = MemAtomicOp_ADD;
  when '001' op = MemAtomicOp_BIC;
  when '010' op = MemAtomicOp_EOR;
  when '011' op = MemAtomicOp_ORR;
  when '100' op = MemAtomicOp_SMAX;
  when '101' op = MemAtomicOp_SMIN;
  when '110' op = MemAtomicOp_UMAX;
  when '111' op = MemAtomicOp_UMIN;
Assembler Symbols

<Ws> Is the 32-bit name of the general-purpose register holding the data value to be operated on with the contents of the memory location, encoded in the "Rs" field.

<Wt> Is the 32-bit name of the general-purpose register to be loaded, encoded in the "Rt" field.

<Xn|SP> Is the 64-bit name of the general-purpose base register or stack pointer, encoded in the "Rn" field.

Alias Conditions

<table>
<thead>
<tr>
<th>Alias</th>
<th>Is preferred when</th>
</tr>
</thead>
<tbody>
<tr>
<td>STSMAXB, STSMAXLB</td>
<td>A == '0' &amp; Rt == '11111'</td>
</tr>
</tbody>
</table>

Operation

```plaintext
bits(64) address;
bits(datasize) value;
bits(datasize) data;
bits(datasize) result;

if value = HaveMTEExt () then
  SetNotTagCheckedInstruction (n == 31);

value = X[s];
if n == 31 then
  CheckSPAlignment ();
  address = SP[];
else
  address = X[n];

// All observers in the shareability domain observe the
// following load and store atomically.
data = Mem [address, datasize DIV 8, ldacctype];

case op of
  when MemAtomicOp_ADD result = data + value;
  when MemAtomicOp_BIC result = data AND NOT(value);
  when MemAtomicOp_EOR result = data EOR value;
  when MemAtomicOp_OR result = data OR value;
  when MemAtomicOp_SMX result = if SInt (data) > SInt (value) then data else value;
  when MemAtomicOp_SMX result = if SInt (data) > SInt (value) then value else data;
  when MemAtomicOp_UMAX result = if UInt (data) > UInt (value) then value else data;
  when MemAtomicOp_UMAX result = if UInt (data) > UInt (value) then value else data;

  Mem [address, datasize DIV 8, stacctype] = result;

if t != 31 then
  X[t] = ZeroExtend (data, regsize);
```

Operational information

If PSTATE.DIT is 1, the timing of this instruction is insensitive to the value of the data being loaded or stored.
LDSMAXH, LDSMAXAH, LDSMAXALH, LDSMAXLH

Atomic signed maximum on halfword in memory atomically loads a 16-bit halfword from memory, compares it against the value held in a register, and stores the larger value back to memory, treating the values as signed numbers. The value initially loaded from memory is returned in the destination register.

- If the destination register is not WZR, LDSMAXAH and LDSMAXALH load from memory with acquire semantics.
- LDSMAXLH and LDSMAXALH store to memory with release semantics.
- LDSMAXH has no memory ordering requirements.

For more information about memory ordering semantics see Load-Acquire, Store-Release.
For information about memory accesses see Load/Store addressing modes.

This instruction is used by the alias STSMAXH, STSMAXLH.

Integer
(ARMv8.1)

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 0 | 1 | 1 | 1 | 0 | 0 | A | R | 1 | Rs | 0 | 1 | 0 | 0 | 0 | Rn | Rt |

size opc

LDSMAXAH (A == 1 && R == 0)

LDSMAXAH <Ws>, <Wt>, [<Xn|SP>]

LDSMAXALH (A == 1 && R == 1)

LDSMAXALH <Ws>, <Wt>, [<Xn|SP>]

LDSMAXH (A == 0 && R == 0)

LDSMAXH <Ws>, <Wt>, [<Xn|SP>]

LDSMAXLH (A == 0 && R == 1)

LDSMAXLH <Ws>, <Wt>, [<Xn|SP>]

```c
if !HaveAtomicExt() then UNDEFINED;
integer t = !; then UnallocatedEncoding();
integer t = UInt(Rt);
integer n = UInt(Rn);
integer s = UInt(Rs);

integer datasize = 8 << UInt(size);
integer regsize = if datasize == 64 then 64 else 32;
AccType ldacctype = if A == '1' && Rt != '11111' then AccType_ORDEREDATOMICRW else AccType_ATOMICRW;
AccType stacctype = if R == '1' then AccType_ORDEREDATOMICRW else AccType_ATOMICRW;
MemAtomicOp op;
case opc of
  when '000' op = MemAtomicOp_ADD;
  when '001' op = MemAtomicOp_BIC;
  when '010' op = MemAtomicOp_EOR;
  when '011' op = MemAtomicOp_ORR;
  when '100' op = MemAtomicOp_SMAX;
  when '101' op = MemAtomicOp_SMIN;
  when '110' op = MemAtomicOp_UMAX;
  when '111' op = MemAtomicOp_UMIN;
```
Assembler Symbols

<Ws> Is the 32-bit name of the general-purpose register holding the data value to be operated on with the contents of the memory location, encoded in the "Rs" field.

<Wt> Is the 32-bit name of the general-purpose register to be loaded, encoded in the "Rt" field.

<Xn|SP> Is the 64-bit name of the general-purpose base register or stack pointer, encoded in the "Rn" field.

Alias Conditions

<table>
<thead>
<tr>
<th>Alias</th>
<th>Is preferred when</th>
</tr>
</thead>
<tbody>
<tr>
<td>STSMAXH, STSMAXLH</td>
<td>A == '0' &amp; Rt == '1111'</td>
</tr>
</tbody>
</table>

Operation

```plaintext
bits(64) address;
bits(datasize) value;
bits(datasize) data;
bits(datasize) result;

if
HaveMTEExt () then
  SetNotTagCheckedInstruction(n == 31);

value = X[s];
if n == 31 then
  CheckSPAlignment ();
  address = SP[];
else
  address = X[n];

// All observers in the shareability domain observe the
// following load and store atomically.
data = Mem [address, datasize DIV 8, ldacctype];

case op of
  when MemAtomicOp_ADD result = data + value;
  when MemAtomicOp_BIC result = data AND NOT(value);
  when MemAtomicOp_EOR result = data EOR value;
  when MemAtomicOp.ORR result = data OR value;
  when MemAtomicOp.SMAX result = if SInt(data) > SInt(value) then data else value;
  when MemAtomicOp.SMIN result = if SInt(data) > SInt(value) then value else data;
  when MemAtomicOp.UMAX result = if UInt(data) > UInt(value) then value else data;
  when MemAtomicOp.UMIN result = if UInt(data) > UInt(value) then value else data;

Mem [address, datasize DIV 8, stacctype] = result;
if t != 31 then
  X[t] = ZeroExtend(data, regsize);
```

Operational information

If PSTATE.DIT is 1, the timing of this instruction is insensitive to the value of the data being loaded or stored.
LDSMIN, LDSMINA, LDSMINAL, LDSMINL

Atomic signed minimum on word or doubleword in memory atomically loads a 32-bit word or 64-bit doubleword from memory, compares it against the value held in a register, and stores the smaller value back to memory, treating the values as signed numbers. The value initially loaded from memory is returned in the destination register.

- If the destination register is not one of WZR or XZR, LDSMINA and LDSMINAL load from memory with acquire semantics.
- LDSMINL and LDSMINAL store to memory with release semantics.
- LDSMIN has no memory ordering requirements.

For more information about memory ordering semantics see Load-Acquire, Store-Release. For information about memory accesses see Load/Store addressing modes.

This instruction is used by the alias STSMIN, STSMINL.

Integer
(ARMv8.1)

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| x  | 1  | 1  | 1  | 0  | 0  | A  | R  | 1  | Rs | 0  | 1  | 0  | 1  | 0  | 0  | Rn |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |

size opc
32-bit LDSMIN (size == 10 && A == 0 && R == 0)

LDSMIN <Ws>, <Wt>, [<Xn|SP>]

32-bit LDSMINA (size == 10 && A == 1 && R == 0)

LDSMINA <Ws>, <Wt>, [<Xn|SP>]

32-bit LDSMINAL (size == 10 && A == 1 && R == 1)

LDSMINAL <Ws>, <Wt>, [<Xn|SP>]

32-bit LDSMINL (size == 10 && A == 0 && R == 1)

LDSMINL <Ws>, <Wt>, [<Xn|SP>]

64-bit LDSMIN (size == 11 && A == 0 && R == 0)

LDSMIN <Xs>, <Xt>, [<Xn|SP>]

64-bit LDSMINA (size == 11 && A == 1 && R == 0)

LDSMINA <Xs>, <Xt>, [<Xn|SP>]

64-bit LDSMINAL (size == 11 && A == 1 && R == 1)

LDSMINAL <Xs>, <Xt>, [<Xn|SP>]

64-bit LDSMINL (size == 11 && A == 0 && R == 1)

LDSMINL <Xs>, <Xt>, [<Xn|SP>]

if !HaveAtomicExt() then UNDEFINED;

integer t = UInt(Rt);
integer n = UInt(Rn);
integer s = UInt(Rs);

integer datasize = 8 << UInt(size);
integer regsize = if datasize == 64 then 64 else 32;

AccType ldacctype = if A == '1' && Rt != '11111' then AccType_ORDEREDATOMICRW else AccType_ATOMICRW;
AccType stacctype = if R == '1' then AccType_ORDEREDATOMICRW else AccType_ATOMICRW;
MemAtomicOp op;

case opc of
when '000' op = MemAtomicOp_ADD;
when '001' op = MemAtomicOp_BIC;
when '010' op = MemAtomicOp_EOR;
when '011' op = MemAtomicOp_ORR;
when '100' op = MemAtomicOp_SMAX;
when '101' op = MemAtomicOp_SMIN;
when '110' op = MemAtomicOp_UMAX;
when '111' op = MemAtomicOp_UMIN;

Assembler Symbols

<Ws> Is the 32-bit name of the general-purpose register holding the data value to be operated on with the contents of the memory location, encoded in the "Rs" field.

<Wt> Is the 32-bit name of the general-purpose register to be loaded, encoded in the "Rt" field.

<Xs> Is the 64-bit name of the general-purpose register holding the data value to be operated on with the contents of the memory location, encoded in the "Rs" field.
Alias Conditions

<table>
<thead>
<tr>
<th>Alias</th>
<th>Is preferred when</th>
</tr>
</thead>
<tbody>
<tr>
<td>STSMIN, STSMINL</td>
<td>A == '0' &amp;&amp; Rt == '11111'</td>
</tr>
</tbody>
</table>

Operation

```plaintext
bits(64) address;
bits(datasize) value;
bits(datasize) data;
bits(datasize) result;

if value = HaveMTEExt() then
  SetNotTagCheckedInstruction(n == 31);

value = X[s];
if n == 31 then
  CheckSPAlignment();
  address = SP[];
else
  address = X[n];

// All observers in the shareability domain observe the
// following load and store atomically.
data = Mem[address, datasize DIV 8, ldacctype];

case op of
  when MemAtomicOp_ADD result = data + value;
  when MemAtomicOp_BIC result = data AND NOT(value);
  when MemAtomicOp_EOR result = data EOR value;
  when MemAtomicOp_ORR result = data OR value;
  when MemAtomicOp_SMAX result = if SInt(data) > SInt(value) then data else value;
  when MemAtomicOp_SMIN result = if SInt(data) > SInt(value) then value else data;
  when MemAtomicOp_UMAX result = if UInt(data) > UInt(value) then data else value;
  when MemAtomicOp_UMIN result = if UInt(data) > UInt(value) then value else data;

  Mem[address, datasize DIV 8, stacctype] = result;

if t != 31 then
  X[t] = ZeroExtend(data, regsize);
```

Operational information

If PSTATE.DIT is 1, the timing of this instruction is insensitive to the value of the data being loaded or stored.
Atomic signed minimum on byte in memory atomically loads an 8-bit byte from memory, compares it against the value held in a register, and stores the smaller value back to memory, treating the values as signed numbers. The value initially loaded from memory is returned in the destination register.

- If the destination register is not WZR, LDSMINAB and LDSMINALB load from memory with acquire semantics.
- LDSMINLB and LDSMINALB store to memory with release semantics.
- LDSMINB has no memory ordering requirements.

For more information about memory ordering semantics see Load-Acquire, Store-Release. For information about memory accesses see Load/Store addressing modes.

This instruction is used by the alias STSMINB, STSMINLB.

**Integer (ARMv8.1)**

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0  | 0  | 1  | 1  | 1  | 0  | 0  | A  | R  | 1  | Rs | 0  | 1  | 0  | 1  | 0  | 0  | Rn | 0  | 0  | 1  | 1  | 0  | 0  |
| size | opc |

**LDSMINB (A == 1 & R == 0)**

LDSMINB <Ws>, <Wt>, [Xn|SP]

**LDSMINALB (A == 1 & R == 1)**

LDSMINALB <Ws>, <Wt>, [Xn|SP]

**LDSMINB (A == 0 & R == 0)**

LDSMINB <Ws>, <Wt>, [Xn|SP]

**LDSMINLB (A == 0 & R == 1)**

LDSMINLB <Ws>, <Wt>, [Xn|SP]

```plaintext
if !HaveAtomicExt() then UNDEFINED;
integer t = 4 then UnallocatedEncoding(4);
integer t = UInt(Rt);
integer n = UInt(Rn);
integer s = UInt(Rs);

integer datasize = 8 << UInt(size);
integer regsize = if datasize == 64 then 64 else 32;
AccType ldacctype = if A == '1' && Rt != '11111' then AccType_ORDEREDATOMICRW else AccType_ORDEREDRW;
AccType stacctype = if R == '1' then AccType_ORDEREDATOMICRW else AccType_ATOMICRW;
MemAtomicOp op;

case opc of
    when '000' op = MemAtomicOp_ADD;
    when '001' op = MemAtomicOp_BIC;
    when '010' op = MemAtomicOp_EOR;
    when '011' op = MemAtomicOp_ORR;
    when '100' op = MemAtomicOp_SMAX;
    when '101' op = MemAtomicOp_SMIN;
    when '110' op = MemAtomicOp_UMAX;
    when '111' op = MemAtomicOp_UMIN;
```

LDSMINB, LDSMINALB, LDSMINLB

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Assembler Symbols

<Ws> Is the 32-bit name of the general-purpose register holding the data value to be operated on with the contents of the memory location, encoded in the "Rs" field.

<Wt> Is the 32-bit name of the general-purpose register to be loaded, encoded in the "Rt" field.

<Xn|SP> Is the 64-bit name of the general-purpose base register or stack pointer, encoded in the "Rn" field.

Alias Conditions

<table>
<thead>
<tr>
<th>Alias</th>
<th>Is preferred when</th>
</tr>
</thead>
<tbody>
<tr>
<td>STSMINB, STSMINLB</td>
<td>A == '0' &amp;&amp; Rt == '11111'</td>
</tr>
</tbody>
</table>

Operation

```plaintext
bits(64) address;
bits(datasize) value;
bits(datasize) data;
bits(datasize) result;

if value = HaveMTEExt() then
  SetNotTagCheckedInstruction(n == 31);

value = X[s];
if n == 31 then
  CheckSPAAlignment();
  address = SP[];
else
  address = X[n];

// All observers in the shareability domain observe the
// following load and store atomically.
data = Mem[address, datasize DIV 8, ldacctype];

case op of
  when MemAtomicOp_ADD result = data + value;
  when MemAtomicOp_BIC result = data AND NOT(value);
  when MemAtomicOp_EOR result = data EOR value;
  when MemAtomicOp_ORR result = data OR value;
  when MemAtomicOp_SMAX result = if SInt(data) > SInt(value) then data else value;
  when MemAtomicOp_SMIN result = if SInt(data) > SInt(value) then value else data;
  when MemAtomicOp_UMAX result = if UInt(data) > UInt(value) then data else value;
  when MemAtomicOp_UMIN result = if UInt(data) > UInt(value) then value else data;

Mem[address, datasize DIV 8, stacctype] = result;

if t != 31 then
  X[t] = ZeroExtend(data, regsize);

Operational information

If PSTATE.DIT is 1, the timing of this instruction is insensitive to the value of the data being loaded or stored.

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Atomic signed minimum on halfword in memory atomically loads a 16-bit halfword from memory, compares it against the value held in a register, and stores the smaller value back to memory, treating the values as signed numbers. The value initially loaded from memory is returned in the destination register.

- If the destination register is not WZR, LDSMINAH and LDSMINALH load from memory with acquire semantics.
- LDSMINLH and LDSMINALH store to memory with release semantics.
- LDSMINH has no memory ordering requirements.

For more information about memory ordering semantics see Load-Acquire, Store-Release. For information about memory accesses see Load/Store addressing modes.

This instruction is used by the alias STSMINH, STSMINLH.

### Integer (ARMv8.1)

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0  | 1  | 1  | 1  | 0  | 0  | A  | R  | 1  | Rs | 0  | 1  | 0  | 1  | 0  | Rn | Rt |

**LDSMINAH (A == 1 & R == 0)**

LDSMINAH <Ws>, <Wt>, [<Xn|SP>]

**LDSMINALH (A == 1 & R == 1)**

LDSMINALH <Ws>, <Wt>, [<Xn|SP>]

**LDSMINH (A == 0 & R == 0)**

LDSMINH <Ws>, <Wt>, [<Xn|SP>]

**LDSMINLH (A == 0 & R == 1)**

LDSMINLH <Ws>, <Wt>, [<Xn|SP>]

```java
if !HaveAtomicExt() then UNDEFINED;
integer t = -1, t = UnallocatedEncoding();
integer n = UInt(Rn);
integer s = UInt(Rs);

integer datasize = 8 << UInt(size);
integer regsize = if datasize == 64 then 64 else 32;
AccType ldacctype = if A == '1' && Rt != '11111' then AccType_ORDEREDATOMICRW else AccType_ATOMICRW;
AccType stacctype = if R == '1' then AccType_ORDEREDATOMICRW else AccType_ATOMICRW;
MemAtomicOp op;

case opc of
  when '000' op = MemAtomicOp_ADD;
  when '001' op = MemAtomicOp_BIC;
  when '010' op = MemAtomicOp_EOR;
  when '011' op = MemAtomicOp_ORR;
  when '100' op = MemAtomicOp_SMAX;
  when '101' op = MemAtomicOp_SMIN;
  when '110' op = MemAtomicOp_UMAX;
  when '111' op = MemAtomicOp_UMIN;
```
Assembler Symbols

<Ws> Is the 32-bit name of the general-purpose register holding the data value to be operated on with the contents of the memory location, encoded in the "Rs" field.

<Wt> Is the 32-bit name of the general-purpose register to be loaded, encoded in the "Rt" field.

<Xn|SP> Is the 64-bit name of the general-purpose base register or stack pointer, encoded in the "Rn" field.

Alias Conditions

<table>
<thead>
<tr>
<th>Alias</th>
<th>Is preferred when</th>
</tr>
</thead>
<tbody>
<tr>
<td>STSMINH, STSMINLH</td>
<td>A == '0' &amp;&amp; Rt == '11111'</td>
</tr>
</tbody>
</table>

Operation

```plaintext
bits(64) address;
bits(datasize) value;
bits(datasize) data;
bits(datasize) result;

if value = HaveMTEExt() then
    SetNotTagCheckedInstruction(n == 31);

value = X[s];
if n == 31 then
    CheckSPAlignment();
    address = SP[];
else
    address = X[n];

// All observers in the shareability domain observe the 
// following load and store atomically.
data = Mem[address, datasize DIV 8, ldacctype];

case op of
    when MemAtomicOp_ADD  result = data + value;
    when MemAtomicOp_BIC  result = data AND NOT(value);
    when MemAtomicOp_EOR  result = data EOR value;
    when MemAtomicOp_ORR  result = data OR value;
    when MemAtomicOp_SMAX result = if SInt(data) > SInt(value) then data else value;
    when MemAtomicOp_SMIN result = if SInt(data) > SInt(value) then value else data;
    when MemAtomicOp_UMAX result = if UInt(data) > UInt(value) then value else data;
    when MemAtomicOp_UMIN result = if UInt(data) > UInt(value) then data else value;
Mem[address, datasize DIV 8, stacctype] = result;

if t != 31 then
    X[t] = ZeroExtend(data, regsize);
```

Operational information

If PSTATE.DIT is 1, the timing of this instruction is insensitive to the value of the data being loaded or stored.

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LDTR

Load Register (unprivileged) loads a word or doubleword from memory, and writes it to a register. The address that is used for the load is calculated from a base register and an immediate offset.

Memory accesses made by the instruction behave as if the instruction was executed at EL0 if the Effective value of PSTATE.UAO is 0 and either:

- The instruction is executed at EL1.
- The instruction is executed at EL2 when the Effective value of HCR_EL2.{E2H, TGE} is {1, 1}.

Otherwise, the memory access operates with the restrictions determined by the Exception level at which the instruction is executed. For information about memory accesses, see Load/Store addressing modes.

### 32-bit (size == 10)

LDTR <Wt>, [<Xn|SP>{, #<simm>}]  

### 64-bit (size == 11)

LDTR <Xt>, [<Xn|SP>{, #<simm>}]  

boolean wback = FALSE;  
boolean postindex = FALSE;  
integer scale = UInt(size);  
bits(64) offset = SignExtend(imm9, 64);

### Assembler Symbols

- <Wt> Is the 32-bit name of the general-purpose register to be transferred, encoded in the "Rt" field.
- <Xt> Is the 64-bit name of the general-purpose register to be transferred, encoded in the "Rt" field.
- <Xn|SP> Is the 64-bit name of the general-purpose base register or stack pointer, encoded in the "Rn" field.
- <simm> Is the optional signed immediate byte offset, in the range -256 to 255, defaulting to 0 and encoded in the "imm9" field.
integer n = UInt(Rn);
integer t = UInt(Rt);

unpriv_at_el1 = PSTATE.EL == EL1AccType && !acctype == AccType_UNPRIV &&
                !HaveNVExt() && HCR_EL2.NV, NV1 == '1' &&
                !unpriv_at_el2 == !HaveEL2() && HCR_EL2.HN == 1 &&
                HCR_EL2.NU == 1 && HCR_EL2.<E2H,TGE> == '1';

user_access_override = !HaveUAOExt() && PSTATE.UAO == '1';
if user_access_override && (unpriv_at_el1 || unpriv_at_el2) then
    acctype = AccType_UNPRIV;
else
    acctype = AccType_NORMAL;

MemOp memop;
boolean signed;
integer regsize;

if opc<1> == '0' then
    // store or zero-extending load
    memop = if opc<0> == '1' then MemOp_LOAD else MemOp_STORE;
    regsize = if size == '11' then 64 else 32;
    signed = FALSE;
else
    if size == '11' then UNDEFINED;
    else
        // sign-extending load
        memop = if size == '11' then UnallocatedEncoding() else
                if size == '11' && opc<0> == '1' then UnallocatedEncoding;
        if size == '10' && opc<0> == '1' then UNDEFINED;
        else
            regsize = if opc<0> == '1' then 32 else 64;
            signed = TRUE;

integer datasize = 8 << scale;
if bits(64) address;
bits(datasize) data;
boolean wb_unknown = FALSE;
boolean rt_unknown = FALSE;

if memop == HaveMTEExt() then
    boolean is_load_store = memop IN {MemOp STORE, MemOp LOAD};
    SetNotTagCheckedInstruction(is_load_store && n == 31 && !wback);

bits(64) address;
bits(datasize) data;

boolean wb_unknown = FALSE;
boolean rt_unknown = FALSE;

if memop == MemOp LOAD && wback && n == t && n != 31 then
    c = ConstranUnpredictable(Unpredictable_WBOVERLAPLD);
    assert c IN {Constraint_WBSUPPRESS, Constraint_UNKNOWN, Constraint_UNDEF, Constraint_NOP};
    case c of
        when Constraint_WBSUPPRESS
            wback = FALSE;       // writeback is suppressed
        when Constraint_UNKNOWN
            wb_unknown = TRUE;   // writeback is UNKNOWN
        when Constraint_UNDEF
            UNDEFINED;
        when UnallocatedEncoding()
            EndOfInstruction();
        when Constraint_NOP
            EndOfInstruction();
    end;

if memop == MemOp STORE && wback && n == t && n != 31 then
    c = ConstranUnpredictable(Unpredictable_WBOVERLAPST);
    assert c IN {Constraint_NONE, Constraint_UNKNOWN, Constraint_UNDEF, Constraint_NOP};
    case c of
        when Constraint_NONE
            rt_unknown = FALSE;  // value stored is original value
        when Constraint_UNKNOWN
            rt_unknown = TRUE;   // value stored is UNKNOWN
        when Constraint_UNDEF
            UnallocatedEncoding;
        when Constraint_NOP
            EndOfInstruction();
    end;

if n == 31 then
    if memop != MemOp_PREFETCH then CheckSPAlignment();
    address = SP[];
else
    address = X[n];
if ! postindex then
    address = address + offset;

case memop of
    when MemOp STORE
        if rt_unknown then
data = bits(datasize) UNKNOWN;
else
data = X[t];)
Mem[address, datasize DIV 8, acctype] = data;
when MemOp LOAD
    data = Mem[address, datasize DIV 8, acctype];
    if signed then
        X[t] = SignExtend(data, regsize);
    else
        X[t] = ZeroExtend(data, regsize);
when MemOp_PREFETCH
    Prefetch(address, t<4:0>);
if wback then
    if wb_unknown then
        address = bits(64) UNKNOWN;
    elsif postindex then
        address = address + offset;
    if n == 31 then
        SP[] = address;
else
    X[n] = address;

Operational information

If PSTATE.DIT is 1, the timing of this instruction is insensitive to the value of the data being loaded or stored.
LDTRB

Load Register Byte (unprivileged) loads a byte from memory, zero-extends it, and writes the result to a register. The address that is used for the load is calculated from a base register and an immediate offset.

Memory accesses made by the instruction behave as if the instruction was executed at EL0 if the Effective value of PSTATE.UAO is 0 and either:

- The instruction is executed at EL1.
- The instruction is executed at EL2 when the Effective value of \( HCR\_EL2\{E2H, TGE\} \) is \{1, 1\}.

Otherwise, the memory access operates with the restrictions determined by the Exception level at which the instruction is executed. For information about memory accesses, see Load/Store addressing modes.

### Unscaled offset

\[
\text{LDTRB} \ <Wt>, \ [<Xn|SP>\{, \ #\<simm>\}]
\]

```c
boolean wback = FALSE;
boolean postindex = FALSE;
integer scale = UInt(size);
bits(64) offset = SignExtend(imm9, 64);
```

### Assembler Symbols

- **<Wt>**  
  Is the 32-bit name of the general-purpose register to be transferred, encoded in the "Rt" field.
- **<Xn|SP>**  
  Is the 64-bit name of the general-purpose base register or stack pointer, encoded in the "Rn" field.
- **<simm>**  
  Is the optional signed immediate byte offset, in the range -256 to 255, defaulting to 0 and encoded in the "imm9" field.
integer n = UInt(Rn);
integer t = UInt(Rt);

unpriv_at_el1 = PSTATE.EL == EL1AccType \&\& (!acctype == EL2EnabledAccType_UNPRIV() \&\& HaveNVExt() \&\& HCR_EL2.NV1 == '1') &&
unpriv_at_el2 = !HaveEL(EL2) \&\& (HaveEL<32>() \&\& HCR_EL2.NU == 1 \&\& HCR_EL2.NUN == 1) \&\&
acctype == HaveVirtHostExt() \&\& PSTATE.EL == EL2\&\& HCR_EL2.<E2H,TGE> == '1';

user_access_override = HaveUAOExt() \&\& PSTATE.UAO == '1';
if !user_access_override \&\& (unpriv_at_el1 | unpriv_at_el2) then
   acctype = AccType_UNPRIV;
else
   acctype = AccType_NORMAL;

MemOp memop;
boolean signed;
integer regsize;

if opc<1> == '0' then
   // store or zero-extending load
   memop = if opc<0> == '1' then MemOp_LOAD else MemOp_STORE;
   regsize = if size == '11' then 64 else 32;
   signed = FALSE;
else
   if size == '11' then UNDEFINED;
   else
      // sign-extending load
      memop = if size == '11' then UnallocatedEncoding()
      else
         // sign-extending load
         memop = MemOp_LOAD;
      if size == '10' \&\& opc<0> == '1' then UnallocatedEncoding;
      if size == '10' \&\& opc<0> == '1' then UNDEFINED;
      regsize = if opc<0> == '1' then 32 else 64;
      signed = TRUE;

integer datasize = 8 << scale;
if bits(64) address;
  bits(datasize) data;
  boolean wb_unknown = FALSE;
  boolean rt_unknown = FALSE;
if memop == HaveMTEExt() then
  boolean is_load_store = memop IN {MemOp_STORE, MemOp_LOAD};
  SetNotTagCheckedInstruction(is_load_store & n == 31 & !wback);

bits(64) address;
bits(datasize) data;
boolean wb_unknown = FALSE;
boolean rt_unknown = FALSE;
if memop == MemOp_LOAD & wback & n == t & n != 31 then
  c = ConstrainUnpredictable(Unpredictable_WBOVERLAPLD);
  assert c IN {Constraint_WBSUPPRESS, Constraint_UNKNOWN, Constraint_UNDEF, Constraint_NOP};
case c of
  when Constraint_WBSUPPRESS wback = FALSE; // writeback is suppressed
  when Constraint_UNKNOWN wb_unknown = TRUE; // writeback is UNKNOWN
  when Constraint_UNDEF
    when UnallocatedEncoding() rt_unknown = FALSE; // value stored is original value
    when Constraint_NOP
      EndOfInstruction();
  when Constraint_NOP
    EndOfInstruction();
if n == 31 then
  if memop != MemOp_PREFETCH then CheckSPAlignment();
  address = SP[];
else
  address = X[n];
if ! postindex then
  address = address + offset;
case memop of
  when MemOp_LOAD
    if rt_unknown then
      data = bits(datasize) UNKNOWN;
    else
      data = X[t];
      Mem[address, datasize DIV 8, acctype] = data;
    when MemOp_PREFETCH
      Prefetch(address, t<4:0>);
if wback then
  if wb_unknown then
    address = bits(64) UNKNOWN;
  elsif postindex then
    address = address + offset;
  if n == 31 then
    SP[] = address;

if memop == MemOp_STORE & wback & n == t & n != 31 then
  c = ConstrainUnpredictable(Unpredictable_WBOVERLAPST);
  assert c IN {Constraint_NONE, Constraint_UNKNOWN, Constraint_UNDEF, Constraint_NOP};
case c of
  when Constraint_NONE rt_unknown = FALSE; // value stored is original value
  when Constraint_UNKNOWN rt_unknown = TRUE; // value stored is UNKNOWN
  when Constraint_UNDEF
    when UnallocatedEncoding() rt_unknown = FALSE; // value stored is original value
    when Constraint_NOP
      UnallocatedEncoding UNDEFINED;
  when Constraint_NOP
    EndOfInstruction();
if n == 31 then
  if memop != MemOp_PREFETCH then CheckSPAlignment();
  address = SP[];
else
  address = X[n];
if ! postindex then
  address = address + offset;
case memop of
  when MemOp_STORE
    if rt_unknown then
      data = bits(datasize) UNKNOWN;
    else
      data = X[t];
      Mem[address, datasize DIV 8, acctype] = data;
    when MemOp_LOAD
      data = Mem[address, datasize DIV 8, acctype];
      if signed then
        X[t] = SignExtend(data, regsize);
      else
        X[t] = ZeroExtend(data, regsize);
      when MemOp_PREFETCH
        Prefetch(address, t<4:0>);
if wback then
  if wb_unknown then
    address = bits(64) UNKNOWN;
  elsif postindex then
    address = address + offset;
  if n == 31 then
    SP[] = address;
else

X[n] = address;

Operational information

If PSTATE.DIT is 1, the timing of this instruction is insensitive to the value of the data being loaded or stored.
LDTRH

Load Register Halfword (unprivileged) loads a halfword from memory, zero-extends it, and writes the result to a register. The address that is used for the load is calculated from a base register and an immediate offset.

Memory accesses made by the instruction behave as if the instruction was executed at EL0 if the Effective value of PSTATE.UAO is 0 and either:
  • The instruction is executed at EL1.
  • The instruction is executed at EL2 when the Effective value of HCR_EL2.{E2H, TGE} is {1, 1}.

Otherwise, the memory access operates with the restrictions determined by the Exception level at which the instruction is executed. For information about memory accesses, see Load/Store addressing modes.

31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0

| 0 1 1 1 | 0 | 0 | 0 | 0 | 1 | 0 | imm9 | 1 | 0 | Rn | Rt |

Unscaled offset

LDTRH <Wt>, [<Xn|SP>{, #<simm>}]

boolean wback = FALSE;
boolean postindex = FALSE;
integer scale = UInt(size);
bits(64) offset = SignExtend(imm9, 64);

Assembler Symbols

<Wt> Is the 32-bit name of the general-purpose register to be transferred, encoded in the "Rt" field.
<Xn|SP> Is the 64-bit name of the general-purpose base register or stack pointer, encoded in the "Rn" field.
<simm> Is the optional signed immediate byte offset, in the range -256 to 255, defaulting to 0 and encoded in the "imm9" field.
integer n = UInt(Rn);
integer t = UInt(Rt);

unpriv_at_el1 = PSTATE.EL == EL1AccType && (acctype == EL2EnabledAccType_UNPRIV() &&
if (HaveNVExt() && HCR_EL2.<NV,NV1> == '1')
unpriv_at_el2 = if HaveEL2() && HCR_EL2.NV == 1 && HCR_EL2.NV1 == 1) then
acctype = HaveVirtHostExt() && PSTATE.EL == EL2 && HCR_EL2.<E2H,TGE> == '1';

user_access_override = HaveUAOExt() && PSTATE.UAO == '1';
if !user_access_override && (unpriv_at_el1 || unpriv_at_el2) then
acctype = AccType_UNPRIV;
else
acctype = AccType_NORMAL;

MemOp memop;
boolean signed;
integer regsize;

if opc<1> == '0' then
  // store or zero-extending load
  memop = if opc<0> == '1' then MemOp_LOAD else MemOp_STORE;
  regsize = if size == '11' then 64 else 32;
  signed = FALSE;
else
  if size == '11' then
    UNDEFINED;
  else
    // sign-extending load
    memop = MemOp_LOAD;
    if size == '10' && opc<0> == '1' then UnallocatedEncoding();
    if size == '10' && opc<0> == '1' then UNDEFINED;
    if size == '10' && opc<0> == '1' then UNDEFINED;
    if size == '11' THEN regsize = if opc<0> == '1' THEN 32 ELSE 64;
    signed = TRUE;

integer datasize = 8 << scale;
if bits(64) address; bits(datasize) data;
boolean wb_unknown = FALSE;
boolean rt_unknown = FALSE;

if memop == MemOp_PREFETCH() then
    boolean is_load_store = memop IN {MemOp_STORE, MemOp_LOAD};
    SetNotTagCheckedInstruction(is_load_store && n == 31 && !wback);

bits(64) address;
bits(datasize) data;

boolean wb_unknown = FALSE;
boolean rt_unknown = FALSE;

if memop == MemOp_STORE && wback && n == t && n != 31 then
    c = ConstrainUnpredictable(Unpredictable_WBOVERLAPLD);
assert c IN {Constraint_WBSUPPRESS, Constraint_UNKNOWN, Constraint_UNDEF, Constraint_NOP};
    case c of
        when Constraint_WBSUPPRESS 
            wback = FALSE;       // writeback is suppressed
        when Constraint_UNKNOWN 
            wb_unknown = TRUE;   // writeback is UNKNOWN
        when Constraint_UNDEF 
            UNDEFINED;
        when UnallocatedEncoding() 
            rt_unknown = FALSE;  // value stored is original value
        when Constraint_NOP 
            EndOfInstruction();
    end;

if memop == MemOp_LOAD && wback && n == t && n != 31 then
    c = ConstrainUnpredictable(Unpredictable_WBOVERLAPST);
assert c IN {Constraint_NONE, Constraint_UNKNOWN, Constraint_UNDEF, Constraint_NOP};
    case c of
        when Constraint_NONE 
            rt_unknown = FALSE; // value stored is original value
        when Constraint_UNKNOWN 
            rt_unknown = TRUE;  // value stored is UNKNOWN
        when Constraint_UNDEF 
            UnallocatedEncoding() 
                UNDEFINED;
        when Constraint_NOP 
            EndOfInstruction();
    end;

if n == 31 then
    if memop != MemOp_PREFETCH then CheckSPAlignment();
    address = SP[];
else
    address = X[n];
if ! postindex then
    address = address + offset;

    case memop of
        when MemOp_STORE
            if rt_unknown then
                data = bits(datasize) UNKNOWN;
            else
                data = X[t];
                Mem[address, datasize DIV 8, acctype] = data;
        when MemOp_LOAD
            data = Mem[address, datasize DIV 8, acctype];
        if signed then
            X[t] = SignExtend(data, regsize);
        else
            X[t] = ZeroExtend(data, regsize);
        when MemOp_PREFETCHPrefetch(address, t<4:0>);
    end;

if wback then
    if wb_unknown then
        address = bits(64) UNKNOWN;
    elseif postindex then
        address = address + offset;
    if n == 31 then
        SP[] = address;
else
    X[n] = address;

**Operational information**

If PSTATE.DIT is 1, the timing of this instruction is insensitive to the value of the data being loaded or stored.
LDTRSB

Load Register Signed Byte (unprivileged) loads a byte from memory, sign-extends it to 32 bits or 64 bits, and writes the result to a register. The address that is used for the load is calculated from a base register and an immediate offset.

Memory accesses made by the instruction behave as if the instruction was executed at EL0 if the Effective value of PSTATE.UAO is 0 and either:

- The instruction is executed at EL1.
- The instruction is executed at EL2 when the Effective value of HCR_EL2.{E2H, TGE} is {1, 1}.

Otherwise, the memory access operates with the restrictions determined by the Exception level at which the instruction is executed. For information about memory accesses, see Load/Store addressing modes.

32-bit (opc == 11)

LDTRSB <Wt>, [<Xn|SP>], #<simm>]

64-bit (opc == 10)

LDTRSB <Xt>, [<Xn|SP>], #<simm>]

boolean wback = FALSE;
boolean postindex = FALSE;
integer scale = UInt(size);
bits(64) offset = SignExtend(imm9, 64);

Assembler Symbols

<Wt> Is the 32-bit name of the general-purpose register to be transferred, encoded in the "Rt" field.
<Xt> Is the 64-bit name of the general-purpose register to be transferred, encoded in the "Rt" field.
<Xn|SP> Is the 64-bit name of the general-purpose base register or stack pointer, encoded in the "Rn" field.
<simm> Is the optional signed immediate byte offset, in the range -256 to 255, defaulting to 0 and encoded in the "imm9" field.
integer n = Uint(Rn);
integer t = Uint(Rt);

unpriv_at_el1 = PSTATE.EL == EL1AccType && !(acctype == EL2EnabledAccType_UNPRIV() &&
                            HaveNVExt() && HCR_EL2.NV.NVI == '1' &&
                            PSTATE.EL == EL2AccType_EL1);

unpriv_at_el2 = !uacce_type || HaveEL2() && (HCR_EL2.NV.NV1 == 1 &&
                            acctype == HaveVirtHostExt() && PSTATE.EL == EL2AccType_EL2);

user_access_override = HaveUAOExt() && PSTATE.UAO == '1';
if !user_access_override && (unpriv_at_el1 || unpriv_at_el2) then
    acctype = AccType_UNPRIV;
else
    acctype = AccType_NORMAL;

MemOp memop;
boolean signed;
in integer regsize;

if opc<1> == '0' then
    // store or zero-extending load
    memop = if opc<0> == '1' then MemOp_LOAD else MemOp_STORE;
    regsize = if size == '11' then 64 else 32;
    signed = FALSE;
else
    if size == '11' then
        UNDEFINED;
    else
        // sign-extending load
        memop = if size == '11' then UnallocatedEncoding()
                  else
                  // sign-extending load
        memop = MemOp_LOAD;
        if size == '10' && opc<0> == '1' then UnallocatedEncoding;
        if size == '10' && opc<0> == '1' then UNDEFINED;
        ()
        regsize = if opc<0> == '1' then 32 else 64;
        signed = TRUE;

integer datasize = 8 << scale;
if bits(64) address;
bits(datasize) data;
boolean wb_unknown = FALSE;
boolean rt_unknown = FALSE;
if memop == HaveMTEEExt() then
    boolean is_load_store = memop IN {MemOp_STORE, MemOp_LOAD};
    SetNotTagCheckedInstruction(is_load_store && n == 31 && !wback);

    bits(64) address;
    bits(datasize) data;
    boolean wb_unknown = FALSE;
    boolean rt_unknown = FALSE;
    if memop == MemOp_STORE && wback && n == t && n != 31 then
        c = ConstrainUnpredictable(Unpredictable_WBOVERLAPLD);
        assert c IN {Constraint_WBSUPPRESS, Constraint_UNKNOWN, Constraint_UNDEF, Constraint_NOP};
        case c of
            when Constraint_WBSUPPRESS wback = FALSE;  // writeback is suppressed
            when Constraint_UNKNOWN wb_unknown = TRUE;  // writeback is UNKNOWN
            when Constraint_UNDEF rt_unknown = FALSE;  // value stored is original value
            when UnallocatedEncoding() rt_unknown = TRUE;  // value stored is UNKNOWN
            when Constraint_NOP EndOfInstruction();
    
if memop == MemOp_LOAD && wback && n == t && n != 31 then
    c = ConstrainUnpredictable(Unpredictable_WBOVERLAPST);
    assert c IN {Constraint_NONE, Constraint_UNKNOWN, Constraint_UNDEF, Constraint_NOP};
    case c of
        when Constraint_NONE rt_unknown = FALSE;  // value stored is original value
        when Constraint_UNKNOWN rt_unknown = TRUE;  // value stored is UNKNOWN
        when Constraint_UNDEF EndOfInstruction();
        when Constraint_NOP EndOfInstruction();

if n == 31 then
    if memop != MemOp_PREFETCH then CheckSPA(align);  // address = SP[];
    else
        address = X[n];
    
if ! postindex then
    address = address + offset;

    case memop of
        when MemOp_STORE
            if rt_unknown then
                data = bits(datasize) UNKNOWN;
            else
                data = X[t];
                Mem[address, datasize DIV 8, acctype] = data;
                data = Mem[address, datasize DIV 8, acctype];
                if signed then
                    X[t] = SignExtend(data, regsize);
                else
                    X[t] = ZeroExtend(data, regsize);
            
        when MemOp_PREFETCH
            if wb_unknown then
                address = bits(64) UNKNOWN;
            elseif postindex then
                address = address + offset;
        if n == 31 then
            SP[] = address;
else
    X[n] = address;

Operational information

If PSTATE.DIT is 1, the timing of this instruction is insensitive to the value of the data being loaded or stored.
LDTRSH

Load Register Signed Halfword (unprivileged) loads a halfword from memory, sign-extends it to 32 bits or 64 bits, and writes the result to a register. Memory accesses made by the instruction behave as if the instruction was executed at EL0 if the Effective value of PSTATE.UAO is 0 and either:

- The instruction is executed at EL1.
- The instruction is executed at EL2 when the Effective value of HCR_EL2.{E2H, TGE} is {1, 1}.

Otherwise, the memory access operates with the restrictions determined by the Exception level at which the instruction is executed. For information about memory accesses, see Load/Store addressing modes.

32-bit (opc == 11)

LDTRSH <Wt>, [<Xn|SP>{, #<simm>}

64-bit (opc == 10)

LDTRSH <Xt>, [<Xn|SP>{, #<simm>}

boolean wback = FALSE;
boolean postindex = FALSE;
integer scale = UInt(size);
b(64) offset = SignExtend(imm9, 64);

Assembler Symbols

<Wt> Is the 32-bit name of the general-purpose register to be transferred, encoded in the "Rt" field.
<Xt> Is the 64-bit name of the general-purpose register to be transferred, encoded in the "Rt" field.
<Xn|SP> Is the 64-bit name of the general-purpose base register or stack pointer, encoded in the "Rn" field.
<simm> Is the optional signed immediate byte offset, in the range -256 to 255, defaulting to 0 and encoded in the "imm9" field.
integer n = \texttt{UInt}(Rn);
integer t = \texttt{UInt}(Rt);

\begin{verbatim}
unpriv_at_el1 = PSTATE.EL == EL1AccType \&\& (acctype == EL2EnabledAccType_UNPRIV() \&\&
\texttt{HaveNVExt() \&\& HCR_EL2.<NV,NV1> == '11');
unpriv_at_el2 = -1 \&\& \texttt{HaveEL(EL2) \&\& (HCR_EL2.NU == 1 \&\& HCR_EL2.NI == 1)} then
\texttt{acctype == HaveVirtHostExt() \&\& PSTATE.EL == EL2 \&\& HCR_EL2.<E2H,TGE> == '11');
user_access_override = \texttt{HaveUAOExt() \&\& PSTATE.UAO == '1');
if !user_access_override \&\& (unpriv_at_el1 || unpriv_at_el2) then
\texttt{acctype = AccType_UNPRIV;}
else
\texttt{acctype = AccType_NORMAL;}
\end{verbatim}

\begin{verbatim}
MemOp memop;
boolean signed;
integer regsize;
if opc<1> == '0' then
  // store or zero-extending load
  memop = if opc<0> == '1' then MemOp_LOAD else MemOp_STORE;
  regsize = if size == '11' then 64 else 32;
  signed = FALSE;
else
  if size == '11' then
    \texttt{UNDEFINED;}
  else
    // sign-extending load
    memop = if size == '11' then UnallocatedEncoding();
    else
    // sign-extending load
    memop = MemOp_LOAD;
    if size == '10' \&\& opc<0> == '1' then UnallocatedEncoding;
    if size == '10' \&\& opc<0> == '1' then UNDEFINED;
  endif
  regsize = if opc<0> == '1' then 32 else 64;
  signed = TRUE;
\end{verbatim}

integer datasize = 8 << scale;
if bits(64) address;
    bits(datasize) data;
    boolean wb_unknown = FALSE;
    boolean rt_unknown = FALSE;

    if memop == HaveMTEExt() then
        boolean is_load_store = memop IN {MemOp_STORE, MemOp_LOAD};
        SetNotTagCheckedInstruction(is_load_store && n == 31 && !wback);
    
    bits(64) address;
    bits(datasize) data;
    boolean wb_unknown = FALSE;
    boolean rt_unknown = FALSE;

    if memop == MemOp_LOAD && wback && n == t && n != 31 then
        c = ConstrainUnpredictable(Unpredictable_WBOVERLAPLD);
        assert c IN {Constraint_WBSUPPRESS, Constraint_UNKNOWN, Constraint_UNDEF, Constraint_NOP};
        case c of
            when Constraint_WBSUPPRESS wback = FALSE;       // writeback is suppressed
            when Constraint_UNKNOWN wb_unknown = TRUE;       // writeback is UNKNOWN
            when Constraint_UNDEF rt_unknown = FALSE;  // value stored is original value
            when UnallocatedEncoding();
            when Constraint_NOP EndOfInstruction();
    
    if memop == MemOp_STORE && wback && n == t && n != 31 then
        c = ConstrainUnpredictable(Unpredictable_WBOVERLAPST);
        assert c IN {Constraint_NONE, Constraint_UNKNOWN, Constraint_UNDEF, Constraint_NOP};
        case c of
            when Constraint_NONE rt_unknown = FALSE;  // value stored is original value
            when Constraint_UNKNOWN rt_unknown = TRUE;   // value stored is UNKNOWN
            when Constraint_UNDEF UnallocatedEncoding() UNDEFINED;
            when Constraint_NOP EndOfInstruction();
    
    if n == 31 then
        if memop != MemOp_PREFETCH then CheckSPAlignment();
        address = SP[];
    else
        address = X[n];

    if ! postindex then
        address = address + offset;

    case memop of
        when MemOp_STORE
            if rt_unknown then
                data = bits(datasize) UNKNOWN;
            else
                data = X[t];
                Mem[address, datasize DIV 8, acctype] = data;
            
            when MemOp_LOAD
                data = Mem[address, datasize DIV 8, acctype];
                if signed then
                    X[t] = SignExtend(data, regsize);
                else
                    X[t] = ZeroExtend(data, regsize);
                
                when MemOp_PREFETCHPrefetch(address, t<4:0>);
    
    if wback then
        if wb_unknown then
            address = bits(64) UNKNOWN;
        elsif postindex then
            address = address + offset;
        if n == 31 then
            SP[] = address;
else

    X[n] = address;

---

**Operational information**

If PSTATE.DIT is 1, the timing of this instruction is insensitive to the value of the data being loaded or stored.
Load Register Signed Word (unprivileged) loads a word from memory, sign-extends it to 64 bits, and writes the result to a register. The address that is used for the load is calculated from a base register and an immediate offset.

Memory accesses made by the instruction behave as if the instruction was executed at EL0 if the **Effective value** of PSTATE.UAO is 0 and either:

- The instruction is executed at EL1.
- The instruction is executed at EL2 when the **Effective value** of HCR_EL2.{E2H, TGE} is \{1, 1\}.

Otherwise, the memory access operates with the restrictions determined by the Exception level at which the instruction is executed. For information about memory accesses, see *Load/Store addressing modes*.

### Unscaled offset

LDTRSW `<Xt>`, `[<Xn|SP>{, #<simm>}]`

boolean wback = FALSE;
boolean postindex = FALSE;
integer scale = UInt(size);
bits(64) offset = SignExtend(imm9, 64);

### Assembler Symbols

- `<Xt>` is the 64-bit name of the general-purpose register to be transferred, encoded in the "Rt" field.
- `<Xn|SP>` is the 64-bit name of the general-purpose base register or stack pointer, encoded in the "Rn" field.
- `<simm>` is the optional signed immediate byte offset, in the range -256 to 255, defaulting to 0 and encoded in the "imm9" field.
integer n = UInt(Rn);
integer t = UInt(Rt);

unpriv_at_el1 = PSTATE.EL == (Rt);
unpriv_at_el2 = PSTATE.EL == (Rt);

if HaveNVExt() && HCR_EL2.<NV,NV1> == '11';

if !user_access_override && (unpriv_at_el1 || unpriv_at_el2) then
    acctype = AccType_UNPRIV;
else
    acctype = AccType_NORMAL;

MemOp memop;
boolean signed;
integer regsize;

if opc<1> == '0' then
    // store or zero-extending load
    memop = if opc<0> == '1' then MemOp_LOAD else MemOp_STORE;
    regsize = if size == '11' then 64 else 32;
    signed = FALSE;
else
    if size == '11' then
        UNDEFINED;
    else
        // sign-extending load
        memop = if size == '11' then UnallocatedEncoding();
        else
            // sign-extending load
            memop = MemOp_LOAD;
            if size == '10' && opc<0> == '1' then UnallocatedEncoding;
            if size == '10' && opc<0> == '1' then UNDEFINED;
            regsize = if opc<0> == '1' then 32 else 64;
            signed = TRUE;

integer datasize = 8 << scale;
if bits(64) address;
bits(datasize) data;
boolean wb_unknown = FALSE;
boolean rt_unknown = FALSE;

if memop == HaveMTEExt() then
    boolean is_load_store = memop IN {MemOp STORE, MemOp LOAD};
    SetNotTagCheckedInstruction(is_load_store && n == 31 && !wback);

bits(64) address;
bits(datasize) data;
boolean wb_unknown = FALSE;
boolean rt_unknown = FALSE;

if memop == MemOp LOAD && wback && n == t && n != 31 then
    c = ConstrainUnpredictable(Unpredictable_WBOVERLAPLD);
    assert c IN {Constraint_WBSUPPRESS, Constraint_UNKNOWN, Constraint_UNDEF, Constraint_NOP};
    case c of
        when Constraint_WBSUPPRESS
            wback = FALSE;  // writeback is suppressed
        when Constraint_UNKNOWN
            wb_unknown = TRUE;  // writeback is UNKNOWN
        when Constraint_UNDEF
            rt_unknown = FALSE;  // value stored is original value
        when UnallocatedEncoding()
            rt_unknown = TRUE;  // value stored is UNKNOWN
        when Constraint_NOP
            EndOfInstruction();

if memop == MemOp STORE && wback && n == t && n != 31 then
    c = ConstrainUnpredictable(Unpredictable_WBOVERLAPST);
    assert c IN {Constraint_NONE, Constraint_UNKNOWN, Constraint_UNDEF, Constraint_NOP};
    case c of
        when Constraint_NONE
            rt_unknown = FALSE;  // value stored is original value
        when Constraint_UNKNOWN
            rt_unknown = TRUE;  // value stored is UNKNOWN
        when Constraint_UNDEF
            UnallocatedEncoding() UNDEFINED;
        when Constraint_NOP
            EndOfInstruction();

if n == 31 then
    if memop != MemOp_PREFETCH then CheckSPAlignment();
    address = SP[];
else
    address = X[n];

if ! postindex then
    address = address + offset;

case memop of
    when MemOp STORE
        if rt_unknown then
            data = bits(datasize) UNKNOWN;
        else
            data = X[t];
            Mem[address, datasize DIV 8, acctype] = data;
    when MemOp LOAD
        data = Mem[address, datasize DIV 8, acctype];
        if signed then
            X[t] = SignExtend(data, regsize);
        else
            X[t] = ZeroExtend(data, regsize);
    when MemOp_PREFETCHPrefetch(address, t<4:0>);

if wback then
    if wb_unknown then
        address = bits(64) UNKNOWN;
    elsif postindex then
        address = address + offset;
    if n == 31 then
        SP[] = address;
else

\( X[n] = \text{address}; \)

**Operational information**

If PSTATE.DIT is 1, the timing of this instruction is insensitive to the value of the data being loaded or stored.
LDUMAX, LDUMAXA, LDUMAXAL, LDUMAXL

Atomic unsigned maximum on word or doubleword in memory atomically loads a 32-bit word or 64-bit doubleword from memory, compares it against the value held in a register, and stores the larger value back to memory, treating the values as unsigned numbers. The value initially loaded from memory is returned in the destination register.

- If the destination register is not one of WZR or XZR, LDUMAXA and LDUMAXAL load from memory with acquire semantics.
- LDUMAXL and LDUMAXAL store to memory with release semantics.
- LDUMAX has no memory ordering requirements.

For more information about memory ordering semantics see Load-Acquire, Store-Release.
For information about memory accesses see Load/Store addressing modes.

This instruction is used by the alias STUMAX, STUMAXL.

Integer
(ARMv8.1)

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</table>
32-bit LDUMAX (size == 10 & A == 0 & R == 0)

LDUMAX <Ws>, <Wt>, [<Xn|SP>]

32-bit LDUMAXA (size == 10 & A == 1 & R == 0)

LDUMAXA <Ws>, <Wt>, [<Xn|SP>]

32-bit LDUMAXAL (size == 10 & A == 1 & R == 1)

LDUMAXAL <Ws>, <Wt>, [<Xn|SP>]

32-bit LDUMAXL (size == 10 & A == 0 & R == 1)

LDUMAXL <Ws>, <Wt>, [<Xn|SP>]

64-bit LDUMAX (size == 11 & A == 0 & R == 0)

LDUMAX <Xs>, <Xt>, [<Xn|SP>]

64-bit LDUMAXA (size == 11 & A == 1 & R == 0)

LDUMAXA <Xs>, <Xt>, [<Xn|SP>]

64-bit LDUMAXAL (size == 11 & A == 1 & R == 1)

LDUMAXAL <Xs>, <Xt>, [<Xn|SP>]

64-bit LDUMAXL (size == 11 & A == 0 & R == 1)

LDUMAXL <Xs>, <Xt>, [<Xn|SP>]

if !HaveAtomicExt() then UNDEFINED;
integer t = UInt(Rt);
integer n = UInt(Rn);
integer s = UInt(Rs);
integer datasize = 8 << UInt(size);
integer regsize = if datasize == 64 then 64 else 32;

AccType ldacctype = if A == '1' & Rt != '11111' then AccType_ORDEREDATOMICRW else AccType_ATOMICRW;
AccType stacctype = if R == '1' then AccType_ORDEREDATOMICRW else AccType_ATOMICRW;

MemAtomicOp op;
case opc of
  when '000' op = MemAtomicOp_ADD;
  when '001' op = MemAtomicOp_BIC;
  when '010' op = MemAtomicOp_EOR;
  when '011' op = MemAtomicOp_ORR;
  when '100' op = MemAtomicOp_SMAX;
  when '101' op = MemAtomicOp_SMIN;
  when '110' op = MemAtomicOp_UMAX;
  when '111' op = MemAtomicOp_UMIN;

Assembler Symbols

<Ws> Is the 32-bit name of the general-purpose register holding the data value to be operated on with the contents of the memory location, encoded in the "Rs" field.

<Wt> Is the 32-bit name of the general-purpose register to be loaded, encoded in the "Rt" field.

<Xs> Is the 64-bit name of the general-purpose register holding the data value to be operated on with the contents of the memory location, encoded in the "Rs" field.
Is the 64-bit name of the general-purpose register to be loaded, encoded in the "Rt" field.

Is the 64-bit name of the general-purpose base register or stack pointer, encoded in the "Rn" field.

### Alias Conditions

<table>
<thead>
<tr>
<th>Alias</th>
<th>Is preferred when</th>
</tr>
</thead>
<tbody>
<tr>
<td>STUMAX, STUMAXL</td>
<td>A == '0' &amp;&amp; Rt == '1111'</td>
</tr>
</tbody>
</table>

### Operation

```c
if (value = HaveMTEExt()) then
    SetNotTagCheckedInstruction(n == 31);

value = X[s];
if n == 31 then
    CheckSPAlignment();
    address = SP[];
else
    address = X[n];

// All observers in the shareability domain observe the
// following load and store atomically.
data = Mem[address, datasize DIV 8, ldacctype];

case op of
    when MemAtomicOp_ADD result = data + value;
    when MemAtomicOp_BIC result = data AND NOT(value);
    when MemAtomicOp_EOR result = data EOR value;
    when MemAtomicOp_ORR result = data OR value;
    when MemAtomicOp_SMAX result = if SInt(data) > SInt(value) then data else value;
    when MemAtomicOp_SMIN result = if SInt(data) > SInt(value) then value else data;
    when MemAtomicOp_UMAX result = if UInt(data) > UInt(value) then data else value;
    when MemAtomicOp_UMIN result = if UInt(data) > UInt(value) then value else data;

Mem[address, datasize DIV 8, stacctype] = result;

if t != 31 then
    X[t] = ZeroExtend(data, regsize);
```

### Operational information

If PSTATE.DIT is 1, the timing of this instruction is insensitive to the value of the data being loaded or stored.
LDUMAXB, LDUMAXAB, LDUMAXALB, LDUMAXLB

Atomic unsigned maximum on byte in memory atomically loads an 8-bit byte from memory, compares it against the value held in a register, and stores the larger value back to memory, treating the values as unsigned numbers. The value initially loaded from memory is returned in the destination register.

- If the destination register is not WZR, LDUMAXAB and LDUMAXALB load from memory with acquire semantics.
- LDUMAXLB and LDUMAXALB store to memory with release semantics.
- LDUMAXB has no memory ordering requirements.

For more information about memory ordering semantics see Load-Acquire, Store-Release.
For information about memory accesses see Load/Store addressing modes.

This instruction is used by the alias STUMAXB, STUMAXLB.

Integer
(ARMv8.1)

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0  | 0  | 1  | 1  | 1  | 0  | 0  | 0  | A  | R  | 1  | Rs | 0  | 1  | 1  | 0  | 0  | 0  | Rn | 0  | 1  | 1  | 0  | 0  | 0  | R  |

size opc

LDUMAXB (A == 1 && R == 0)

LDUMAXB <Ws>, <Wt>, [<Xn|SP>]

LDUMAXLB (A == 1 && R == 1)

LDUMAXLB <Ws>, <Wt>, [<Xn|SP>]

LDUMAXB (A == 0 && R == 0)

LDUMAXB <Ws>, <Wt>, [<Xn|SP>]

LDUMAXLB (A == 0 && R == 1)

LDUMAXLB <Ws>, <Wt>, [<Xn|SP>]

if !HaveAtomicExt() then UNDEFINED;
integer t = if !HasAtomicExt() then UnallocatedEncoding() else
integer t = Uint(Rt);
integer n = Uint(Rn);
integer s = Uint(Rs);

integer datasize = 8 << Uint(size);
integer regsize = if datasize == 64 then 64 else 32;
AccType ldaccetype = if A == '1' && Rt != '11111' then AccType_ORDEREDATOMICRW else AccType_ATOMICRW;
AccType stacctype = if R == '1' then AccType_ORDEREDATOMICRW else AccType_ATOMICRW;
MemAtomicOp op;
case opc of
  when '000' op = MemAtomicOp_ADD;
  when '001' op = MemAtomicOp_BIC;
  when '010' op = MemAtomicOp_EOR;
  when '011' op = MemAtomicOp_ORR;
  when '100' op = MemAtomicOp_SMAX;
  when '101' op = MemAtomicOp_SMIN;
  when '110' op = MemAtomicOp_UMAX;
  when '111' op = MemAtomicOp_UMIN;
Assembler Symbols

<Ws> Is the 32-bit name of the general-purpose register holding the data value to be operated on with the contents of the memory location, encoded in the "Rs" field.

<Wt> Is the 32-bit name of the general-purpose register to be loaded, encoded in the "Rt" field.

<Xn|SP> Is the 64-bit name of the general-purpose base register or stack pointer, encoded in the "Rn" field.

Alias Conditions

<table>
<thead>
<tr>
<th>Alias</th>
<th>Is preferred when</th>
</tr>
</thead>
<tbody>
<tr>
<td>STUMAXB, STUMAXLB</td>
<td>A == '0' &amp;&amp; Rt == '1111'</td>
</tr>
</tbody>
</table>

Operation

```plaintext
bits(64) address;
bits(datasize) value;
bits(datasize) data;
bits(datasize) result;

if value = HaveMTEExt() then
    SetNotTagCheckedInstruction(n == 31);

value = X[s];
if n == 31 then
    CheckSPAlignment();
    address = SP[];
else
    address = X[n];

// All observers in the shareability domain observe the
// following load and store atomically.
data = Mem[address, datasize DIV 8, ldacctype];

case op of
    when MemAtomicOp_ADD result = data + value;
    when MemAtomicOp_BIC result = data AND NOT(value);
    when MemAtomicOp_EOR result = data EOR value;
    when MemAtomicOp_ORR result = data OR value;
    when MemAtomicOp_SMAX result = if SInt(data) > SInt(value) then data else value;
    when MemAtomicOp_SMIN result = if SInt(data) > SInt(value) then value else data;
    when MemAtomicOp_UMAX result = if UInt(data) > UInt(value) then value else data;
    when MemAtomicOp_UMIN result = if UInt(data) > UInt(value) then value else data;

Mem[address, datasize DIV 8, stacctype] = result;

if t != 31 then
    X[t] = ZeroExtend(data, regsize);
```

Operational information

If PSTATE.DIT is 1, the timing of this instruction is insensitive to the value of the data being loaded or stored.

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**LDUMAXH, LDUMAXAH, LDUMAXALH, LDUMAXLH**

Atomic unsigned maximum on halfword in memory atomically loads a 16-bit halfword from memory, compares it against the value held in a register, and stores the larger value back to memory, treating the values as unsigned numbers. The value initially loaded from memory is returned in the destination register.

- If the destination register is not WZR, **LDUMAXAH** and **LDUMAXALH** load from memory with acquire semantics.
- **LDUMAXLH** and **LDUMAXALH** store to memory with release semantics.
- **LDUMAXH** has no memory ordering requirements.

For more information about memory ordering semantics see [Load-Acquire, Store-Release](#). For information about memory accesses see [Load/Store addressing modes](#).

This instruction is used by the alias **STUMAXH, STUMAXLH**.

**Integer**

(ARMv8.1)

31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0

<table>
<thead>
<tr>
<th>size</th>
<th>opc</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 1 1 1 0 0 0</td>
<td>A R 1</td>
</tr>
</tbody>
</table>

**LDUMAXAH (A == 1 && R == 0)**

LDUMAXAH <Ws>, <Wt>, [<Xn|SP>]

**LDUMAXALH (A == 1 && R == 1)**

LDUMAXALH <Ws>, <Wt>, [<Xn|SP>]

**LDUMAXH (A == 0 && R == 0)**

LDUMAXH <Ws>, <Wt>, [Xn|SP>]

**LDUMAXLH (A == 0 && R == 1)**

LDUMAXLH <Ws>, <Wt>, [Xn|SP>]

```plaintext
if !HaveAtomicExt() then UNDEFINED;
integer t = Integer(UnallocatedEncoding());
integer n = Uint(Rn);
integer s = Uint(Rs);

integer datasize = 8 << Uint(size);
integer regsize = if datasize == 64 then 64 else 32;

AccType ldacctype = if A == '1' && Rt != '11111' then AccType_ORDEREDATOMICRW else AccType_ATOMICRW;
AccType stacctype = if R == '1' then AccType_ORDEREDATOMICRW else AccType_ATOMICRW;
MemAtomicOp op;

case opc of
    when '000' op = MemAtomicOp_ADD;
    when '001' op = MemAtomicOp_BIC;
    when '010' op = MemAtomicOp_EOR;
    when '011' op = MemAtomicOp_ORR;
    when '100' op = MemAtomicOp_SMAX;
    when '101' op = MemAtomicOp_SMIN;
    when '110' op = MemAtomicOp_UMAX;
    when '111' op = MemAtomicOp_UMIN;
```
Assembler Symbols

<Ws> Is the 32-bit name of the general-purpose register holding the data value to be operated on with the contents of the memory location, encoded in the "Rs" field.

<Wt> Is the 32-bit name of the general-purpose register to be loaded, encoded in the "Rt" field.

<Xn|SP> Is the 64-bit name of the general-purpose base register or stack pointer, encoded in the "Rn" field.

### Alias Conditions

<table>
<thead>
<tr>
<th>Alias</th>
<th>Is preferred when</th>
</tr>
</thead>
<tbody>
<tr>
<td>STUMAXH, STUMAXLH</td>
<td>A == '0' &amp;&amp; Rt == '11111'</td>
</tr>
</tbody>
</table>

### Operation

```plaintext
bits(64) address;
bits(datasize) value;
bits(datasize) data;
bits(datasize) result;

if value = HaveMTEExt() then
    SetNotTagCheckedInstruction(n == 31);

value = X[s];
if n == 31 then
    CheckSPAlignment();
    address = SP[];
else
    address = X[n];

// All observers in the shareability domain observe the
// following load and store atomically.
data = Mem[address, datasize DIV 8, ldacctype];

case op of
    when MemAtomicOp_ADD result = data + value;
    when MemAtomicOp_BIC result = data AND NOT(value);
    when MemAtomicOp_EOR result = data EOR value;
    when MemAtomicOp_ORR result = data OR value;
    when MemAtomicOp_SMAD result = if SInt(data) > SInt(value) then data else value;
    when MemAtomicOp_SMAD result = if SInt(data) > SInt(value) then value else data;
    when MemAtomicOp_UMAD result = if UInt(data) > UInt(value) then data else value;
    when MemAtomicOp_UMAD result = if UInt(data) > UInt(value) then value else data;

Mem[address, datasize DIV 8, stacctype] = result;

if t != 31 then
    X[t] = ZeroExtend(data, regsize);
```

### Operational information

If PSTATE.DIT is 1, the timing of this instruction is insensitive to the value of the data being loaded or stored.

Internal version only: isa v30.25, AdvSIMD v27.0, pseudocode v85-xml-00bet8_rc3.316; Build timestamp: 2018-09-13T13:2018-06-16T09:45:00

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LDUMIN, LDUMINA, LDUMINAL, LDUMINL

Atomic unsigned minimum on word or doubleword in memory atomically loads a 32-bit word or 64-bit doubleword from memory, compares it against the value held in a register, and stores the smaller value back to memory, treating the values as unsigned numbers. The value initially loaded from memory is returned in the destination register.

- If the destination register is not one of WZR or XZR, LDUMINA and LDUMINAL load from memory with acquire semantics.
- LDUMINL and LDUMINAL store to memory with release semantics.
- LDUMIN has no memory ordering requirements.

For more information about memory ordering semantics see Load-Acquire, Store-Release. For information about memory accesses see Load/Store addressing modes.

This instruction is used by the alias STUMIN, STUMINL.

<table>
<thead>
<tr>
<th>Integer</th>
</tr>
</thead>
<tbody>
<tr>
<td>(ARMv8.1)</td>
</tr>
</tbody>
</table>

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|------|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 1 | x | 1 | 1 | 1 | 0 | 0 | 0 | A | R | 1 | Rs | 0 | 1 | 1 | 1 | 0 | 0 | Rn | Rt | size | opc |
32-bit LDUMIN (size == 10 & A == 0 & R == 0)

LDUMIN <Ws>, <Wt>, [<Xn|SP>]

32-bit LDUMINA (size == 10 & A == 1 & R == 0)

LDUMINA <Ws>, <Wt>, [<Xn|SP>]

32-bit LDUMINAL (size == 10 & A == 1 & R == 1)

LDUMINAL <Ws>, <Wt>, [<Xn|SP>]

32-bit LDUMINL (size == 10 & A == 0 & R == 1)

LDUMINL <Ws>, <Wt>, [<Xn|SP>]

64-bit LDUMIN (size == 11 & A == 0 & R == 0)

LDUMIN <Xs>, <Xt>, [<Xn|SP>]

64-bit LDUMINA (size == 11 & A == 1 & R == 0)

LDUMINA <Xs>, <Xt>, [<Xn|SP>]

64-bit LDUMINAL (size == 11 & A == 1 & R == 1)

LDUMINAL <Xs>, <Xt>, [<Xn|SP>]

64-bit LDUMINL (size == 11 & A == 0 & R == 1)

LDUMINL <Xs>, <Xt>, [<Xn|SP>]

if !HaveAtomicExt() then UNDEFINED;
integer t = UInt(Rt);
integer n = UInt(Rn);
integer s = UInt(Rs);

integer datasize = 8 << UInt(size);
integer regsize = if datasize == 64 then 64 else 32;

AccType ldacctype = if A == '1' && Rt != '11111' then AccType_ORDEREDATOMICRW else AccType_ATOMICRW;

AccType stacctype = if R == '1' then AccType_ORDEREDATOMICRW else AccType_ATOMICRW;

MemAtomicOp op;
case opc of
when '000' op = MemAtomicOp_ADD;
when '001' op = MemAtomicOp_BIC;
when '010' op = MemAtomicOp_EOR;
when '011' op = MemAtomicOp_ORR;
when '100' op = MemAtomicOp_SMAX;
when '101' op = MemAtomicOp_SMIN;
when '110' op = MemAtomicOp_UMAX;
when '111' op = MemAtomicOp_UMIN;

Assembler Symbols

<Ws> Is the 32-bit name of the general-purpose register holding the data value to be operated on with the contents of the memory location, encoded in the "Rs" field.

<Wt> Is the 32-bit name of the general-purpose register to be loaded, encoded in the "Rt" field.

<Xs> Is the 64-bit name of the general-purpose register holding the data value to be operated on with the contents of the memory location, encoded in the "Rs" field.
Is the 64-bit name of the general-purpose register to be loaded, encoded in the "Rt" field.

Is the 64-bit name of the general-purpose base register or stack pointer, encoded in the "Rn" field.

### Alias Conditions

<table>
<thead>
<tr>
<th>Alias</th>
<th>Is preferred when</th>
</tr>
</thead>
<tbody>
<tr>
<td>STUMIN, STUMINL</td>
<td>( A == '0' &amp;&amp; Rn == '11111' )</td>
</tr>
</tbody>
</table>

### Operation

```plaintext
bits(64) address;
bits(datasize) value;
bits(datasize) data;
bits(datasize) result;

if \( \text{HaveMTEExt()} \) then
    SetNotTagCheckedInstruction(n == 31);

value = X[s];
if n == 31 then
    CheckSPAinement();
    address = SP[];
else
    address = X[n];

// All observers in the shareability domain observe the
// following load and store atomically.
data = \( \text{Mem}[\text{address, datasize DIV 8, ldacctype}] \);

case op of
    when MemAtomicOp_ADD result = data + value;
    when MemAtomicOp_BIC result = data AND NOT(value);
    when MemAtomicOp_EOR result = data EOR value;
    when MemAtomicOp_ORR result = data OR value;
    when MemAtomicOp_SMAX result = if SInt(data) > SInt(value) then data else value;
    when MemAtomicOp_SMIN result = if SInt(data) > SInt(value) then value else data;
    when MemAtomicOp_UMAX result = if UInt(data) > UInt(value) then data else value;
    when MemAtomicOp_UMIN result = if UInt(data) > UInt(value) then value else data;

Mem[address, datasize DIV 8, stacctype] = result;

if t != 31 then
    X[t] = \( \text{ZeroExtend}(\text{data}, \text{regsize}) \);
```

### Operational information

If PSTATE.DIT is 1, the timing of this instruction is insensitive to the value of the data being loaded or stored.
LDUMINB, LDUMINAB, LDUMINALB, LDUMINLB

Atomic unsigned minimum on byte in memory atomically loads an 8-bit byte from memory, compares it against the value held in a register, and stores the smaller value back to memory, treating the values as unsigned numbers. The value initially loaded from memory is returned in the destination register.

- If the destination register is not WZR, LDUMINAB and LDUMINALB load from memory with acquire semantics.
- LDUMINLB and LDUMINALB store to memory with release semantics.
- LDUMINB has no memory ordering requirements.

For more information about memory ordering semantics see [Load-Acquire, Store-Release](#).

For information about memory accesses see [Load/Store addressing modes](#).

This instruction is used by the alias STUMINB, STUMINLB.

Integer
(ARMv8.1)

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9  | 8  | 7  | 6  | 5  | 4  | 3  | 2  | 1  | 0  |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0  | 0  | 1  | 1  | 1  | 0  | 0  | 0  | A  | R  | 1  | Rs | 0  | 1  | 1  | 1  | 0  | 0  | Rn | 0  | 0  | 1  | 1  | 0  | 0  | 1  | 1  | 0  | 0  | 0  | 0  |

<table>
<thead>
<tr>
<th>size</th>
<th>opc</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

LDUMINAB (A == 1 & R == 0)

LDUMINAB <W>, <W>, [<Xn>|SP]}

LDUMINALB (A == 1 & R == 1)

LDUMINALB <W>, <W>, [<Xn>|SP]}

LDUMINB (A == 0 & R == 0)

LDUMINB <W>, <W>, [<Xn>|SP]}

LDUMINLB (A == 0 & R == 1)

LDUMINLB <W>, <W>, [<Xn>|SP]}

```plaintext
if !HaveAtomicExt() then UNDEFINED;
integer t = if !HaveAtomicExt() then UnallocatedEncoding();
integer n = UInt(Rn);
integer s = UInt(Rs);
integer datasize = 8 << UInt(size);
integer regsize = if datasize == 64 then 64 else 32;
AccType ldacctype = if A == '1' && Rt != '1111' then AccType_ORDEREDATOMICRW else AccType_ATOMICRW;
AccType stacctype = if R == '1' then AccType_ORDEREDATOMICRW else AccType_ATOMICRW;
MemAtomicOp op;
case opc of
  when '000' op = MemAtomicOp_ADD;
  when '001' op = MemAtomicOp_BIC;
  when '010' op = MemAtomicOp_EOR;
  when '011' op = MemAtomicOp_ORR;
  when '100' op = MemAtomicOp_SMAX;
  when '101' op = MemAtomicOp_SMIN;
  when '110' op = MemAtomicOp_UMAX;
  when '111' op = MemAtomicOp_UMIN;
```
Assembler Symbols

<Ws> Is the 32-bit name of the general-purpose register holding the data value to be operated on with the contents of the memory location, encoded in the "Rs" field.

<Wt> Is the 32-bit name of the general-purpose register to be loaded, encoded in the "Rt" field.

<Xn|SP> Is the 64-bit name of the general-purpose base register or stack pointer, encoded in the "Rn" field.

Alias Conditions

<table>
<thead>
<tr>
<th>Alias</th>
<th>Is preferred when</th>
</tr>
</thead>
<tbody>
<tr>
<td>STUMINB, STUMINLB</td>
<td>A == '0' &amp; Rt == '11111'</td>
</tr>
</tbody>
</table>

Operation

```plaintext
bits(64) address;
bots(datasize) value;
bots(datasize) data;
bots(datasize) result;

if value = HaveMTEExt() then
    SetNotTagCheckedInstruction(n == 31);

value = X[s];
if n == 31 then
    CheckSPAlignment();
    address = SP[];
else
    address = X[n];

// All observers in the shareability domain observe the
// following load and store atomically.
data = Mem[address, datasize DIV 8, ldacctype];

case op of
    when MemAtomicOp_ADD result = data + value;
    when MemAtomicOp_BIC result = data AND NOT(value);
    when MemAtomicOp_EOR result = data EOR value;
    when MemAtomicOp_ORR result = data OR value;
    when MemAtomicOp_SMAX result = if SInt(data) > SInt(value) then data else value;
    when MemAtomicOp_SMIN result = if SInt(data) > SInt(value) then value else data;
    when MemAtomicOp_UMAX result = if UInt(data) > UInt(value) then value else data;
    when MemAtomicOp_UMIN result = if UInt(data) > UInt(value) then value else data;

Mem[address, datasize DIV 8, stacctype] = result;

if t != 31 then
    X[t] = ZeroExtend(data, regsize);
```

Operational information

If PSTATE.DIT is 1, the timing of this instruction is insensitive to the value of the data being loaded or stored.
**LDUMINH, LDUMINAH, LDUMINALH, LDUMINLH**

Atomic unsigned minimum on halfword in memory atomically loads a 16-bit halfword from memory, compares it against the value held in a register, and stores the smaller value back to memory, treating the values as unsigned numbers. The value initially loaded from memory is returned in the destination register.

- If the destination register is not WZR, LDUMINAH and LDUMINALH load from memory with acquire semantics.
- LDUMINLH and LDUMINALH store to memory with release semantics.
- LDUMINH has no memory ordering requirements.

For more information about memory ordering semantics see Load-Acquire, Store-Release. For information about memory accesses see Load/Store addressing modes.

This instruction is used by the alias STUMINH, STUMINLH.

### Integer

**ARMv8.1**

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9  | 8  | 7  | 6  | 5  | 4  | 3  | 2  | 1  | 0  |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0  | 1  | 1  | 1  | 1  | 0  | 0  | 0  | A  | R  | 1  | Rs | 0  | 1  | 1  | 1  | 0  | 0  | Rn |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |

#### LDUMINAH (A == 1 && R == 0)

LDUMINAH <Ws>, <Wt>, [<Xn|SP]>

#### LDUMINALH (A == 1 && R == 1)

LDUMINALH <Ws>, <Wt>, [<Xn|SP]>

#### LDUMINH (A == 0 && R == 0)

LDUMINH <Ws>, <Wt>, [<Xn|SP]>

#### LDUMINLH (A == 0 && R == 1)

LDUMINLH <Ws>, <Wt>, [<Xn|SP]>

```plaintext
if !HaveAtomicExt() then UNDEFINED;
integer t = 1 then UnallocatedEncoding();
integer t = UInt(Rt);
integer n = UInt(Rn);
integer s = UInt(Rs);

integer datasize = 8 << UInt(size);
integer regsize = if datasize == 64 then 64 else 32;
AccType ldacctype = if A == '1' && Rt != '11111' then AccType_ORDEREDATOMICRW else AccType_ATOMICRW;
AccType stacctype = if R == '1' then AccType_ORDEREDATOMICRW else AccType_ATOMICRW;
MemAtomicOp op;

case opc of
  when '000' op = MemAtomicOp_ADD;
  when '001' op = MemAtomicOp_BIC;
  when '010' op = MemAtomicOp_EOR;
  when '011' op = MemAtomicOp_ORR;
  when '100' op = MemAtomicOp_SMAX;
  when '101' op = MemAtomicOp_SMIN;
  when '110' op = MemAtomicOp_UMAX;
  when '111' op = MemAtomicOp_UMIN;
```
Assembler Symbols

<Ws> Is the 32-bit name of the general-purpose register holding the data value to be operated on with the contents of the memory location, encoded in the "Rs" field.

<Wt> Is the 32-bit name of the general-purpose register to be loaded, encoded in the "Rt" field.

<Xn|SP> Is the 64-bit name of the general-purpose base register or stack pointer, encoded in the "Rn" field.

Alias Conditions

<table>
<thead>
<tr>
<th>Alias</th>
<th>Is preferred when</th>
</tr>
</thead>
<tbody>
<tr>
<td>STUMINH, STUMINLH</td>
<td>A == '0' &amp; &amp; Rt == '11111'</td>
</tr>
</tbody>
</table>

Operation

```
bits(64) address;
bits(datasize) value;
bits(datasize) data;
bits(datasize) result;

if value = HaveMTEExt() then
    SetNotTagCheckedInstruction(n == 31); 

value = X[s];
if n == 31 then
    CheckSPAlignment();
    address = SP[];
else
    address = X[n];

// All observers in the shareability domain observe the
// following load and store atomically.

data = Mem[address, datasize DIV 8, ldacctype];

case op of
    when MemAtomicOp_ADD result = data + value;
    when MemAtomicOp_BIC result = data AND NOT(value);
    when MemAtomicOp_EOR result = data EOR value;
    when MemAtomicOp_ORR result = data OR value;
    when MemAtomicOp_SMAX result = if SInt(data) > SInt(value) then data else value;
    when MemAtomicOp_SMIN result = if SInt(data) < SInt(value) then data else value;
    when MemAtomicOp_UMAX result = if UInt(data) > UInt(value) then data else value;
    when MemAtomicOp_UMIN result = if UInt(data) < UInt(value) then data else value;

Mem[address, datasize DIV 8, stacctype] = result;

if t != 31 then
    X[t] = ZeroExtend(data, regsize);
```

Operational information

If PSTATE.DIT is 1, the timing of this instruction is insensitive to the value of the data being loaded or stored.

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LDUR (SIMD&FP)

Load SIMD&FP Register (unscaled offset). This instruction loads a SIMD&FP register from memory. The address that is used for the load is calculated from a base register value and an optional immediate offset.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

<table>
<thead>
<tr>
<th>size</th>
<th>1 1 1 1 0 0</th>
<th>x 1 0 0</th>
<th>imm9</th>
<th>0 0</th>
<th>Rn</th>
<th>Rt</th>
</tr>
</thead>
</table>

| opc  |
| 0 0  |

8-bit (size == 00 && opc == 01)

LDUR <Bt>, [<Xn|SP>{, #<simm>}

16-bit (size == 01 && opc == 01)

LDUR <Ht>, [<Xn|SP>{, #<simm>}

32-bit (size == 10 && opc == 01)

LDUR <St>, [<Xn|SP>{, #<simm>}

64-bit (size == 11 && opc == 01)

LDUR <Dt>, [<Xn|SP>{, #<simm>}

128-bit (size == 00 && opc == 11)

LDUR <Qt>, [<Xn|SP>{, #<simm>}

boolean wback = FALSE;
boolean postindex = FALSE;
integer scale = UInt(opc<1>:size);
if scale > 4 then UNDEFINED;
bias(64) offset = 64 if scale > 4 then UnallocatedEncoding();
bias(64) offset = SignExtend(imm9, 64);

Assembler Symbols

<Bt>  Is the 8-bit name of the SIMD&FP register to be transferred, encoded in the "Rt" field.
<Dt>  Is the 64-bit name of the SIMD&FP register to be transferred, encoded in the "Rt" field.
<Ht>  Is the 16-bit name of the SIMD&FP register to be transferred, encoded in the "Rt" field.
<Qt>  Is the 128-bit name of the SIMD&FP register to be transferred, encoded in the "Rt" field.
<St>  Is the 32-bit name of the SIMD&FP register to be transferred, encoded in the "Rt" field.
<Xn|SP> Is the 64-bit name of the general-purpose base register or stack pointer, encoded in the "Rn" field.
<simm> Is the optional signed immediate byte offset, in the range -256 to 255, defaulting to 0 and encoded in the "imm9" field.

Shared Decode

integer n = UInt(Rn);
integer t = UInt(Rt);
AccType acctype = AccType_VEC;
MemOp memop = if opc<0> == '1' then MemOp_LOAD else MemOp_STORE;
integer datasize = 8 << scale;
if HaveMTEExt() then
    boolean is_load_store = memop IN {MemOp_STORE, MemOp_LOAD};
    SetNotTagCheckedInstruction(is_load_store && n == 31 && !wback);

CheckFPAdvSIMDEnabled64();

bits(64) address;
bits(datasize) data;

if n == 31 then
    CheckSPAignment();
    address = SP[];
else
    address = X[n];

if ! postindex then
    address = address + offset;

case memop of
    when MemOp_STORE
        data = V[t];
        Mem[address, datasize DIV 8, acctype] = data;
    when MemOp_LOAD
        data = Mem[address, datasize DIV 8, acctype];
        V[t] = data;

if wback then
    if postindex then
        address = address + offset;
    if n == 31 then
        SP[] = address;
    else
        X[n] = address;

Operational information

If PSTATE.DIT is 1, the timing of this instruction is insensitive to the value of the data being loaded or stored.
LDUR

Load Register (unscaled) calculates an address from a base register and an immediate offset, loads a 32-bit word or 64-bit doubleword from memory, zero-extends it, and writes it to a register. For information about memory accesses, see Load/Store addressing modes.

32-bit (size == 10)

LDUR <Wt>, [<Xn|SP>{, #<simm>}

64-bit (size == 11)

LDUR <Xt>, [<Xn|SP>{, #<simm>}

boolean wback = FALSE;
boolean postindex = FALSE;
integer scale = UInt(size);
bits(64) offset = SignExtend(imm9, 64);

Assembler Symbols

<Wt> Is the 32-bit name of the general-purpose register to be transferred, encoded in the "Rt" field.
<Xt> Is the 64-bit name of the general-purpose register to be transferred, encoded in the "Rt" field.
<Xn|SP> Is the 64-bit name of the general-purpose base register or stack pointer, encoded in the "Rn" field.
<simm> Is the optional signed immediate byte offset, in the range -256 to 255, defaulting to 0 and encoded in the "imm9" field.
integer n = UInt(Rn);
integer t = UInt(Rt);
AccType accType = AccType_NORMAL;
MemOp memop;
boolean signed;
integer regsize;

if opc<1> == '0' then
    // store or zero-extending load
    memop = if opc<0> == '1' then MemOp_LOAD else MemOp_STORE;
    regsize = if size == '11' then 64 else 32;
    signed = FALSE;
else
    if size == '11' then
        memop = MemOp_PREFETCH;
        if opc<0> == '1' then UNDEFINED;
    else
        // sign-extending load
        memop = if opc<0> == '1' then UnallocatedEncoding();
        else
            // sign-extending load
            memop = MemOp_LOAD;
            if size == '10' && opc<0> == '1' then UnallocatedEncoding;
            if size == '10' && opc<0> == '1' then UNDEFINED;
        if opc<0> == '1' then 32 else 64;
        signed = TRUE;

integer datasize = 8 << scale;
if bits(64) address;
bits(datasize) data;
boolean wb_unknown = FALSE;
boolean rt_unknown = FALSE;
if memop == HaveMTEExt() then
    boolean is_load_store = memop IN {MemOp_STORE, MemOp_LOAD};
    SetNotTagCheckedInstruction(is_load_store && n == 31 && !wback);

bits(64) address;
bits(datasize) data;
boolean wb_unknown = FALSE;
boolean rt_unknown = FALSE;
if memop == MemOp_LOAD && wback && n == t && n != 31 then
    c = ConstrunUnpredictable(Unpredictable_WBOVERLAPLD);
    assert c IN {Constraint_WBSUPPRESS, Constraint_UNKNOWN, Constraint_UNDEF, Constraint_NOP};
    case c of
        when Constraint_WBSUPPRESS
            wback = FALSE;       // writeback is suppressed
        when Constraint_UNKNOWN
            wb_unknown = TRUE;   // writeback is UNKNOWN
        when Constraint_UNDEF
            UNDEFINED;
        when UnallocatedEncoding()
            rt_unknown = FALSE;  // value stored is original value
        when Constraint_NOP
            EndOfInstruction();
    end case;

if memop == MemOp_STORE && wback && n == t && n != 31 then
    c = ConstrunUnpredictable(Unpredictable_WBOVERLAPST);
    assert c IN {Constraint_NONE, Constraint_UNKNOWN, Constraint_UNDEF, Constraint_NOP};
    case c of
        when Constraint_NONE
            rt_unknown = FALSE; // value stored is original value
        when Constraint_UNKNOWN
            rt_unknown = TRUE;  // value stored is UNKNOWN
        when Constraint_UNDEF
            UnallocatedEncoding
            UNDEFINED;
        when Constraint_NOP
            EndOfInstruction();
    end case;

if n == 31 then
    if memop != MemOp_PREFETCH then CheckSPAlignment();
    address = SP[];
else
    address = X[n];
if ! postindex then
    address = address + offset;

case memop of
    when MemOp_STORE
        if rt_unknown then
            data = bits(datasize) UNKNOWN;
        else
            data = X[t];
            Mem[address, datasize DIV 8, acctype] = data;
        when MemOp_LOAD
            data = Mem[address, datasize DIV 8, acctype];
            if signed then
                X[t] = SignExtend(data, regsize);
            else
                X[t] = ZeroExtend(data, regsize);
            when MemOp_PREFETCH
                Prefetch(address, t<4:0>);
if wback then
    if wb_unknown then
        address = bits(64) UNKNOWN;
    elsif postindex then
        address = address + offset;
if n == 31 then
    SP[] = address;
else
    X[n] = address;

Operational information

If PSTATE.DIT is 1, the timing of this instruction is insensitive to the value of the data being loaded or stored.
LDURB

Load Register Byte (unscaled) calculates an address from a base register and an immediate offset, loads a byte from memory, zero-extends it, and writes it to a register. For information about memory accesses, see Load/Store addressing modes.

Unscaled offset

LDURB <Wt>, [<Xn|SP>{, #<simm>}] 

boolean wback = FALSE;
boolean postindex = FALSE;
integer scale = UInt(size);
bits(64) offset = SignExtend(imm9, 64);

Assembler Symbols

<Wt> Is the 32-bit name of the general-purpose register to be transferred, encoded in the "Rt" field.
<Xn|SP> Is the 64-bit name of the general-purpose base register or stack pointer, encoded in the "Rn" field.
<simm> Is the optional signed immediate byte offset, in the range -256 to 255, defaulting to 0 and encoded in the "imm9" field.

Shared Decode

integer n = UInt(Rn);
integer t = UInt(Rt);
AccType acctype = AccType_NORMAL;
MemOp memop;
boolean signed;
integer regsize;
if opc<1> == '0' then
    // store or zero-extending load
    memop = if opc<0> == '1' then MemOp_LOAD else MemOp_STORE;
    regsize = if size == '11' then 64 else 32;
    signed = FALSE;
else
    if size == '11' then
        memop = MemOp_PREFETCH;
        if opc<0> == '1' then UNDEFINED;
    else
        // sign-extending load
        memop = if opc<0> == '1' then UnallocatedEncoding();
        else
            // sign-extending load
            memop = if size == '10' && opc<0> == '1' then UnallocatedEncoding();
            if size == '10' && opc<0> == '1' then UNDEFINED;
        //
        regsize = if opc<0> == '1' then 32 else 64;
        signed = TRUE;

    integer datasize = 8 << scale;
Operation
if bits(64) address;
bits(datasize) data;
boolean wb_unknown = FALSE;
boolean rt_unknown = FALSE;

if memop == HaveMTEExt() then
    boolean is_load_store = memop IN {MemOp STORE, MemOp LOAD};
    SetNotTagCheckedInstruction(is_load_store && n == 31 && !wback);

    bits(64) address;
    bits(datasize) data;
    boolean wb_unknown = FALSE;
    boolean rt_unknown = FALSE;

    if memop == MemOp LOAD && wback && n == t && n != 31 then
        c = ConstrainUnpredictable(Unpredictable_WBOVERLAPLD);
        assert c IN {Constraint_WBSUPPRESS, Constraint_UNKNOWN, Constraint_UNDEF, Constraint_NOP};
        case c of
            when Constraint_WBSUPPRESS
                wback = FALSE;       // writeback is suppressed
            when Constraint_UNKNOWN
                wb_unknown = TRUE;   // writeback is UNKNOWN
            when Constraint_UNDEF
                UNDEFINED;
            when UnallocatedEncoding()
            when Constraint_NOP
                EndOfInstruction();

    if memop == MemOp STORE && wback && n == t && n != 31 then
        c = ConstrainUnpredictable(Unpredictable_WBOVERLAPST);
        assert c IN {Constraint_NONE, Constraint_UNKNOWN, Constraint_UNDEF, Constraint_NOP};
        case c of
            when Constraint_NONE
                rt_unknown = FALSE;  // value stored is original value
            when Constraint_UNKNOWN
                rt_unknown = TRUE;   // value stored is UNKNOWN
            when Constraint_UNDEF
                UnallocatedEncoding
                UNDEFINED;
        end;
            when Constraint_NOP
                EndOfInstruction();

    if n == 31 then
        if memop != MemOp_PREFETCH then CheckSPAlignment();
        address = SP[ ];
    else
        address = X[n];

    if ! postindex then
        address = address + offset;

    case memop of
        when MemOp STORE
            if rt_unknown then
                data = bits(datasize) UNKNOWN;
            else
                data = X[t];
        Mem[address, datasize DIV 8, acctype] = data;

        when MemOp LOAD
            data = Mem[address, datasize DIV 8, acctype];
            if signed then
                X[t] = SignExtend(data, regsize);
            else
                X[t] = ZeroExtend(data, regsize);

            when MemOp_PREFETCHPrefetch(address, t<4:0>);

        if wback then
            if wb_unknown then
                address = bits(64) UNKNOWN;
            elsif postindex then
                address = address + offset;
            if n == 31 then
                SP[ ] = address;
else
    X[n] = address;

**Operational information**

If PSTATE.DIT is 1, the timing of this instruction is insensitive to the value of the data being loaded or stored.
LDURH

Load Register Halfword (unscaled) calculates an address from a base register and an immediate offset, loads a halfword from memory, zero-extends it, and writes it to a register. For information about memory accesses, see Load/Store addressing modes.

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9  | 8  | 7  | 6  | 5  | 4  | 3  | 2  | 1  | 0  |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0  | 1  | 1  | 1  | 0  | 0  | 0  | 0  | 1  | 0  | imm9| 0  | 0  | Rn | Rt |

**Unscaled offset**

LDURH `<Wt>`, `<Xn|SP>{, #<simm>}`

boolean wback = FALSE;
boolean postindex = FALSE;
integer scale = UINT(size);
bite(64) offset = SignExtend(imm9, 64);

**Assembler Symbols**

`<Wt>` Is the 32-bit name of the general-purpose register to be transferred, encoded in the "Rt" field.

`<Xn|SP>` Is the 64-bit name of the general-purpose base register or stack pointer, encoded in the "Rn" field.

`<simm>` Is the optional signed immediate byte offset, in the range -256 to 255, defaulting to 0 and encoded in the "imm9" field.

**Shared Decode**

```plaintext
integer n = UINT(Rn);
integer t = UINT(Rt);
AccType acctype = AccType_NORMAL;
MemOp memop;
boolean signed;
integer regsize;
if opc<1> == '0' then
    // store or zero-extending load
    memop = if opc<0> == '1' then MemOp_LOAD else MemOp_STORE;
    regsize = if size == '11' then 64 else 32;
    signed = FALSE;
else
    if size == '11' then
        memop = MemOp_PREFETCH;
    else
        if opc<0> == '1' then UNDEFINED;
    // sign-extending load
    memop = if opc<0> == '1' then UnallocatedEncoding();
else
    // sign-extending load
    memop = MemOp_LOAD;
    if size == '10' && opc<0> == '1' then UnallocatedEncoding();
    if size == '10' && opc<0> == '1' then UNDEFINED;
    regsize = if opc<0> == '1' then 32 else 64;
    signed = TRUE;
integer datasize = 8 << scale;
```
if bits(64) address;
bites(datasize) data;
boolean wb_unknown = FALSE;
boolean rt_unknown = FALSE;

if memop == HaveMTEExt() then
    boolean is_load_store = memop IN {MemOp_STORE, MemOp_LOAD};
    SetNotTagCheckedInstruction(is_load_store && n == 31 && !wback);

bits(64) address;
bites(datasize) data;

boolean wb_unknown = FALSE;
boolean rt_unknown = FALSE;

if memop == MemOp_LOAD && wback && n == t && n != 31 then
    c = ConstrainUnpredictable(Unpredictable_WBOVERLAPLD);
    assert c IN {Constraint_WBSUPPRESS, Constraint_UNKNOWN, Constraint_UNDEF, Constraint_NOP};
    case c of
        when Constraint_WBSUPPRESS wback = FALSE; // writeback is suppressed
        when Constraint_UNKNOWN wb_unknown = TRUE; // writeback is UNKNOWN
        when Constraint_UNDEF rt_unknown = TRUE; // value stored is UNKNOWN
        when AllocatingUnpredictable UNDEFINED;
        when Constraint_NOP EndOfInstruction();

if memop == MemOp_STORE && wback && n == t && n != 31 then
    c = ConstrainUnpredictable(Unpredictable_WBOVERLAPST);
    assert c IN {Constraint_NONE, Constraint_UNKNOWN, Constraint_UNDEF, Constraint_NOP};
    case c of
        when Constraint_NONE rt_unknown = FALSE; // value stored is original value
        when Constraint_UNKNOWN rt_unknown = TRUE; // value stored is UNKNOWN
        when Constraint_UNDEF rt_unknown = TRUE; // value stored is UNKNOWN
        when AllocatingUnpredictable UNDEFINED;
        when Constraint_NOP EndOfInstruction();

if n == 31 then
    if memop != MemOp_PREFETCH then CheckSPAlignment();
    address = SP[];
else
    address = X[n];

if ! postindex then
    address = address + offset;

case memop of
    when MemOp_STORE
        if rt_unknown then
            data = bits(datasize) UNKNOWN;
        else
            data = X[t];
            Mem[address, datasize DIV 8, acctype] = data;
    when MemOp_LOAD
        data = Mem[address, datasize DIV 8, acctype];
        if signed then
            X[t] = SignExtend(data, regsize);
        else
            X[t] = ZeroExtend(data, regsize);
    when MemOp_PREFETCHPrefetch(address, t<4:0>);

if wback then
    if wb_unknown then
        address = bits(64) UNKNOWN;
    elsif postindex then
        address = address + offset;
    if n == 31 then
        SP[] = address;
else
    \text{X}[n] = \text{address};

\textbf{Operational information}

If PSTATE.DIT is 1, the timing of this instruction is insensitive to the value of the data being loaded or stored.
LDURSB

Load Register Signed Byte (unscaled) calculates an address from a base register and an immediate offset, loads a signed byte from memory, sign-extends it, and writes it to a register. For information about memory accesses, see *Load/Store addressing modes*.

| 31  | 30  | 29  | 28  | 27  | 26  | 25  | 24  | 23  | 22  | 21  | 20  | 19  | 18  | 17  | 16  | 15  | 14  | 13  | 12  | 11  | 10  | 9   | 8   | 7   | 6   | 5   | 4   | 3   | 2   | 1   | 0   |
|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| 0   | 0   | 1   | 1   | 0   | 0   | 1   | x   | 0   | imm9| 0   | 0   | Rn  |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |

**32-bit (opc == 11)**

```plaintext
LDURSB <Wt>, [<Xn|SP>{, #<simm>}
```

**64-bit (opc == 10)**

```plaintext
LDURSB <Xt>, [<Xn|SP>{, #<simm>}
```

boolean wback = FALSE;
boolean postindex = FALSE;
integer scale = UInt(size);
bits(64) offset = SignExtend(imm9, 64);

**Assembler Symbols**

- `<W>` Is the 32-bit name of the general-purpose register to be transferred, encoded in the "Rt" field.
- `<X>` Is the 64-bit name of the general-purpose register to be transferred, encoded in the "Rt" field.
- `<Xn|SP>` Is the 64-bit name of the general-purpose base register or stack pointer, encoded in the "Rn" field.
- `<simm>` Is the optional signed immediate byte offset, in the range -256 to 255, defaulting to 0 and encoded in the "imm9" field.
integer n = UInt(Rn);
integer t = UInt(Rt);
AccType acctype = AccType_NORMAL;
MemOp memop;
boolean signed;
integer regsize;

if opc<1> == '0' then
    // store or zero-extending load
    memop = if opc<0> == '1' then MemOp_LOAD else MemOp_STORE;
    regsize = if size == '11' then 64 else 32;
    signed = FALSE;
else
    if size == '11' then
        memop = MemOp_PREFETCH;
        if opc<0> == '1' then UNDEFINED;
    else
        // sign-extending load
        memop = if opc<0> == '1' then UnallocatedEncoding();
        else
            // sign-extending load
            memop = MemOp_LOAD;
            if size == '10' && opc<0> == '1' then UnallocatedEncoding();
            if size == '10' && opc<0> == '1' then UNDEFINED;
        
        regsize = if opc<0> == '1' then 32 else 64;
        signed = TRUE;

integer datasize = 8 << scale;
if memop == MemOp_STORE then
    assert c IN {Constraint_NONE, Constraint_UNKNOWN, Constraint_UNDEF, Constraint_NOP};
case c of
    when Constraint_NONE rt_unknown = FALSE; // value stored is original value
    when Constraint_UNKNOWN rt_unknown = TRUE; // value stored is UNKNOWN
    when Constraint_UNDEF UnallocatedEncoding;
    when Constraint_NOP EndOfInstruction();

if memop == MemOp_STORE if ! wback then
    address = bits(64) UNKNOWN;
elsif postindex then
    address = address + offset;
end case memop of
when MemOp_STORE
    if rt_unknown then
        data = bits(datasize) UNKNOWN;
    else
        data = \textit{X}[t];
        \textit{Mem}[address, datasize \div 8, acctype] = data;
    end if
    when MemOp_LOAD
        data = \textit{Mem}[address, datasize \div 8, acctype];
        if signed then
            \textit{X}[t] = \text{SignExtend}(data, regsize);
        else
            \textit{X}[t] = \text{ZeroExtend}(data, regsize);
        end if
        when MemOp_PREFETCH(address, t<4:0>);

if wback then
    if wb_unknown then
        address = bits(64) UNKNOWN;
    elsif postindex then
        address = address + offset;
    end if
end if

if n == 31 then
    if memop != MemOp_PREFETCH then CheckSPAlignment();
    address = SP[];
else
    address = \textit{X}[n];
end if

if ! postindex then
    address = address + offset;
end if
else
    X[n] = address;

Operational information

If PSTATE.DIT is 1, the timing of this instruction is insensitive to the value of the data being loaded or stored.
LDURSH

Load Register Signed Halfword (unscaled) calculates an address from a base register and an immediate offset, loads a signed halfword from memory, sign-extends it, and writes it to a register. For information about memory accesses, see Load/Store addressing modes.

32-bit (opc == 11)

LDURSH <Wt>, [<Xn|SP>{, #<simm>}

64-bit (opc == 10)

LDURSH <Xt>, [<Xn|SP>{, #<simm>}

boolean wback = FALSE;
boolean postindex = FALSE;
integer scale = UInt(size);
bits(64) offset = SignExtend(imm9, 64);

Assembler Symbols

<Wt> Is the 32-bit name of the general-purpose register to be transferred, encoded in the "Rt" field.
<Xt> Is the 64-bit name of the general-purpose register to be transferred, encoded in the "Rt" field.
<Xn|SP> Is the 64-bit name of the general-purpose base register or stack pointer, encoded in the "Rn" field.
<simm> Is the optional signed immediate byte offset, in the range -256 to 255, defaulting to 0 and encoded in the "imm9" field.
integer n = UInt(Rn);
integer t = UInt(Rt);
AccType acctype = AccType_NORMAL;
MemOp memop;
boolean signed;
integer regsize;

if opc<1> == '0' then
   // store or zero-extending load
   memop = if opc<0> == '1' then MemOp_LOAD else MemOp_STORE;
   regsize = if size == '11' then 64 else 32;
   signed = FALSE;
else
   if size == '11' then
      memop = MemOp_PREFETCH;
      if opc<0> == '1' then UNDEFINED;
   else
      // sign-extending load
      memop = if opc<0> == '1' then UnallocatedEncoding();
   
   else
      // sign-extending load
      memop = MemOp_LOAD;
      if size == '10' && opc<0> == '1' then UnallocatedEncoding;
      if size == '10' && opc<0> == '1' then UNDEFINED;

regsize = if opc<0> == '1' then 32 else 64;
signed = TRUE;

integer datasize = 8 << scale;
if bits(64) address;
bites(datasize) data;
boolean wb_unknown = FALSE;
boolean rt_unknown = FALSE;

if memop == HaveMTEExt() then
    boolean is_load_store = memop IN {MemOp STORE, MemOp LOAD};
    SetNotTagCheckedInstruction(is_load_store && n == 31 && !wback);

bits(64) address;
bites(datasize) data;
boolean wb_unknown = FALSE;
boolean rt_unknown = FALSE;

if memop == MemOp LOAD && wback && n == t && n != 31 then
    c = ConstratUnpredictable(Unpredictable_WBOVERLAPLD);
    assert c IN {Constraint_WBSUPPRESS, Constraint_UNKNOWN, Constraint_UNDEF, Constraint_NOP};
case c of
    when Constraint_WBSUPPRESS wback = FALSE;  // writeback is suppressed
    when Constraint_UNKNOWN wb_unknown = TRUE;  // writeback is UNKNOWN
    when Constraint_UNDEF rt_unknown = TRUE;  // value stored is UNKNOWN
    when UnallocatedEncoding();
    when Constraint_NOP EndOfInstruction();

if memop == MemOp STORE && wback && n == t && n != 31 then
    c = ConstratUnpredictable(Unpredictable_WBOVERLAPST);
    assert c IN {Constraint_NONE, Constraint_UNKNOWN, Constraint_UNDEF, Constraint_NOP};
case c of
    when Constraint_NONE rt_known = FALSE;  // value stored is original value
    when Constraint_UNKNOWN rt_known = TRUE;  // value stored is UNKNOWN
    when Constraint_UNDEF rt_known = TRUE;  // value stored is UNKNOWN
    when UnallocatedEncoding();
    when Constraint_NOP EndOfInstruction();

if n == 31 then
    if memop != MemOp_PREFETCH then CheckSPAlignment();
    address = SP();
else
    address = X[t];

if !postindex then
    address = address + offset;

case memop of
    when MemOp STORE
        if rt_unknown then
            data = bits(datasize) UNKNOWN;
        else
            data = X[t];
        end;
        Mem[address, datasize DIV 8, acctype] = data;
    when MemOp LOAD
        data = Mem[address, datasize DIV 8, acctype];
        if signed then
            X[t] = SignExtend(data, regsize);
        else
            X[t] = ZeroExtend(data, regsize);
        end;
    when MemOp_PREFETCH(Prefetch(address, t<4:0>));

if wback then
    if wb_unknown then
        address = bits(64) UNKNOWN;
    elsif postindex then
        address = address + offset;
    end;
    if n == 31 then
        SP[] = address;
else
    X[n] = address;

Operational information

If PSTATE.DIT is 1, the timing of this instruction is insensitive to the value of the data being loaded or stored.
LDURSW

Load Register Signed Word (unscaled) calculates an address from a base register and an immediate offset, loads a signed word from memory, sign-extends it, and writes it to a register. For information about memory accesses, see Load/Store addressing modes.

Unscaled offset

LDURSW \(<X_t>, [<X_n|SP>{, #<simm>}]\)

boolean wback = FALSE;
boolean postindex = FALSE;
integer scale = UInt(size);
bits(64) offset = SignExtend(imm9, 64);

Assembler Symbols

\(<X_t>\) Is the 64-bit name of the general-purpose register to be transferred, encoded in the "Rt" field.
\(<X_n|SP>\) Is the 64-bit name of the general-purpose base register or stack pointer, encoded in the "Rn" field.
\(<simm>\) Is the optional signed immediate byte offset, in the range -256 to 255, defaulting to 0 and encoded in the "imm9" field.

Shared Decode

integer n = UInt(Rn);
integer t = UInt(Rt);
AccType acctype = AccType_NORMAL;
MemOp memop;
boolean signed;
integer regsize;
if opc<1> == '0' then // store or zero-extending load
    memop = if opc<0> == '1' then MemOp_LOAD else MemOp_STORE;
    regsize = if size == '11' then 64 else 32;
    signed = FALSE;
else if size == '11' then
    memop = MemOp_PREFETCH;
    if opc<0> == '1' then UNDEFINED;
else
    // sign-extending load
    memop = if opc<0> == '1' then UnallocatedEncoding() else if size == '10' && opc<0> == '1' then UnallocatedEncoding;
else
    // sign-extending load
    memop = MemOp_LOAD;
    if size == '10' && opc<0> == '1' then UnallocatedEncoding;
    if size == '10' && opc<0> == '1' then UNDEFINED;
if opc<0> == '1' then
    regsize = if opc<0> == '1' then 32 else 64;
    signed = TRUE;
integer datasize = 8 << scale;
if bits(64) address;
bits(datasize) data;
boolean wb_unknown = FALSE;
boolean rt_unknown = FALSE;

if memop == MemOp_PREFETCH() then
    CheckSPAInAlignment();
    address = SP[];
else
    address = X[n];
if ! postindex then
    address = address + offset;

if memop == MemOp_STORE && wback && n == t && n != 31 then
    c = ConstrUnpredictable(Unpredictable_WBOVERLAPLD);
    assert c IN {Constraint_WBSUPPRESS, Constraint_UNKNOWN, Constraint_UNDEF, Constraint_NOP};
case c of
    when Constraint_WBSUPPRESS wback = FALSE; // writeback is suppressed
    when Constraint_UNKNOWN wb_unknown = TRUE; // writeback is UNKNOWN
    when Constraint_UNDEF rt_unknown = UNDEFINED;
    when UnallocatedEncoding()
    when Constraint_NOP EndOfInstruction();

if memop == MemOp_STORE && wback && n == t && n != 31 then
    c = ConstrUnpredictable(Unpredictable_WBOVERLAPST);
    assert c IN {Constraint_NONE, Constraint_UNKNOWN, Constraint_UNDEF, Constraint_NOP};
case c of
    when Constraint_NONE rt_unknown = FALSE; // value stored is original value
    when Constraint_UNKNOWN rt_unknown = TRUE; // value stored is UNKNOWN
    when Constraint_UNDEF UnallocatedEncoding UNDEFINED;
    when Constraint_NOP EndOfInstruction();

if n == 31 then
    if memop != MemOp_PREFETCH then CheckSPAInAlignment();
    address = SP[];
else
    address = X[n];
if ! postindex then
    address = address + offset;

if memop == MemOp_STORE
    if rt_unknown then
        data = bits(datasize) UNKNOWN;
    else
        data = X[t];
    Mem[address, datasize DIV 8, acctype] = data;

if memop == MemOp_LOAD
    data = Mem[address, datasize DIV 8, acctype];
    if signed then
        X[t] = SignExtend(data, regsize);
    else
        X[t] = ZeroExtend(data, regsize);
    when MemOp_PREFETCHPrefetch(address, t<4:0>);
else
    \( X[n] = \text{address}; \)

Operational information

If PSTATE.DIT is 1, the timing of this instruction is insensitive to the value of the data being loaded or stored.
LDXP

Load Exclusive Pair of Registers derives an address from a base register value, loads two 32-bit words or two 64-bit doublewords from memory, and writes them to two registers. A 32-bit pair requires the address to be doubleword aligned and is single-copy atomic at doubleword granularity. A 64-bit pair requires the address to be quadword aligned and is single-copy atomic for each doubleword at doubleword granularity. The PE marks the physical address being accessed as an exclusive access. This exclusive access mark is checked by Store Exclusive instructions. See Synchronization and semaphores. For information about memory accesses see Load/Store addressing modes.

See Synchronization and semaphores. For information about memory accesses see Load/Store addressing modes.

Assembler Symbols

\(<\text{Wt1}>\) Is the 32-bit name of the first general-purpose register to be transferred, encoded in the "Rt" field.

\(<\text{Wt2}>\) Is the 32-bit name of the second general-purpose register to be transferred, encoded in the "Rt2" field.

\(<\text{Xt1}>\) Is the 64-bit name of the first general-purpose register to be transferred, encoded in the "Rt" field.

\(<\text{Xt2}>\) Is the 64-bit name of the second general-purpose register to be transferred, encoded in the "Rt2" field.

\(<\text{Xn}\vert\text{SP}>\) Is the 64-bit name of the general-purpose base register or stack pointer, encoded in the "Rn" field.
Operation
bits(64) address;
bits(datasize) data;
constant integer dbytes = datasize DIV 8;
boolean rt_unknown = FALSE;
boolean rn_unknown = FALSE;

if memop == HaveMTEExt() then
    boolean is_load_store = memop IN {MemOp STORE, MemOp LOAD};
    SetNotTagCheckedInstruction(is_load_store && n == 31);

if memop == MemOp LOAD && pair && t == t2 then
    Constraint c = ConstrainUnpredictable(Unpredictable_LDPOVERLAP);
    assert c IN {Constraint_UNKNOWN, Constraint_UNDEF, Constraint_NOP};
    case c of
        when Constraint_UNKNOWN rt_unknown = TRUE;   // result is UNKNOWN
        when Constraint_UNDEF rt_unknown = FALSE;    // result is FALSE
        when Constraint_NOP EndOfInstruction();

if memop == MemOp STORE then
    if s == t || (pair && s == t2) then
        Constraint c = ConstrainUnpredictable(Unpredictable_DATAOVERLAP);
        assert c IN {Constraint_UNKNOWN, Constraint_NONE, Constraint_UNDEF, Constraint_NOP};
        case c of
            when Constraint_UNKNOWN rt_unknown = TRUE;   // store UNKNOWN value
            when Constraint_NONE rt_known = FALSE;       // store original value
            when Constraint_UNDEF EndOfInstruction();
        end;
    end;

if n == 31 then
    CheckSPAlignment();
    address = SP[];
elsif rn_unknown then
    address = bits(64) UNKNOWN;
else
    address = X[n];
end;

case memop of
    when MemOp STORE
        if rt_unknown then
            data = bits(datasize) UNKNOWN;
        elsif pair then
            bits(datasize DIV 2) el1 = X[t];
            bits(datasize DIV 2) el2 = X[t2];
            data = if BigEndian() then el1 : el2 else el2 : el1;
        else
            data = X[t];
        end;
        bit status = '1';
        // Check whether the Exclusives monitors are set to include the
        // physical memory locations corresponding to virtual address
        // range [address, address+dbytes-1].
        if AArch64.ExclusiveMonitorsPass(address, dbytes) then
            // This atomic write will be rejected if it does not refer
            // to the same physical locations after address translation.
            Mem[address, dbytes, acctype] = data;
            status = ExclusiveMonitorsStatus();
        end;
        X[s] = ZeroExtend(status, 32);
    end;

when MemOp LOAD
// Tell the Exclusives monitors to record a sequence of one or more atomic
// memory reads from virtual address range [address, address+dbytes-1].
// The Exclusives monitor will only be set if all the reads are from the
// same dbytes-aligned physical address, to allow for the possibility of
// an atomicity break if the translation is changed between reads.
AArch64.SetExclusiveMonitors(address, dbytes);

if pair then
  if rt_unknown then
    // ConstrainedUNPREDICTABLE case
    X[t] = bits(datasize) UNKNOWN;
  elsif elsize == 32 then
    // 32-bit load exclusive pair (atomic)
    data = Mem[address, dbytes, acctype];
    if BigEndian() then
      X[t] = data<datasize-1:elsize>;
      X[t2] = data<elsize-1:0>;
    else
      X[t] = data<elsize-1:0>;
      X[t2] = data<datasize-1:elsize>;
    else // elsize == 64
      // 64-bit load exclusive pair (not atomic),
      // but must be 128-bit aligned
      if address != Align(address, dbytes) then
        iswrite = FALSE;
        secondstage = FALSE;
        AArch64.Abort(address, AArch64.AlignmentFault(acctype, iswrite, secondstage));
      else
        data = Mem[address + 0, 8, acctype];
        X[t] = Mem[address + 8, 8, acctype];
        X[t2] = Mem[address + 0, 8, acctype];
      end if
    end if
  end if
else // elsize == 64
  // 64-bit load exclusive pair (not atomic),
  // but must be 128-bit aligned
  if address != Align(address, dbytes) then
    iswrite = FALSE;
    secondstage = FALSE;
    AArch64.Abort(address, AArch64.AlignmentFault(acctype, iswrite, secondstage));
  else
    data = Mem[address, dbytes, acctype];
    X[t] = ZeroExtend(data, regsize);
  end if
end if

Operational information

If PSTATE.DIT is 1, the timing of this instruction is insensitive to the value of the data being loaded or stored.
LDXR

Load Exclusive Register derives an address from a base register value, loads a 32-bit word or a 64-bit doubleword from memory, and writes it to a register. The memory access is atomic. The PE marks the physical address being accessed as an exclusive access. This exclusive access mark is checked by Store Exclusive instructions. See Synchronization and semaphores. For information about memory accesses see Load/Store addressing modes.

32-bit (size == 10)

LDXR <Wt>, [<Xn|SP>{,#0}]

64-bit (size == 11)

LDXR <Xt>, [<Xn|SP>{,#0}]

integer n = UInt(Rn);
integer t = UInt(Rt);
integer t2 = UInt(Rt2); // ignored by load/store single register
integer s = UInt(Rs);   // ignored by all loads and store-release

AccType accctype = if o0 == '1' then AccType_ORDERED_ATOMIC else AccType_ATOMIC;
boolean pair = FALSE;
MemOp memop = if L == '1' then MemOp_LOAD else MemOp_STORE;
integer elsize = 8 << UInt(size);
integer regsize = if elsize == 64 then 64 else 32;
integer datasize = if pair then elsize * 2 else elsize;

Assembler Symbols

<Wt> Is the 32-bit name of the general-purpose register to be transferred, encoded in the "Rt" field.
<Xt> Is the 64-bit name of the general-purpose register to be transferred, encoded in the "Rt" field.
<Xn|SP> Is the 64-bit name of the general-purpose base register or stack pointer, encoded in the "Rn" field.
bits(64) address;
bhits(datasize) data;
constant integer dbytes = datasize DIV 8;
boolean rt_unknown = FALSE;
boolean rn_unknown = FALSE;

if memop == HaveMTEExt() then
    boolean is_load_store = memop IN {MemOp STORE, MemOp LOAD};
    SetNotTagCheckedInstruction(is_load_store && n == 31);

if memop == MemOp LOAD && pair && t == t2 then
    Constraint c = ConstrainUnpredictable(Unpredictable LDPOVERLAP);
    assert c IN {Constraint_UNKNOWN, Constraint_UNDEF, Constraint_NOP};
    case c of
        when Constraint_UNKNOWN rt_unknown = TRUE; // result is UNKNOWN
        when Constraint_UNDEF UNDEFINED;
        when Constraint_NOP EndOfInstruction();
    if memop == MemOp STORE then
        if s == t || (pair && s == t2) then
            Constraint c = ConstrainUnpredictable(Unpredictable DATAOVERLAP);
            assert c IN {Constraint_UNKNOWN, Constraint_NONE, Constraint_UNDEF, Constraint_NOP};
            case c of
                when Constraint_UNKNOWN rt_unknown = TRUE; // store UNKNOWN value
                when Constraint_NONE rt_unknown = FALSE; // store original value
                when Constraint_UNDEF UNDEFINED;
                when UnallocatedEncoding() EndOfInstruction();
        if s == n && n != 31 then
            Constraint c = ConstrainUnpredictable(Unpredictable BASEOVERLAP);
            assert c IN {Constraint_UNKNOWN, Constraint_NONE, Constraint_UNDEF, Constraint_NOP};
            case c of
                when Constraint_UNKNOWN rn_unknown = TRUE; // address is UNKNOWN
                when Constraint_NONE rn_unknown = FALSE; // address is original base
                when Constraint_UNDEF UnallocatedEncoding UNDEFINED;
            if n == 31 then
                CheckSPAlignment();
                address = SP[ ];
            elsif rn_unknown then
                address = bits(64) UNKNOWN;
            else
                address = X[n];
            case memop of
                when MemOp STORE
                    if rt_unknown then
                        data = bits(datasize) UNKNOWN;
                    elsif pair then
                        bits(datasize DIV 2) el1 = X[t];
                        bits(datasize DIV 2) el2 = X[t2];
                        data = if BigEndian() then el1 : el2 else el2 : el1;
                    else
                        data = X[t];
                    bit status = '1';
                    // Check whether the Exclusives monitors are set to include the
                    // physical memory locations corresponding to virtual address
                    // range [address, address+dbytes-1].
                    if AArch64.ExclusiveMonitorsPass(address, dbytes) then
                        // This atomic write will be rejected if it does not refer
                        // to the same physical locations after address translation.
                        Mem[address, dbytes, acctype] = data;
                        status = ExclusiveMonitorsStatus();
                        X[s] = ZeroExtend(status, 32);
                    WHEN MemOp LOAD

LDXR Page 847
// Tell the Exclusives monitors to record a sequence of one or more atomic
// memory reads from virtual address range [address, address+dbytes-1].
// The Exclusives monitor will only be set if all the reads are from the
// same dbytes-aligned physical address, to allow for the possibility of
// an atomicity break if the translation is changed between reads.
AArch64.SetExclusiveMonitors(address, dbytes);

if pair then
  if rt_unknown then
    // ConstrainedUNPREDICTABLE case
    X[t] = bits(datasize) UNKNOWN;
  elsif elsize == 32 then
    // 32-bit load exclusive pair (atomic)
    data = Mem[address, dbytes, acctype];
    if BigEndian() then
      X[t] = data<datasize-1:elsize>;
      X[t2] = data<elsize-1:0>;
    else
      X[t] = data<elsize-1:0>;
      X[t2] = data<datasize-1:elsize>;
  else // elsize == 64
    // 64-bit load exclusive pair (not atomic),
    // but must be 128-bit aligned
    if address != Align(address, dbytes) then
      iswrite = FALSE;
      secondstage = FALSE;
      AArch64.Abort(address, AArch64.AlignmentFault(acctype, iswrite, secondstage));
    X[t] = Mem[address + 0, 8, acctype];
    X[t2] = Mem[address + 8, 8, acctype];
  else
    data = Mem[address, dbytes, acctype];
    X[t] = ZeroExtend(data, regsize);

Operational information

If PSTATE.DIT is 1, the timing of this instruction is insensitive to the value of the data being loaded or stored.
LDXRB

Load Exclusive Register Byte derives an address from a base register value, loads a byte from memory, zero-extends it and writes it to a register. The memory access is atomic. The PE marks the physical address being accessed as an exclusive access. This exclusive access mark is checked by Store Exclusive instructions. See *Synchronization and semaphores*. For information about memory accesses see *Load/Store addressing modes*.

| 31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10  9  8  7  6  5  4  3  2  1  0 |
| 0 0 0 1 0 0 0 0 1 0 | 1 | 0 | (1) | (1) | (1) | (1) | 0 | (1) | (1) | (1) | (1) | Rn | Rt |
| size | L | Rs | o0 | Rt2 |

No offset

**LDXRB** `<Wt>`, ` [<Xn|SP>], #0>`

`integer n = UInt(Rn);`
`integer t = UInt(Rt);`
`integer t2 = UInt(Rt2); // ignored by load/store single register`
`integer s = UInt(Rs);   // ignored by all loads and store-release`

AccType acctype = if o0 == '1' then AccType_ORDERED_ATOMIC else AccType_ATOMIC;
boolean pair = FALSE;
MemOp memop = if L == '1' then MemOp_LOAD else MemOp_STORE;
integer elsize = 8 << UInt(size);
integer datasize = if pair then elsize * 2 else elsize;

Assembler Symbols

`<Wt>` Is the 32-bit name of the general-purpose register to be transferred, encoded in the "Rt" field.

`<Xn|SP>` Is the 64-bit name of the general-purpose base register or stack pointer, encoded in the "Rn" field.
bits(64) address;
bits(datasize) data;
constant integer dbytes = datasize DIV 8;
boolean rt_unknown = FALSE;
boolean rn_unknown = FALSE;

if memop == HaveMTEExt() then
    boolean is_load_store = memop IN {MemOp STORE, MemOp LOAD} ;
    SetNotTagCheckedInstruction(is_load_store && n == 31);
endif

if memop == MemOp LOAD && pair && t == t2 then
    Constraint c = ConstrainUnpredictable(Unpredictable_LDPOVERLAP);
assert c IN {Constraint_UNKNOWN, Constraint_UNDEF, Constraint_NOP};
case c of
    when Constraint_UNKNOWN rt_unknown = TRUE; // result is UNKNOWN
    when Constraint_UNDEF rt_unknown = FALSE; // store original value
    when Constraint_NOP EndOfInstruction();
endif

if memop == MemOp STORE then
    if s == t || (pair && s == t2) then
        Constraint c = ConstrainUnpredictable(Unpredictable_DATAOVERLAP);
assert c IN {Constraint_UNKNOWN, Constraint_NONE, Constraint_UNDEF, Constraint_NOP};
case c of
    when Constraint_UNKNOWN rt_unknown = TRUE; // store UNKNOWN value
    when Constraint_NONE rt_unknown = FALSE; // store original value
    when Constraint_UNDEF EndOfInstruction();
    when Constraint_NOP EndOfInstruction();
endif
if s == n && n != 31 then
    Constraint c = ConstrainUnpredictable(Unpredictable_BASEOVERLAP);
assert c IN {Constraint_UNKNOWN, Constraint_NONE, Constraint_UNDEF, Constraint_NOP};
case c of
    when Constraint_UNKNOWN rn_unknown = TRUE; // address is UNKNOWN
    when Constraint_NONE rn_unknown = FALSE; // address is original base
    when Constraint_UNDEF EndOfInstruction();
endif
if n == 31 then
    CheckSPAlignment();
    address = SP[];
elsif rn_unknown then
    address = bits(64) UNKNOWN;
else
    address = X[n];
endif

case memop of
    when MemOp STORE
        if rt_unknown then
            data = bits(datasize) UNKNOWN;
        elsif pair then
            bits(datasize DIV 2) el1 = X[t];
            bits(datasize DIV 2) el2 = X[t2];
            data = if BigEndian() then el1 : el2 else el2 : el1;
        else
            data = X[t];
        endif
        bit status = '1';
        // Check whether the Exclusives monitors are set to include the
        // physical memory locations corresponding to virtual address
        // range [address, address+dbytes-1].
        if AArch64.ExclusiveMonitorsPass(address, dbytes) then
            // This atomic write will be rejected if it does not refer
            // to the same physical locations after address translation.
            Mem[address, dbytes, acctype] = data;
            status = ExclusiveMonitorsStatus();
            X[s] = ZeroExtend(status, 32);
        endif
    endif
when MemOp LOAD
// Tell the Exclusives monitors to record a sequence of one or more atomic
// memory reads from virtual address range [address, address+dbytes-1].
// The Exclusives monitor will only be set if all the reads are from the
// same dbytes-aligned physical address, to allow for the possibility of
// an atomicity break if the translation is changed between reads.
AArch64.SetExclusiveMonitors(address, dbytes);

if pair then
  if rt_unknown then
    // ConstrainedUNPREDICTABLE case
    X[t] = bits(datasize) UNKNOWN;
  elsif elsize == 32 then
    // 32-bit load exclusive pair (atomic)
    data = Mem[address, dbytes, acctype];
    if BigEndian() then
      X[t] = data<datasize-1:elsize>;
      X[t2] = data<elsize-1:0>;
    else
      X[t] = data<elsize-1:0>;
      X[t2] = data<datasize-1:elsize>;
  else // elsize == 64
    // 64-bit load exclusive pair (not atomic),
    // but must be 128-bit aligned
    if address != Align(address, dbytes) then
      iswrite = FALSE;
      secondstage = FALSE;
      AArch64.Abort(address, AArch64.AlignmentFault(acctype, iswrite, secondstage));
    X[t] = Mem[address + 0, 8, acctype];
    X[t2] = Mem[address + 8, 8, acctype];
  else
    data = Mem[address, dbytes, acctype];
    X[t] = ZeroExtend(data, regsize);
  end

Operational information

If PSTATE.DIT is 1, the timing of this instruction is insensitive to the value of the data being loaded or stored.
LDXRH

Load Exclusive Register Halfword derives an address from a base register value, loads a halfword from memory, zero-extends it and writes it to a register. The memory access is atomic. The PE marks the physical address being accessed as an exclusive access. This exclusive access mark is checked by Store Exclusive instructions. See Synchronization and semaphores. For information about memory accesses see Load/Store addressing modes.

No offset

LDXRH <Wt>, [<Xn|SP>{,0}]

integer n = UInt(Rn);
integer t = UInt(Rt);
integer t2 = UInt(Rt2); // ignored by load/store single register
integer s = UInt(Rs);   // ignored by all loads and store-release

AccType acctype = if o0 == '1' then AccType_ORDEREDATOMIC else AccType_ATOMIC;
boolean pair = FALSE;
MemOp memop = if L == '1' then MemOp_LOAD else MemOp_STORE;
integer elsize = 8 << UInt(size);
integer datasize = if pair then elsize * 2 else elsize;

Assembler Symbols

<Wt> Is the 32-bit name of the general-purpose register to be transferred, encoded in the "Rt" field.
<Xn|SP> Is the 64-bit name of the general-purpose base register or stack pointer, encoded in the "Rn" field.
bits(64) address;
b借贷 datatise) data;
constant integer dbytes = datatise DIV 8;
boolean rt_unknown = FALSE;
boolean rn_unknown = FALSE;

if memop == HaveMTEExt() then
    SetNotTagCkeckedInstruction(is_load_store & n == 31);

if memop == MemOp LOAD then
    MemOp LOAD & pair & t == t2 then
        Constraint c = ConstrainUnpredictable(Unpredictable_LDPOVERLAP);
        assert c IN {Constraint_UNKNOWN, Constraint_UNDEF, Constraint_NOP};
        case c of
            when Constraint_UNKNOWN rt unknown = TRUE;  
            when Constraint_UNDEF rt unknown = FALSE;  
            when UnallocatedEncoding();
        when Constraint_NOP EndOfInstruction();

if memop == MemOp STORE then
    if s == t || (pair & & s == t2) then
        Constraint c = ConstrainUnpredictable(Unpredictable_DATAOVERLAP);
        assert c IN {Constraint_UNKNOWN, Constraint_NONE, Constraint_UNDEF, Constraint_NOP};
        case c of
            when Constraint_UNKNOWN rt unknown = TRUE;  
            when Constraint_NONE rt unknown = FALSE;  
            when Constraint_UNDEF UNDEFINED;
        when UnallocatedEncoding();
        when Constraint_NOP EndOfInstruction();
        if s == n & n != 31 then
            Constraint c = ConstrainUnpredictable(Unpredictable_BASEOVERLAP);
            assert c IN {Constraint_UNKNOWN, Constraint_NONE, Constraint_UNDEF, Constraint_NOP};
            case c of
                when Constraint_UNKNOWN rn unknown = TRUE;  
                when Constraint_NONE rn unknown = FALSE;  
                when Constraint_UNDEF UNDEFINED;
        when UnallocatedEncoding();

        if n == 31 then
            CheckSPAlignment();
            address = SP[];
        elsif rn unknown then
            address = bits(64) UNKNOWN;
        else
            address = X[n];

case memop of
    when MemOp STORE
        if rt unknown then
            data = bits(datatise) UNKNOWN;
        elsif pair then
            bits(datatise DIV 2) el1 = X[t];
            bits(datatise DIV 2) el2 = X[t2];
            data = if BigEndian() then el1 : el2 else el2 : el1;
        else
            data = X[t];

        bit status = '1';
        // Check whether the Exclusives monitors are set to include the
        // physical memory locations corresponding to virtual address
        // range [address, address+dbytes-1].
        if AArch64.ExclusiveMonitorsPass(address, dbytes) then
            // This atomic write will be rejected if it does not refer
            // to the same physical locations after address translation.
            Mem[address, dbytes, acctype] = data;
            status = ExclusiveMonitorsStatus();
            X[s] = ZeroExtend(status, 32);
        }

    when MemOp LOAD
Tell the Exclusives monitors to record a sequence of one or more atomic memory reads from virtual address range [address, address+dbytes-1]. The Exclusives monitor will only be set if all the reads are from the same dbytes-aligned physical address, to allow for the possibility of an atomicity break if the translation is changed between reads.

`AArch64.SetExclusiveMonitors(address, dbytes);`

if pair then
  if rt_unknown then
    // ConstrainedUNPREDICTABLE case
    X[t] = bits(datasize) UNKNOWN;
  elsif elsize == 32 then
    // 32-bit load exclusive pair (atomic)
    data = `Mem[address, dbytes, acctype];`
    if BigEndian() then
      X[t] = data<datasize-1:elsize>;
      X[t2] = data<elsize-1:0>;
    else
      X[t] = data<elsize-1:0>;
      X[t2] = data<datasize-1:elsize>;
    end
  else // elsize == 64
    // 64-bit load exclusive pair (not atomic),
    // but must be 128-bit aligned
    if address != `Align(address, dbytes) then
      iswrite = FALSE;
      secondstage = FALSE;
      AArch64.Abort(address, AArch64.AlignmentFault(acctype, iswrite, secondstage));
    end
    X[t] = `Mem[address + 0, 8, acctype];`
    X[t2] = `Mem[address + 8, 8, acctype];`
  end
data = `Mem[address, dbytes, acctype];`
X[t] = ZeroExtend(data, regsize);

Operational information

If PSTATE.DIT is 1, the timing of this instruction is insensitive to the value of the data being loaded or stored.
MLA (by element)

Multiply-Add to accumulator (vector, by element). This instruction multiplies the vector elements in the first source SIMD&FP register by the specified value in the second source SIMD&FP register, and accumulates the results with the vector elements of the destination SIMD&FP register. All the values in this instruction are unsigned integer values.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

Vector

MLA <Vd>.<T>, <Vn>.<T>, <Vm>.<Ts>[<index>]

integer idxdsizd = if H == '1' then 128 else 64;
integer index;
bit Rmhi;
case size of
   when '01' index = UInt(H:L:M); Rmhi = '0';
   when '10' index = UInt(H:L); Rmhi = M;
   otherwise UNDEFINED;
integer d = otherwise UnallocatedEncoding(0);
integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rmhi:Rm);
integer esize = 8 << UInt(size);
integer datasize = if Q == '1' then 128 else 64;
integer elements = datasize DIV esize;
boolean sub_op = (o2 == '1');

Assembler Symbols

<Vd> Is the name of the SIMD&FP destination register, encoded in the "Rd" field.
<T> Is an arrangement specifier, encoded in “size:Q”:

<table>
<thead>
<tr>
<th>size</th>
<th>Q</th>
<th>&lt;T&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>x</td>
<td>RESERVED</td>
</tr>
<tr>
<td>01</td>
<td>0</td>
<td>4H</td>
</tr>
<tr>
<td>01</td>
<td>1</td>
<td>8H</td>
</tr>
<tr>
<td>10</td>
<td>0</td>
<td>2S</td>
</tr>
<tr>
<td>10</td>
<td>1</td>
<td>4S</td>
</tr>
<tr>
<td>11</td>
<td>x</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

<Vn> Is the name of the first SIMD&FP source register, encoded in the "Rn" field.

<Vm> Is the name of the second SIMD&FP source register, encoded in “size:M:Rm”:

<table>
<thead>
<tr>
<th>size</th>
<th>&lt;Vm&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>RESERVED</td>
</tr>
<tr>
<td>01</td>
<td>0:Rm</td>
</tr>
<tr>
<td>10</td>
<td>M:Rm</td>
</tr>
<tr>
<td>11</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

Restricted to V0-V15 when element size <Ts> is H.

<Ts> Is an element size specifier, encoded in “size”:
Is the element index, encoded in "size:L:H:M":

```
Operation

CheckFPAdvSIMDEnabled64();
bits(datasize) operand1 = V[n];
bits(idxdsize) operand2 = V[m];
bits(datasize) operand3 = V[d];
bits(datasize) result;
integer element1;
integer element2;
bits(esize) product;

element2 = UInt(Elem[operand2, index, esize]);
for e = 0 to elements-1
    element1 = UInt(Elem[operand1, e, esize]);
    product = (element1 * element2)<esize-1:0>;
    if sub_op then
        Elem[result, e, esize] = Elem[operand3, e, esize] - product;
    else
        Elem[result, e, esize] = Elem[operand3, e, esize] + product;
V[d] = result;
```

Operational information

If PSTATE.DIT is 1:
- The execution time of this instruction is independent of:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
- The response of this instruction to asynchronous exceptions does not vary based on:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
MLA (vector)

Multiply-Add to accumulator (vector). This instruction multiplies corresponding elements in the vectors of the two source SIMD&FP registers, and accumulates the results with the vector elements of the destination SIMD&FP register.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

Three registers of the same type

MLA <Vd>.<T>, <Vn>.<T>, <Vm>.<T>

integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rm);
if size == '11' then UNDEFINED;
integer esize = 8 << if size == '1' then ReservedValue();
integer datasize = if Q == '1' then 128 else 64;
integer elements = datasize DIV esize;
boolean sub_op = (U == '1');

Assembler Symbols

<Vd> Is the name of the SIMD&FP destination register, encoded in the "Rd" field.
<T> Is an arrangement specifier, encoded in "size:Q":

<table>
<thead>
<tr>
<th>size</th>
<th>Q</th>
<th>&lt;T&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>0</td>
<td>8B</td>
</tr>
<tr>
<td>00</td>
<td>1</td>
<td>16B</td>
</tr>
<tr>
<td>01</td>
<td>0</td>
<td>4H</td>
</tr>
<tr>
<td>01</td>
<td>1</td>
<td>8H</td>
</tr>
<tr>
<td>10</td>
<td>0</td>
<td>2S</td>
</tr>
<tr>
<td>10</td>
<td>1</td>
<td>4S</td>
</tr>
<tr>
<td>11</td>
<td>x</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

<Vn> Is the name of the first SIMD&FP source register, encoded in the "Rn" field.
<Vm> Is the name of the second SIMD&FP source register, encoded in the "Rm" field.
Operation

```c
CheckFPAdvSIMDEnabled64();
bits(datasize) operand1 = V[n];
bits(datasize) operand2 = V[m];
bits(datasize) operand3 = V[d];
bits(datasize) result;
bits(usize) element1;
bits(usize) element2;
bits(usize) product;
for e = 0 to elements-1
    element1 = Elem[operand1, e, usize];
    element2 = Elem[operand2, e, usize];
    product = (UInt(element1) * UInt(element2))<usize-1:0>;
    if sub_op then
        Elem[result, e, usize] = Elem[operand3, e, usize] - product;
    else
        Elem[result, e, usize] = Elem[operand3, e, usize] + product;
V[d] = result;
```

Operational information

If PSTATE.DIT is 1:

- The execution time of this instruction is independent of:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
- The response of this instruction to asynchronous exceptions does not vary based on:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
MLS (by element)

Multiply-Subtract from accumulator (vector, by element). This instruction multiplies the vector elements in the first source SIMD&FP register by the specified value in the second source SIMD&FP register, and subtracts the results from the vector elements of the destination SIMD&FP register. All the values in this instruction are unsigned integer values.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

```
<table>
<thead>
<tr>
<th>0</th>
<th>Q</th>
<th>1</th>
<th>0</th>
<th>1</th>
<th>1</th>
<th>1</th>
<th>size</th>
<th>L</th>
<th>M</th>
<th>Rm</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>H</td>
<td>0</td>
<td>Rn</td>
<td>Rd</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
```

```ml
Vector

MLS <Vd>.<T>, <Vn>.<T>, <Vm>.<Ts>[<index>]

integer idxdsiz = if H == '1' then 128 else 64;
integer index;
bit Rmhi;
case size of
  when '01' index = UInt(H:L:M); Rmhi = '0';
  when '10' index = UInt(H:L); Rmhi = M;
  otherwise UNDEFINED;
integer d = otherwise UnallocatedEncoding();
integer d = UInt(Rd);
integer n =(UInt(Rn));
integer m = UInt(Rmhi:Rm);
integer esize = 8 << UInt(size);
integer datasize = if Q == '1' then 128 else 64;
integer elements = datasize DIV esize;
boolean sub_op = (o2 == '1');
```

Assembler Symbols

**<Vd>**

Is the name of the SIMD&FP destination register, encoded in the "Rd" field.

**<T>**

Is an arrangement specifier, encoded in "size:Q":

```
<table>
<thead>
<tr>
<th>size</th>
<th>Q</th>
<th>&lt;T&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>x</td>
<td>RESERVED</td>
</tr>
<tr>
<td>01</td>
<td>0</td>
<td>4H</td>
</tr>
<tr>
<td>01</td>
<td>1</td>
<td>8H</td>
</tr>
<tr>
<td>10</td>
<td>0</td>
<td>2S</td>
</tr>
<tr>
<td>10</td>
<td>1</td>
<td>4S</td>
</tr>
<tr>
<td>11</td>
<td>x</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>
```

**<Vn>**

Is the name of the first SIMD&FP source register, encoded in the "Rn" field.

**<Vm>**

Is the name of the second SIMD&FP source register, encoded in "size:M:Rm":

```
<table>
<thead>
<tr>
<th>size</th>
<th>&lt;Vm&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>RESERVED</td>
</tr>
<tr>
<td>01</td>
<td>0:Rm</td>
</tr>
<tr>
<td>10</td>
<td>M:Rm</td>
</tr>
<tr>
<td>11</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>
```

Restricted to V0-V15 when element size <Ts> is H.

**<Ts>**

Is an element size specifier, encoded in "size":

---

MLS (by element)
Operation

```c
CheckFPAdvSIMDEnabled64();
bits(datasize) operand1 = V[n];
bits(idxdsize) operand2 = V[m];
bits(datasize) operand3 = V[d];
bits(datasize) result;
integer element1;
integer element2;
bits(esize) product;

element2 = UInt(Elem[operand2, index, esize]);
for e = 0 to elements-1
  element1 = UInt(Elem[operand1, e, esize]);
  product = (element1 * element2)<esize-1:0>;
  if sub_op then
    Elem[result, e, esize] = Elem[operand3, e, esize] - product;
  else
    Elem[result, e, esize] = Elem[operand3, e, esize] + product;
V[d] = result;
```

Operational information

If PSTATE.DIT is 1:

- The execution time of this instruction is independent of:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
- The response of this instruction to asynchronous exceptions does not vary based on:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
MLS (vector)

Multiply-Subtract from accumulator (vector). This instruction multiplies corresponding elements in the vectors of the two source SIMD&FP registers, and subtracts the results from the vector elements of the destination SIMD&FP register.

Depending on the settings in the \texttt{CPACR\_EL1}, \texttt{CPTR\_EL2}, and \texttt{CPTR\_EL3} registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9  | 8  | 7  | 6  | 5  | 4  | 3  | 2  | 1  | 0  |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0  | Q  | 1  | 0  | 1  | 1  | 0  | size | 1  | Rd | 1  | 0  | 0  | 1  | 0  | 1  | Rn | 1  | 0  | 0  | 1  | 0  | 1  | 0  | 1  | 0  | 1  | 0  | 1  | 0  | 1  | 0  | 1  |

Three registers of the same type

\texttt{MLS \langle V_d \rangle.\langle T \rangle}, \texttt{\langle V_n \rangle.\langle T \rangle}, \texttt{\langle V_m \rangle.\langle T \rangle}

\begin{verbatim}
integer d = \texttt{UInt}(Rd);
integer n = \texttt{UInt}(Rn);
integer m = \texttt{UInt}(Rm);
if size == '11' then UNDEFINED;
integer esize = 8 \times if size == '11' then \texttt{ReservedValue}() else \texttt{UInt}(size);
integer datasize = if Q == '1' then 128 else 64;
integer elements = datasize \div esize;
boolean sub_op = (U == '1');
\end{verbatim}

Assembler Symbols

\begin{itemize}
\item \texttt{\langle V_d \rangle} Is the name of the SIMD&FP destination register, encoded in the “Rd” field.
\item \texttt{\langle T \rangle} Is an arrangement specifier, encoded in “size:Q”:
\begin{verbatim}
size Q <T>
00 0 8B
00 1 16B
01 0 4H
01 1 8H
10 0 2S
10 1 4S
11 x RESERVED
\end{verbatim}
\item \texttt{\langle V_n \rangle} Is the name of the first SIMD&FP source register, encoded in the “Rn” field.
\item \texttt{\langle V_m \rangle} Is the name of the second SIMD&FP source register, encoded in the “Rm” field.
\end{itemize}
Operation

```c
CheckFPAdvSIMEnabled64();
bits(datasize) operand1 = V[n];
bits(datasize) operand2 = V[m];
bits(datasize) operand3 = V[d];
bits(datasize) result;
bits(esize) element1;
bits(esize) element2;
bits(esize) product;
for e = 0 to elements-1
   element1 = Elem[operand1, e, esize];
   element2 = Elem[operand2, e, esize];
   product = (UInt(element1) * UInt(element2))<esize-1:0>;
   if sub_op then
      Elem[result, e, esize] = Elem[operand3, e, esize] - product;
   else
      Elem[result, e, esize] = Elem[operand3, e, esize] + product;
V[d] = result;
```

Operational information

If PSTATE.DIT is 1:

- The execution time of this instruction is independent of:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
- The response of this instruction to asynchronous exceptions does not vary based on:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.

MOV (to/from SP)

Move between register and stack pointer: \( Rd = Rn \).

This is an alias of \textit{ADD (immediate)}. This means:

- The encodings in this description are named to match the encodings of \textit{ADD (immediate)}.
- The description of \textit{ADD (immediate)} gives the operational pseudocode for this instruction.

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9  | 8  | 7  | 6  | 5  | 4  | 3  | 2  | 1  | 0  |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| sf | 0  | 0  | 1  | 0  | 0  | 0  | 1  | \( \frac{0}{1} \) | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | Rn | Rd |
| op | S  | shift | imm12 |

32-bit (\( sf = 0 \))

\[
\text{MOV}<Wd|WSP>, <Wn|WSP>
\]

is equivalent to

\[
\text{ADD}<Wd|WSP>, <Wn|WSP>, #0
\]

and is the preferred disassembly when \( (Rd == '11111' \mid Rn == '11111') \).

64-bit (\( sf = 1 \))

\[
\text{MOV}<Xd|SP>, <Xn|SP>
\]

is equivalent to

\[
\text{ADD}<Xd|SP>, <Xn|SP>, #0
\]

and is the preferred disassembly when \( (Rd == '11111' \mid Rn == '11111') \).

**Assembler Symbols**

- \(<Wd|WSP>\): Is the 32-bit name of the destination general-purpose register or stack pointer, encoded in the "Rd" field.
- \(<Wn|WSP>\): Is the 32-bit name of the source general-purpose register or stack pointer, encoded in the "Rn" field.
- \(<Xd|SP>\): Is the 64-bit name of the destination general-purpose register or stack pointer, encoded in the "Rd" field.
- \(<Xn|SP>\): Is the 64-bit name of the source general-purpose register or stack pointer, encoded in the "Rn" field.

**Operation**

The description of \textit{ADD (immediate)} gives the operational pseudocode for this instruction.
MOVI

Move Immediate (vector). This instruction places an immediate constant into every vector element of the destination SIMD&FP register. Depending on the settings in the `CPACR_EL1`, `CPTR_EL2`, and `CPTR_EL3` registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.
8-bit (op == 0 && cmode == 1110)

\[ \text{MOVI } <Vd>,<T>, \#<imm8>{, LSL \#0} \]

16-bit shifted immediate (op == 0 && cmode == 10x0)

\[ \text{MOVI } <Vd>,<T>, \#<imm8>{, LSL \#<amount>} \]

32-bit shifted immediate (op == 0 && cmode == 0xx0)

\[ \text{MOVI } <Vd>,<T>, \#<imm8>{, LSL \#<amount>} \]

32-bit shifting ones (op == 0 && cmode == 110x)

\[ \text{MOVI } <Vd>,<T>, \#<imm8>, \text{MSL \#<amount>} \]

64-bit scalar (Q == 0 && op == 1 && cmode == 1110)

\[ \text{MOVI } <Dd>, \#<imm> \]

64-bit vector (Q == 1 && op == 1 && cmode == 1110)

\[ \text{MOVI } <Vd>.2D, \#<imm> \]

```
integer rd = UInt(Rd);
integer datasize = if Q == '1' then 128 else 64;
bits(datasize) imm;
bits(64) imm64;

ImmediateOp operation;
case cmode:op of
 when '0xx00' operation = ImmediateOp_MOVI;
 when '0xx01' operation = ImmediateOp_MVNI;
 when '0xx10' operation = ImmediateOp_ORR;
 when '0xx11' operation = ImmediateOp_BIC;
 when '10x00' operation = ImmediateOp_MOVI;
 when '10x01' operation = ImmediateOp_MVNI;
 when '10x10' operation = ImmediateOp_ORR;
 when '10x11' operation = ImmediateOp_BIC;
 when '110x0' operation = ImmediateOp_MOVI;
 when '110x1' operation = ImmediateOp_MVNI;
 when '1110x' operation = ImmediateOp_MOVI;
 when '11110' operation = ImmediateOp_MOVI;
 when '11111' // FMOV Dn,#imm is in main FP instruction set
 if Q == '0' then UNDEFINED;
 operation = if Q == '0' then UnallocatedEncoding();
 operation = ImmediateOp_MOVI;

imm64 = AdvSIMDExpandImm(op, cmode, a:b:c:d:e:f:g:h);
imm = Replicate(imm64, datasize DIV 64);
```

Assembler Symbols

- `<Dd>`: Is the 64-bit name of the SIMD&FP destination register, encoded in the "Rd" field.
- `<Vd>`: Is the name of the SIMD&FP destination register, encoded in the "Rd" field.
- `<T>`: For the 8-bit variant: is an arrangement specifier, encoded in "Q":

MOVI
For the 16-bit variant: is an arrangement specifier, encoded in “Q”:

```
  Q  <T>
0  8B
1  16B
```

For the 32-bit variant: is an arrangement specifier, encoded in “Q”:

```
  Q  <T>
0  4B
1  8B
```

<imm8> Is an 8-bit immediate encoded in "a:b:c:d:e:f:g:h".

<amount> For the 16-bit shifted immediate variant: is the shift amount encoded in “cmode<1>”:

```
cmode<1>  <amount>
0  0
1  8
```

defaulting to 0 if LSL is omitted.

For the 32-bit shifted immediate variant: is the shift amount encoded in “cmode<2:1>”:

```
cmode<2:1>  <amount>
00  0
01  8
10  16
11  24
```

defaulting to 0 if LSL is omitted.

For the 32-bit shifting ones variant: is the shift amount encoded in “cmode<0>”:

```
cmode<0>  <amount>
0  8
1  16
```

**Operation**

```c
CheckFPAdvSIMDEnabled64();
bits(datasize) operand;
bits(datasize) result;

case operation of
  when ImmediateOp_MOVI
      result = imm;
  when ImmediateOp_MVNI
      result = NOT(imm);
  when ImmediateOp_ORR
      operand = V[rd];
      result = operand OR imm;
  when ImmediateOp_BIC
      operand = V[rd];
      result = operand AND NOT(imm);

V[rd] = result;
```

**Operational information**

If PSTATE.DIT is 1:

- The execution time of this instruction is independent of:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
- The response of this instruction to asynchronous exceptions does not vary based on:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
(old) htmldiff from- (new)
MOVK

Move wide with keep moves an optionally-shifted 16-bit immediate value into a register, keeping other bits unchanged.

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9  | 8  | 7  | 6  | 5  | 4  | 3  | 2  | 1  | 0  |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| sf | 1  | 1  | 0  | 0  | 1  | 0  | 1  | hw | imm16 | Rd |

32-bit (sf == 0)

MOVK <Wd>, #<imm>[, LSL #<shift>]

64-bit (sf == 1)

MOVK <Xd>, #<imm>[, LSL #<shift>]

integer d = UInt(Rd);
integer datasize = if sf == '1' then 64 else 32;
integer imm = imm16;
integer pos;
MoveWideOp opcode;

case opc of
  when '00' opcode = MoveWideOp_N;
  when '10' opcode = MoveWideOp_Z;
  when '11' opcode = MoveWideOp_K;
  otherwise UNDEFINED;
if sf == '0' && hw<1> == '1' then UNDEFINED;
pos = otherwise UnallocatedEncoding();
if sf == '0' && hw<1> == '1' then UnallocatedEncoding();
pos = UInt(hw:'0000');

Assembler Symbols

<Wd> Is the 32-bit name of the general-purpose destination register, encoded in the "Rd" field.
<Xd> Is the 64-bit name of the general-purpose destination register, encoded in the "Rd" field.
<imm> Is the 16-bit unsigned immediate, in the range 0 to 65535, encoded in the "imm16" field.
<shift> For the 32-bit variant: is the amount by which to shift the immediate left, either 0 (the default) or 16, encoded in the "hw" field as <shift>/16.
For the 64-bit variant: is the amount by which to shift the immediate left, either 0 (the default), 16, 32 or 48, encoded in the "hw" field as <shift>/16.

Operation

bits(datasize) result;
if opcode == MoveWideOp_K then
  result = X[d];
else
  result = Zeros();
result<pos+15:pos> = imm;
if opcode == MoveWideOp_N then
  result = NOT(result);
X[d] = result;
Operational information

If PSTATE.DIT is 1:

- The execution time of this instruction is independent of:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
- The response of this instruction to asynchronous exceptions does not vary based on:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
MOVN

Move wide with NOT moves the inverse of an optionally-shifted 16-bit immediate value to a register.

This instruction is used by the alias MOV (inverted wide immediate).

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9  | 8  | 7  | 6  | 5  | 4  | 3  | 2  | 1  | 0  |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| sf | 0  | 0  | 1  | 0  | 0  | 0  | 1  | hw | imm16 |
| opc|

32-bit (sf == 0)

MOVN <Wd>, #<imm>{, LSL #<shift>}

64-bit (sf == 1)

MOVN <Xd>, #<imm>{, LSL #<shift>}

integer d = UInt(Rd);
integer datasize = if sf == '1' then 64 else 32;
bits(16) imm = imm16;
integer pos;
MoveWideOp opcode;

case opc of
  when '00' opcode = MoveWideOp_N;
  when '10' opcode = MoveWideOp_Z;
  when '11' opcode = MoveWideOp_K;
  otherwise UNDEFINED;

if sf == '0' && hw<1> == '1' then UNDEFINED;
pos = otherwise UnallocatedEncoding();

if sf == '0' && hw<1> == '1' then UnallocatedEncoding();
pos = UInt(hw:'0000');

Assembler Symbols

<Wd> Is the 32-bit name of the general-purpose destination register, encoded in the "Rd" field.
<Xd> Is the 64-bit name of the general-purpose destination register, encoded in the "Rd" field.
<imm> Is the 16-bit unsigned immediate, in the range 0 to 65535, encoded in the "imm16" field.
<shift> For the 32-bit variant: is the amount by which to shift the immediate left, either 0 (the default) or 16, encoded in the "hw" field as <shift>/16.
For the 64-bit variant: is the amount by which to shift the immediate left, either 0 (the default), 16, 32 or 48, encoded in the "hw" field as <shift>/16.

Alias Conditions

<table>
<thead>
<tr>
<th>Alias</th>
<th>Of variant</th>
<th>Is preferred when</th>
</tr>
</thead>
<tbody>
<tr>
<td>MOV (inverted wide immediate)</td>
<td>64-bit</td>
<td>! (IsZero(imm16) &amp;&amp; hw != '00')</td>
</tr>
<tr>
<td>MOV (inverted wide immediate)</td>
<td>32-bit</td>
<td>! (IsZero(imm16) &amp;&amp; hw != '00') &amp;&amp; ! IsOnes(imm16)</td>
</tr>
</tbody>
</table>
Operation

```c
bits(datasize) result;
if opcode == MoveWideOp_K then
    result = X[d];
else
    result = Zeros();
result<pos+15:pos> = imm;
if opcode == MoveWideOp_N then
    result = NOT(result);
X[d] = result;
```

Operational information

If PSTATE.DIT is 1:

- The execution time of this instruction is independent of:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
- The response of this instruction to asynchronous exceptions does not vary based on:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
**MOVZ**

Move wide with zero moves an optionally-shifted 16-bit immediate value to a register.

This instruction is used by the alias **MOV (wide immediate)**.

32-bit (sf == 0)

MOVZ <Wd>, #<imm>{, LSL #<shift>}

64-bit (sf == 1)

MOVZ <Xd>, #<imm>{, LSL #<shift>}

```plaintext
integer d = Uint(Rd);
integer datasize = if sf == '1' then 64 else 32;
bits(16) imm = imm16;
integer pos;
MoveWideOp opcode;

case opc of
  when '00' opcode = MoveWideOp_N;
  when '10' opcode = MoveWideOp_Z;
  when '11' opcode = MoveWideOp_K;
  otherwise UNDEFINED;

if sf == '0' && hw<1> == '1' then UNDEFINED;
pos = otherwise UnallocatedEncoding();

if sf == '0' && hw<1> == '1' then UnallocatedEncoding();
pos = Uint(hw:'0000');
```

**Assembler Symbols**

- **<Wd>** Is the 32-bit name of the general-purpose destination register, encoded in the "Rd" field.
- **<Xd>** Is the 64-bit name of the general-purpose destination register, encoded in the "Rd" field.
- **<imm>** Is the 16-bit unsigned immediate, in the range 0 to 65535, encoded in the "imm16" field.
- **<shift>** For the 32-bit variant: is the amount by which to shift the immediate left, either 0 (the default) or 16, encoded in the "hw" field as <shift>/16.
  
  For the 64-bit variant: is the amount by which to shift the immediate left, either 0 (the default), 16, 32 or 48, encoded in the "hw" field as <shift>/16.

**Alias Conditions**

<table>
<thead>
<tr>
<th>Alias</th>
<th>Is preferred when</th>
</tr>
</thead>
<tbody>
<tr>
<td>MOV (wide immediate)</td>
<td>! (IsZero(imm16) &amp;&amp; hw != '00')</td>
</tr>
</tbody>
</table>
Operation

```c
bits(datasize) result;
if opcode == MoveWideOp_K then
    result = X[d];
else
    result = Zeros();
result<pos+15:pos> = imm;
if opcode == MoveWideOp_N then
    result = NOT(result);
X[d] = result;
```

Operational information

If PSTATE.DIT is 1:

- The execution time of this instruction is independent of:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
- The response of this instruction to asynchronous exceptions does not vary based on:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
MSR (immediate)

Move immediate value to Special Register moves an immediate value to selected bits of the PSTATE. For more information, see Process state, PSTATE.

The bits that can be written by the D1 instruction are I, F, and SP. This set of bits is expanded in extensions to the architecture as follows:

- ARMv8.1-PAN: PSTATE.D adds to PSTATE.A the PSTATE.PAN, PSTATE.I, and PSTATE.F, and PSTATE.SP bit.
- ARMv8.2-UAO: ARMv8.0-SSBS adds the PSTATE.SSBS.UAO bit.
- ARMv8.4-DIT: If ARMv8.1-PAN is implemented, the PSTATE.PAN.DIT bit.
- If ARMv8.2-UAO is implemented, PSTATE.UAO.
- If ARMv8.4-DIT is implemented, PSTATE.DIT.

31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
1 1 0 1 0 1 0 0 0 0 0 0 op1 0 1 0 0 CRm | op2 1 1 1 1

System

MSR <pstatefield>, #<imm>

if op1 == '000' & op2 == '000' then SEE "CFINV";
if op1 == '000' & op2 == '001' then SEE "XAFlag";
if op1 == '000' & op2 == '010' then SEE "AXFlag";
AArch64.CheckSystemAccess('00', op1, '0100', CRm, op2, '11111', '0');

bits(4) operand = CRm;
PSTATEField field;
case op1:op2 of
  when '000 000'
    field = PSTATEField_DAIFSet;
  when '000 011'
    if !HaveUAOExt() then
      field = UnallocatedEncoding();
    else
      field = PSTATEField_UAO;
  when '000 100'
    if !HavePANExt() then
      field = UnallocatedEncoding();
    else
      field = PSTATEField_PAN;
  when '000 101'
    field = PSTATEField_SP;
  when '011 010'
    if !HaveDITExt() then
      field = UnallocatedEncoding();
    else
      field = PSTATEField_DIT;
  when '011 110'
    field = PSTATEField_DAIFClr;
  when '011 111'
    field = PSTATEField_DAIFClr;
  when '011 110' field = PSTATEField_DAIFSet;
  when '011 111' field = PSTATEField_DAIFClr;
  when '011 011'
    if !HaveSSBSExt() then
      field = PSTATEField_SBS;
    else
      if !otherwise
         field = PSTATEField_SSBS;
  otherwise
    field = UnallocatedEncoding();
AArch64.SystemRegisterTrap(EL, '00', op1, '0100', '11111', CRm, '0');

Assembler Symbols

<pstatefield> is a PSTATE field name, encoded in “op1:op2”: 

System

MSR <pstatefield>, #<imm>
Is a 4-bit unsigned immediate, in the range 0 to 15, encoded in the "CRm" field.

**Operation**

```plaintext
case field of
  when PSTATEField_SSBS
       PSTATE.SSBS = operand<0>;
  when PSTATEField_SP
       PSTATE.SP = operand<0>;
  when PSTATEField_DAIFSet
       PSTATE.D = PSTATE.D OR operand<3>;
       PSTATE.A = PSTATE.A OR operand<2>;
       PSTATE.I = PSTATE.I OR operand<1>;
       PSTATE.F = PSTATE.F OR operand<0>;
  when PSTATEField_DAIFClr
       PSTATE.D = PSTATE.D AND NOT(operand<3>);
       PSTATE.A = PSTATE.A AND NOT(operand<2>);
       PSTATE.I = PSTATE.I AND NOT(operand<1>);
       PSTATE.F = PSTATE.F AND NOT(operand<0>);
  when PSTATEField_PAN
       PSTATE.PAN = operand<0>;
  when PSTATEField_UAO
       PSTATE.UAO = operand<0>;
  when PSTATEField_DIT
       PSTATE.DIT = operand<0>;
```

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MUL (by element)

Multiply (vector, by element). This instruction multiplies the vector elements in the first source SIMD&FP register by the specified value in the second source SIMD&FP register, places the results in a vector, and writes the vector to the destination SIMD&FP register. All the values in this instruction are unsigned integer values.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

Vector

\[
\begin{align*}
\text{MUL} & \quad <Vd>\cdot<T>, \quad <Vn>\cdot<T>, \quad <Vm>\cdot<Ts>[<index>] \\
\text{integer idxdsize} & = \text{if } H == '1' \text{ then } 128 \text{ else } 64; \\
\text{integer index;} & \\
\text{bit Rmhi; & } \\
\text{case size of & } \\
\text{when '01' index} & = \text{UInt}(H:L:M); \quad \text{Rmhi} = '0'; \quad & \\
\text{when '10' index} & = \text{UInt}(H:L); \quad \text{Rmhi} = M; & \\
\text{otherwise UNDEFINED; & } \\
\text{integer d} & = \quad \text{otherwise UnallocatedEncoding()}; \\
\text{integer d} & = \text{UInt}(Rd); \\
\text{integer n} & = \text{UInt}(Rn); \\
\text{integer m} & = \text{UInt}(Rmhi:Rm); \\
\text{integer esize} & = 8 \ll \text{UInt}(size); \\
\text{integer datasize} & = \text{if } Q == '1' \text{ then } 128 \text{ else } 64; \\
\text{integer elements} & = \text{datasize} \div \text{esize};
\end{align*}
\]

Assembler Symbols

\(<Vd>\) Is the name of the SIMD&FP destination register, encoded in the "Rd" field.

\(<T>\) Is an arrangement specifier, encoded in "size:Q":

<table>
<thead>
<tr>
<th>size</th>
<th>Q</th>
<th>&lt;T&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>x</td>
<td>RESERVED</td>
</tr>
<tr>
<td>01</td>
<td>0</td>
<td>4H</td>
</tr>
<tr>
<td>01</td>
<td>1</td>
<td>8H</td>
</tr>
<tr>
<td>10</td>
<td>0</td>
<td>2S</td>
</tr>
<tr>
<td>10</td>
<td>1</td>
<td>4S</td>
</tr>
<tr>
<td>11</td>
<td>x</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

\(<Vn>\) Is the name of the first SIMD&FP source register, encoded in the "Rn" field.

\(<Vm>\) Is the name of the second SIMD&FP source register, encoded in “size:M:Rm”:

<table>
<thead>
<tr>
<th>size</th>
<th>&lt;Vm&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>RESERVED</td>
</tr>
<tr>
<td>01</td>
<td>0:Rm</td>
</tr>
<tr>
<td>10</td>
<td>M:Rm</td>
</tr>
<tr>
<td>11</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

Restricted to V0-V15 when element size <Ts> is H.

\(<Ts>\) Is an element size specifier, encoded in “size”:

<table>
<thead>
<tr>
<th>size</th>
<th>&lt;Ts&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>RESERVED</td>
</tr>
<tr>
<td>01</td>
<td>H</td>
</tr>
<tr>
<td>10</td>
<td>S</td>
</tr>
<tr>
<td>11</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>
Is the element index, encoded in “size:L:H:M”:

<table>
<thead>
<tr>
<th>size</th>
<th>&lt;index&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>RESERVED</td>
</tr>
<tr>
<td>01</td>
<td>H:L:M</td>
</tr>
<tr>
<td>10</td>
<td>H:L</td>
</tr>
<tr>
<td>11</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

**Operation**

```plaintext
CheckFPAdvSIMDEnabled64();

bits(datasize) operand1 = V[n];
bits(idxdsz) operand2 = V[m];
bits(datasize) result;
integer element1;
integer element2;
bits(esize) product;

element2 = UInt(Elem[operand2, index, esize]);
for e = 0 to elements-1
    element1 = UInt(Elem[operand1, e, esize]);
    product = (element1 * element2)<esize-1:0>;
    Elem[result, e, esize] = product;

V[d] = result;
```

**Operational information**

If PSTATE.DIT is 1:
- The execution time of this instruction is independent of:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
- The response of this instruction to asynchronous exceptions does not vary based on:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
MUL (vector)

Multiply (vector). This instruction multiplies corresponding elements in the vectors of the two source SIMD&FP registers, places the results in a vector, and writes the vector to the destination SIMD&FP register.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

Three registers of the same type

MUL <Vd>.<T>, <Vn>.<T>, <Vm>.<T>

integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rm);
if U == '1' && size != '00' then UNDEFINED;
if size == '11' then UNDEFINED;
integer esize = 8 <<
if U == '1' && size != '00' then ReservedValue();
if size == '11' then ReservedValue();
integer esize = 8 << UInt(size);
integer datasize = if Q == '1' then 128 else 64;
integer elements = datasize DIV esize;
boolean poly = (U == '1');

Assembler Symbols

<Vd> Is the name of the SIMD&FP destination register, encoded in the "Rd" field.
<T>  Is an arrangement specifier, encoded in “size:Q”:

<table>
<thead>
<tr>
<th>size</th>
<th>Q</th>
<th>&lt;T&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>0</td>
<td>8B</td>
</tr>
<tr>
<td>00</td>
<td>1</td>
<td>16B</td>
</tr>
<tr>
<td>01</td>
<td>0</td>
<td>4H</td>
</tr>
<tr>
<td>01</td>
<td>1</td>
<td>8H</td>
</tr>
<tr>
<td>10</td>
<td>0</td>
<td>2S</td>
</tr>
<tr>
<td>10</td>
<td>1</td>
<td>4S</td>
</tr>
<tr>
<td>11</td>
<td>x</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

<Vn> Is the name of the first SIMD&FP source register, encoded in the "Rn" field.
<Vm> Is the name of the second SIMD&FP source register, encoded in the "Rm" field.
Operation

```c
CheckFPAdvSIMDEnabled64();
bits(datasize) operand1 = V[n];
bits(datasize) operand2 = V[m];
bits(datasize) result;
bits(esize) element1;
bits(esize) element2;
bits(esize) product;

for e = 0 to elements - 1
    element1 = Elem[operand1, e, esize];
    element2 = Elem[operand2, e, esize];
    if poly then
        product = PolynomialMult(element1, element2)<esize-1:0>;
    else
        product = (UInt(element1) * UInt(element2))<esize-1:0>;
    Elem[result, e, esize] = product;
V[d] = result;
```

Operational information

If PSTATE.DIT is 1:

- The execution time of this instruction is independent of:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
- The response of this instruction to asynchronous exceptions does not vary based on:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.

Internal version only: isa v30.25, AdvSIMD v27.01, pseudocode v85-xml-000ec8_rc3055 ; Build timestamp: 2018-09-13T12:20:00Z

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MVNI

Move inverted Immediate (vector). This instruction places the inverse of an immediate constant into every vector element of the destination SIMD&FP register.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

### 16-bit shifted immediate (cmode == 10x0)

MVNI <Vd>.<T>, #<imm8>{, LSL #<amount>}

### 32-bit shifted immediate (cmode == 0xx0)

MVNI <Vd>.<T>, #<imm8>{, LSL #<amount>}

### 32-bit shifting ones (cmode == 110x)

MVNI <Vd>.<T>, #<imm8>, MSL #<amount>

Assembler Symbols

<Vd> Is the name of the SIMD&FP destination register, encoded in the "Rd" field.

<T> For the 16-bit variant: is an arrangement specifier, encoded in “Q”:

<table>
<thead>
<tr>
<th>Q</th>
<th>0</th>
<th>4H</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>8H</td>
<td></td>
</tr>
</tbody>
</table>
For the 32-bit variant: is an arrangement specifier, encoded in “Q”:

<table>
<thead>
<tr>
<th>Q</th>
<th>&lt;T&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>2S</td>
</tr>
<tr>
<td>1</td>
<td>4S</td>
</tr>
</tbody>
</table>

<imm8>  Is an 8-bit immediate encoded in "a:b:c:d:e:f:g:h".

<amount>  For the 16-bit shifted immediate variant: is the shift amount encoded in “cmode<1>”:

<table>
<thead>
<tr>
<th>cmode&lt;1&gt;</th>
<th>&lt;amount&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
</tr>
</tbody>
</table>

defaulting to 0 if LSL is omitted.

For the 32-bit shifted immediate variant: is the shift amount encoded in “cmode<2:1>”:

<table>
<thead>
<tr>
<th>cmode&lt;2:1&gt;</th>
<th>&lt;amount&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>0</td>
</tr>
<tr>
<td>01</td>
<td>8</td>
</tr>
<tr>
<td>10</td>
<td>16</td>
</tr>
<tr>
<td>11</td>
<td>24</td>
</tr>
</tbody>
</table>

defaulting to 0 if LSL is omitted.

For the 32-bit shifting ones variant: is the shift amount encoded in “cmode<0>”:

<table>
<thead>
<tr>
<th>cmode&lt;0&gt;</th>
<th>&lt;amount&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>8</td>
</tr>
<tr>
<td>1</td>
<td>16</td>
</tr>
</tbody>
</table>

Operation

```c
CheckFPAdvSIMDEnabled64();
bits(datasize) operand;
bits(datasize) result;

case operation of
    when ImmediateOp_MOVI
        result = imm;
    when ImmediateOp_MVNI
        result = NOT(imm);
    when ImmediateOp_ORR
        operand = V[rd];
        result = operand OR imm;
    when ImmediateOp_BIC
        operand = V[rd];
        result = operand AND NOT(imm);

V[rd] = result;
```

Operational information

If PSTATE.DIT is 1:

- The execution time of this instruction is independent of:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.

- The response of this instruction to asynchronous exceptions does not vary based on:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
NEG (vector)

Negate (vector). This instruction reads each vector element from the source SIMD&FP register, negates each value, puts the result into a vector, and writes the vector to the destination SIMD&FP register.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

It has encodings from 2 classes: Scalar and Vector

Scalar

| 31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0 |
|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| 0   1   1   1   1   1   0   | 1   0   0   0   0   | 0   1   0   1   1   0 |                   |
| U   | Rd   | Rn   | size | integer d = UInt(Rd); |
|     |      |      |      | integer n = UInt(Rn); |

If size != '11' then UNDEFINED;
integer esize = 8 << if size == '11' then ReservedValue(); |
integer esize = 8 << UInt(size); |
integer datasource = esize; |
integer elements = 1; |
boolean neg = (U == '1');

Vector

| 31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0 |
|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| 0   Q   1   0   1   1   1   0   | 1   0   0   0   0   | 0   1   0   1   1   0 |                   |
| U   | Rd   | Rn   | size | integer d = UInt(Rd); |
|     |      |      |      | integer n = UInt(Rn); |

If size:Q == '110' then UNDEFINED;
integer esize = 8 << if size:Q == '110' then ReservedValue(); |
integer esize = 8 << UInt(size); |
integer datasize = if Q == '1' then 128 else 64; |
integer elements = datasize DIV esize; |
boolean neg = (U == '1');

Assembler Symbols

<V> Is a width specifier, encoded in "size":

<table>
<thead>
<tr>
<th>size</th>
<th>&lt;V&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0x</td>
<td>RESERVED</td>
</tr>
<tr>
<td>10</td>
<td>RESERVED</td>
</tr>
<tr>
<td>11</td>
<td>D</td>
</tr>
</tbody>
</table>

<d> Is the number of the SIMD&FP destination register, encoded in the "Rd" field.

<n> Is the number of the SIMD&FP source register, encoded in the "Rn" field.
Is the name of the SIMD&FP destination register, encoded in the "Rd" field.

Is an arrangement specifier, encoded in "size-Q":

<table>
<thead>
<tr>
<th>size</th>
<th>Q</th>
<th>&lt;T&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>0</td>
<td>8B</td>
</tr>
<tr>
<td>00</td>
<td>1</td>
<td>16B</td>
</tr>
<tr>
<td>01</td>
<td>0</td>
<td>4H</td>
</tr>
<tr>
<td>01</td>
<td>1</td>
<td>8H</td>
</tr>
<tr>
<td>10</td>
<td>0</td>
<td>2S</td>
</tr>
<tr>
<td>10</td>
<td>1</td>
<td>4S</td>
</tr>
<tr>
<td>11</td>
<td>0</td>
<td>RESERVED</td>
</tr>
<tr>
<td>11</td>
<td>1</td>
<td>2D</td>
</tr>
</tbody>
</table>

Is the name of the SIMD&FP source register, encoded in the "Rn" field.

Operation

```c
CheckFPAdvSIMDEnabled64();
bits(datasize) operand = V[n];
bits(datasize) result;
integer element;
for e = 0 to elements-1
    element = SInt(Elem[operand, e, esize]);
    if neg then
        element = -element;
    else
        element = Abs(element);
    Elem[result, e, esize] = element<esize-1:0>;
V[d] = result;
```

Operational information

If PSTATE.DIT is 1:

- The execution time of this instruction is independent of:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
- The response of this instruction to asynchronous exceptions does not vary based on:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
NOP

No Operation does nothing, other than advance the value of the program counter by 4. This instruction can be used for instruction alignment purposes.

The timing effects of including a NOP instruction in a program are not guaranteed. It can increase execution time, leave it unchanged, or even reduce it. Therefore, NOP instructions are not suitable for timing loops.

```
31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
1 1 0 1 0 1 0 0 0 0 0 1 1 0 0 1 0 0 0 0 0 0 0 | 1 1 1 1 1
CRm    op2
```

System

```c
SystemHintOp op;

case CRm:op2 of
  when '0000 000' op = SystemHintOp_NOP;
  when '0000 001' op = SystemHintOp_YIELD;
  when '0000 010' op = SystemHintOp_WFE;
  when '0000 011' op = SystemHintOp_WFI;
  when '0000 100' op = SystemHintOp_SEV;
  when '0000 101' op = SystemHintOp_SEVL;
  when '0000 111'
    SEE "XPACLRI";
  when '0001 xxx'
    SEE "PACIA1716, PACIB1716, AUTIA1716, AUTIB1716";
  when '0010 000'
    if ! HaveRASExt () then EndOfInstruction (); // Instruction executes as NOP
    op = SystemHintOp_ESB;
  when '0010 001'
    if ! HaveStatisticalProfiling () then EndOfInstruction (); // Instruction executes as NOP
    op = SystemHintOp_PSB;
  when '0010 010'
    if ! HaveSelfHostedTrace () then EndOfInstruction (); // Instruction executes as NOP
    op = SystemHintOp_TSB;
  when '0010 100'
    op = SystemHintOp_CSDB;
  when '0011 xxx'
    SEE "PACIAZ, PACIASP, PACIBZ, PACIBSP, AUTIAZ, AUTIASP, AUTIBZ, AUTIBSP";
  when '0100 x00'
    op = SystemHintOp_BTI;
    BTypeCompatible = BTypeCompatible_BTI (op2<2:1>);
  otherwise
    EndOfInstruction (); // Instruction executes as NOP
```
Operation

```c
case op of
  when SystemHintOp_YIELDHint_Yield () ;

  when SystemHintOp_WFE
    if IsEventRegisterSet () then
      ClearEventRegister ();
    else
      if PSTATE.EL == EL0 then
        // Check for traps described by the OS which may be EL1 or EL2.
        AArch64.CheckForWFxTrap (EL1, TRUE);
      if EL2Enabled () && PSTATE.EL IN {EL0, EL1} && !IsInHost () then
        // Check for traps described by the Hypervisor.
        AArch64.CheckForWFxTrap (EL2, TRUE);
      if HaveEL (EL3) && PSTATE.EL != EL3 then
        // Check for traps described by the Secure Monitor.
        AArch64.CheckForWFxTrap (EL3, TRUE);
      WaitForEvent ();
    when SystemHintOp_WFI
      if !InterruptPending () then
        if PSTATE.EL == EL0 then
          // Check for traps described by the OS which may be EL1 or EL2.
          AArch64.CheckForWFxTrap (EL1, FALSE);
        if EL2Enabled () && PSTATE.EL IN {EL0, EL1} && !IsInHost () then
          // Check for traps described by the Hypervisor.
          AArch64.CheckForWFxTrap (EL2, FALSE);
        if HaveEL (EL3) && PSTATE.EL != EL3 then
          // Check for traps described by the Secure Monitor.
          AArch64.CheckForWFxTrap (EL3, FALSE);
        WaitForInterrupt ();
    when SystemHintOp_SEV_SendEvent ();

    when SystemHintOp_SEVL_SendEventLocal ();

  when SystemHintOp_ESB_SynchronizeErrors ();
    AArch64.ESBOperation ();
      if EL2Enabled () && PSTATE.EL IN {EL0, EL1} then AArch64.vESBOperation ();
          TakeUnmaskedErrorInterrupts ();

    when SystemHintOp_PSB_ProfilingSynchronizationBarrier ();

  when SystemHintOp_TSB_TraceSynchronizationBarrier ();

  when SystemHintOp_CSDB_ConsumptionOfSpeculativeDataBarrier ();

  when SystemHintOp_BTI
    BTypeNext = '00';

otherwise // do nothing
    SystemHintOp_BTI
    BTypeNext = '00';

otherwise // do nothing
```

Operational information

If PSTATE.DIT is 1:

- The execution time of this instruction is independent of:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
- The response of this instruction to asynchronous exceptions does not vary based on:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.

---

Internal version only: isa 30.25-28.05, AdvSIMD v27.0-25.0, pseudocode v85-xml-00bet8_rc3-35.0; Build timestamp: 2018-09-13T13:04:51Z; 2018-06-16T09:45:45Z

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ORN (shifted register)

Bitwise OR NOT (shifted register) performs a bitwise (inclusive) OR of a register value and the complement of an optionally-shifted register value, and writes the result to the destination register.

This instruction is used by the alias `MVN`.

<table>
<thead>
<tr>
<th>sf</th>
<th>0</th>
<th>1</th>
<th>0</th>
<th>0</th>
<th>0</th>
<th>0</th>
<th>0</th>
<th>shift</th>
<th>1</th>
<th>Rm</th>
<th>imm6</th>
<th>Rn</th>
<th>Rd</th>
</tr>
</thead>
<tbody>
<tr>
<td>opc</td>
<td>N</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

32-bit (sf == 0)

ORN `<Wd>, <Wn>, <Wm>{, <shift> #<amount>}`

64-bit (sf == 1)

ORN `<Xd>, <Xn>, <Xm>{, <shift> #<amount>}`

```plaintext
integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rm);
integer datasize = if sf == '1' then 64 else 32;
boolean setflags;
LogicalOp op;

case opc of
  when '00' op = LogicalOp AND; setflags = FALSE;
  when '01' op = LogicalOp ORR; setflags = FALSE;
  when '10' op = LogicalOp EOR; setflags = FALSE;
  when '11' op = LogicalOp AND; setflags = TRUE;

if sf == '0' && imm6<5> == '1' then UNDEFINED;

ReservedValue();

ShiftType shift_type = DecodeShift(shift);
integer shift_amount = UInt(imm6);
boolean invert = (N == '1');
```

Assembler Symbols

- `<Wd>` Is the 32-bit name of the general-purpose destination register, encoded in the "Rd" field.
- `<Wn>` Is the 32-bit name of the first general-purpose source register, encoded in the "Rn" field.
- `<Wm>` Is the 32-bit name of the second general-purpose source register, encoded in the "Rm" field.
- `<Xd>` Is the 64-bit name of the general-purpose destination register, encoded in the "Rd" field.
- `<Xn>` Is the 64-bit name of the first general-purpose source register, encoded in the "Rn" field.
- `< Xm>` Is the 64-bit name of the second general-purpose source register, encoded in the "Rm" field.
- `<shift>` Is the optional shift to be applied to the final source, defaulting to LSL and encoded in “shift”:

<table>
<thead>
<tr>
<th>shift</th>
<th>&lt;shift&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>LSL</td>
</tr>
<tr>
<td>01</td>
<td>LSR</td>
</tr>
<tr>
<td>10</td>
<td>ASR</td>
</tr>
<tr>
<td>11</td>
<td>ROR</td>
</tr>
</tbody>
</table>

<amount> For the 32-bit variant: is the shift amount, in the range 0 to 31, defaulting to 0 and encoded in the "imm6" field.
For the 64-bit variant: is the shift amount, in the range 0 to 63, defaulting to 0 and encoded in the "imm6" field,
Alias Conditions

<table>
<thead>
<tr>
<th>Alias</th>
<th>Is preferred when</th>
</tr>
</thead>
<tbody>
<tr>
<td>MVN</td>
<td>Rn == '11111'</td>
</tr>
</tbody>
</table>

Operation

```plaintext
bits(datasize) operand1 = X[n];
bits(datasize) operand2 = ShiftReg(m, shift_type, shift_amount);

if invert then operand2 = NOT(operand2);

case op of
    when LogicalOp_AND result = operand1 AND operand2;
    when LogicalOp_ORR result = operand1 OR operand2;
    when LogicalOp_EOR result = operand1 EOR operand2;

if setflags then
    PSTATE.<N,Z,C,V> = result<datasize-1>:IsZeroBit(result):'00';

X[d] = result;
```

Operational information

If PSTATE.DIT is 1:

- The execution time of this instruction is independent of:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
- The response of this instruction to asynchronous exceptions does not vary based on:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
ORR (vector, immediate)

Bitwise inclusive OR (vector, immediate). This instruction reads each vector element from the destination SIMD&FP register, performs a bitwise OR between each result and an immediate constant, places the result into a vector, and writes the vector to the destination SIMD&FP register.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

16-bit (cmode == 10x1)

```
ORR <Vd>.<T>, #imm8{(, LSL #<amount>}
```

32-bit (cmode == 0x1)

```
ORR <Vd>.<T>, #imm8{(, LSL #<amount>}
```

```sql
integer rd = UInt(Rd);

integer datasize = if Q == '1' then 128 else 64;
bits(datasize) imm;
bits(64) imm64;

ImmediateOp operation;

case cmode:op of
    when '0xx00' operation = ImmediateOp_MOVI;
    when '0xx01' operation = ImmediateOp_MVNI;
    when '0xx10' operation = ImmediateOp_ORR;
    when '0xx11' operation = ImmediateOp_BIC;
    when '10x00' operation = ImmediateOp_MOVI;
    when '10x01' operation = ImmediateOp_MVNI;
    when '10x10' operation = ImmediateOp_ORR;
    when '10x11' operation = ImmediateOp_BIC;
    when '110x0' operation = ImmediateOp_MOVI;
    when '110x1' operation = ImmediateOp_MVNI;
    when '1110x' operation = ImmediateOp_MOVI;
    when '11110' operation = ImmediateOp_MOVI;
    when '11111'
        // FMOV Dn,#imm is in main FP instruction set
        if Q == '0' then UNDEFINED;
        if Q == '0' then UnallocatedEncoding();
        operation = ImmediateOp_MOVI;

imm64 = AdvSIMDExpandImm(op, cmode, a:b:c:d:e:f:g:h);
imm = Replicate(imm64, datasize DIV 64);
```

Assembler Symbols

- `<Vd>` is the name of the SIMD&FP register, encoded in the "Rd" field.
- `<T>` For the 16-bit variant: is an arrangement specifier, encoded in “Q”:
  ```
  Q <T>
  0  4H
  1  8H
  ```
- For the 32-bit variant: is an arrangement specifier, encoded in “Q”:
  ```
  Q <T>
  0  2S
  1  4S
  ```
<imm8> Is an 8-bit immediate encoded in "a:b:c:d:e:f:g:h".

<amount> For the 16-bit variant: is the shift amount encoded in "cmode<1>":

<table>
<thead>
<tr>
<th>cmode&lt;1&gt;</th>
<th>amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
</tr>
</tbody>
</table>

defaulting to 0 if LSL is omitted.

For the 32-bit variant: is the shift amount encoded in "cmode<2:1>":

<table>
<thead>
<tr>
<th>cmode&lt;2:1&gt;</th>
<th>amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>0</td>
</tr>
<tr>
<td>01</td>
<td>8</td>
</tr>
<tr>
<td>10</td>
<td>16</td>
</tr>
<tr>
<td>11</td>
<td>24</td>
</tr>
</tbody>
</table>

defaulting to 0 if LSL is omitted.

Operation

```c
CheckFPAdvSIMDEnabled64();
bits(datasize) operand;
bits(datasize) result;

case operation of
  when ImmediateOp_MOVI
    result = imm;
  when ImmediateOp_MVNI
    result = NOT(imm);
  when ImmediateOp_ORR
    operand = V[rd];
    result = operand OR imm;
  when ImmediateOp_BIC
    operand = V[rd];
    result = operand AND NOT(imm);

V[rd] = result;
```

Operational information

If PSTATE.DIT is 1:

- The execution time of this instruction is independent of:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
- The response of this instruction to asynchronous exceptions does not vary based on:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
ORR (immediate)

Bitwise OR (immediate) performs a bitwise (inclusive) OR of a register value and an immediate register value, and writes the result to the destination register.

This instruction is used by the alias MOV (bitmask immediate).

31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
| sf | 0 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | N | immr | | imms | | Rn | Rd |
|----|---|---|---|---|---|---|---|---|---|-----|---|-----|---|-----|

opc

32-bit (sf == 0 & N == 0)

ORR <Wd|WSP>, <Wn>, #<imm>

64-bit (sf == 1)

ORR <Xd|SP>, <Xn>, #<imm>

integer d = UInt(Rd);
integer n = UInt(Rn);
integer datasize = if sf == '1' then 64 else 32;
boolean setflags;
LogicalOp op;
case opc of
  when '00' op = LogicalOp_AND; setflags = FALSE;
  when '01' op = LogicalOp_ORR; setflags = FALSE;
  when '10' op = LogicalOp_EOR; setflags = FALSE;
  when '11' op = LogicalOp_AND; setflags = TRUE;

bits(datasize) imm;
if sf == '0' & N != '0' then UNDEFINED;
(imm, -) = if sf == '0' & N != '0' then ReservedValue();
(imm, -) = DecodeBitMasks(N, imms, immr, TRUE);

Assembler Symbols

<Wd|WSP> Is the 32-bit name of the destination general-purpose register or stack pointer, encoded in the "Rd" field.
<Wn> Is the 32-bit name of the general-purpose source register, encoded in the "Rn" field.
<Xd|SP> Is the 64-bit name of the destination general-purpose register or stack pointer, encoded in the "Rd" field.
<Xn> Is the 64-bit name of the general-purpose source register, encoded in the "Rn" field.
<imm> For the 32-bit variant: is the bitmask immediate, encoded in "imms:immr".
    For the 64-bit variant: is the bitmask immediate, encoded in "N:imms:immr".

Alias Conditions

<table>
<thead>
<tr>
<th>Alias</th>
<th>Is preferred when</th>
</tr>
</thead>
<tbody>
<tr>
<td>MOV (bitmask immediate)</td>
<td>Rn == '11111' &amp;6 &amp; MoveWidePreferred(sf, N, imms, immr)</td>
</tr>
</tbody>
</table>
Operation

```c
bits(datasize) result;
bits(datasize) operand1 = X[n];
bits(datasize) operand2 = imm;

case op of
    when LogicalOp_AND result = operand1 AND operand2;
    when LogicalOp_OR  result = operand1 OR  operand2;
    when LogicalOp_EOR result = operand1 EOR operand2;

if setflags then
    PSTATE.<N,Z,C,V> = result<datasize-1>:IsZeroBit(result):'00';

if d == 31 && !setflags then
    SP[] = result;
else
    X[d] = result;
```

Operational information

If PSTATE.DIT is 1:
- The execution time of this instruction is independent of:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
- The response of this instruction to asynchronous exceptions does not vary based on:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.

ORR (shifted register)

Bitwise OR (shifted register) performs a bitwise (inclusive) OR of a register value and an optionally-shifted register value, and writes the result to the destination register.

This instruction is used by the alias MOV (register).

32-bit (sf == 0)

ORR <Wd>, <Wn>, <Wm>{, <shift> #<amount>}

64-bit (sf == 1)

ORR <Xd>, <Xn>, <Xm>{, <shift> #<amount>}

integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rm);
integer datasize = if sf == '1' then 64 else 32;
boolean setflags;
LogicalOp op;
case opc of
  when '00' op = LogicalOp AND; setflags = FALSE;
  when '01' op = LogicalOp ORR; setflags = FALSE;
  when '10' op = LogicalOp EOR; setflags = FALSE;
  when '11' op = LogicalOp AND; setflags = TRUE;
if sf == '0' && imm6<5> == '1' then UNDEFINED; if sf == '1' && imm6<5> == '1' then
ReservedValue();
ShiftType shift_type = DecodeShift(shift);
integer shift_amount = UInt(imm6);
boolean invert = (N == '1');

Assembler Symbols

<Wd> Is the 32-bit name of the general-purpose destination register, encoded in the "Rd" field.
<Wn> Is the 32-bit name of the first general-purpose source register, encoded in the "Rn" field.
<Wm> Is the 32-bit name of the second general-purpose source register, encoded in the "Rm" field.
<Xd> Is the 64-bit name of the general-purpose destination register, encoded in the "Rd" field.
<Xn> Is the 64-bit name of the first general-purpose source register, encoded in the "Rn" field.
<Xm> Is the 64-bit name of the second general-purpose source register, encoded in the "Rm" field.
<shift> Is the optional shift to be applied to the final source, defaulting to LSL and encoded in “shift”:

<table>
<thead>
<tr>
<th>&lt;shift&gt;</th>
<th>&lt;amount&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>LSL</td>
</tr>
<tr>
<td>01</td>
<td>LSR</td>
</tr>
<tr>
<td>10</td>
<td>ASR</td>
</tr>
<tr>
<td>11</td>
<td>ROR</td>
</tr>
</tbody>
</table>

For the 32-bit variant: is the shift amount, in the range 0 to 31, defaulting to 0 and encoded in the "imm6" field.
For the 64-bit variant: is the shift amount, in the range 0 to 63, defaulting to 0 and encoded in the "imm6" field,
**Alias Conditions**

<table>
<thead>
<tr>
<th>Alias</th>
<th>Is preferred when</th>
</tr>
</thead>
<tbody>
<tr>
<td>MOV (register)</td>
<td>shift == '00' &amp;&amp; imm6 == '000000' &amp;&amp; Rn == '11111'</td>
</tr>
</tbody>
</table>

**Operation**

```plaintext
bits(datasize) operand1 = X[n];
bits(datasize) operand2 = ShiftReg(m, shift_type, shift_amount);
if invert then operand2 = NOT(operand2);

case op of
  when LogicalOp_AND result = operand1 AND operand2;
  when LogicalOp_ORR result = operand1 OR operand2;
  when LogicalOp_EOR result = operand1 EOR operand2;
if setflags then
  PSTATE.<N,Z,C,V> = result<datasize-1>:IsZeroBit(result):'00';
X[d] = result;
```

**Operational information**

If PSTATE.DIT is 1:

- The execution time of this instruction is independent of:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
- The response of this instruction to asynchronous exceptions does not vary based on:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
PACDA, PACDZA

Pointer Authentication Code for Data address, using key A. This instruction computes and inserts a pointer authentication code for a data address, using a modifier and key A.

The address is in the general-purpose register that is specified by <Xd>.

The modifier is:

- In the general-purpose register or stack pointer that is specified by <Xn|SP> for PACDA.
- The value zero, for PACDZA.

### Integer

(ARMv8.3)

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9  | 8  | 7  | 6  | 5  | 4  | 3  | 2  | 1  | 0  |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 1  | 1  | 0  | 1  | 0  | 1  | 0  | 1  | 0  | 1  | 0  | 0  | 0  | 0  | 1  | 0  | 0  | Z  | 0  | 1  | 0  | Rn |

| 1  | 1  | 0  | 1  | 0  | 1  | 0  | 1  | 0  | 0  | 0  | 0  | 1  | 0  | 0  | Z  | 0  | 1  | 0  | Rd |

### PACDA (Z == 0)

PACDA <Xd>, <Xn|SP>

### PACDZA (Z == 1 && Rn == 11111)

PACDZA <Xd>

```java
boolean source_is_sp = FALSE;
integer d = UInt(Rd);
integer n = UInt(Rn);
if !HavePACExt() then
  UNDEFINED;
if Z == '0' then // PACDA
  if n == 31 then source_is_sp = TRUE;
else // PACDZA
  if n !!= 31 then UNDEFINED();
else // PACDZA
  if Z == '0' then // PACDA
    if n == 31 then source_is_sp = TRUE;
  else // PACDZA
    if n !!= 31 then UNallocatedEncoding();
```

### Assembler Symbols

<Xd> Is the 64-bit name of the general-purpose destination register, encoded in the "Rd" field.

<Xn|SP> Is the 64-bit name of the general-purpose source register or stack pointer, encoded in the "Rn" field.

### Operation

```java
if source_is_sp then
  X[d] = AddPACDA(X[d], SP[]);
else
  X[d] = AddPACDA(X[d], X[n]);
```

PACDB, PACDZB

Pointer Authentication Code for Data address, using key B. This instruction computes and inserts a pointer authentication code for a data address, using a modifier and key B.

The address is in the general-purpose register that is specified by <Xd>.

The modifier is:

- In the general-purpose register or stack pointer that is specified by <Xn|SP> for PACDB.
- The value zero, for PACDZB.

### Integer

(ARMv8.3)

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 1  | 1  | 0  | 1  | 0  | 1  | 0  | 1  | 1  | 0  | 0  | 0  | 0  | 0  | 1  | 0  | 0  | 0  | 1  | 0  | 0  | 0  | Z | 0 | 1 | 1 |

### PACDB (Z == 0)

PACDB <Xd>, <Xn|SP>

### PACDZB (Z == 1 && Rn == 1111)

PACDZB <Xd>

```plaintext
boolean source_is_sp = FALSE;
n = UInt(Rn);
if !HavePACExt() then UNDEFINED;
if Z == '0' then // PACDB
  if n == 31 then source_is_sp = TRUE;
else // PACDZB
  if n != 31 then UNDEFINED;() then UnallocatedEncoding();
if Z == '0' then // PACDB
  if n == 31 then source_is_sp = TRUE;
else // PACDZB
  if n != 31 then UnallocatedEncoding();
```

### Assembler Symbols

<Xd> Is the 64-bit name of the general-purpose destination register, encoded in the "Rd" field.

<Xn|SP> Is the 64-bit name of the general-purpose source register or stack pointer, encoded in the "Rn" field.

### Operation

```plaintext
if source_is_sp then
  X[d] = AddPACDB(X[d], SP[]);
else
  X[d] = AddPACDB(X[d], X[n]);
```


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PACGA

Pointer Authentication Code, using Generic key. This instruction computes the pointer authentication code for an address in the first source register, using a modifier in the second source register, and the Generic key. The computed pointer authentication code is returned in the upper 32 bits of the destination register.

<table>
<thead>
<tr>
<th>Rm</th>
<th>0 0 1 1 0 1 1 0</th>
<th>Rd</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rn</td>
<td>0 0 1 1 0 0</td>
<td></td>
</tr>
</tbody>
</table>

Integer

(PARMv8.3)

PACGA <Xd>, <Xn>, <Xm|SP>

boolean source_is_sp = FALSE;
integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rm);

if !HavePACExt() then
    UNDEFINED;
if m == 31 then source_is_sp = TRUE;
if m == 31 then UnallocatedEncoding();
if m == 31 then source_is_sp = TRUE;

Assembler Symbols

<Xd> Is the 64-bit name of the general-purpose destination register, encoded in the "Rd" field.
<Xn> Is the 64-bit name of the first general-purpose source register, encoded in the "Rn" field.
<Xm|SP> Is the 64-bit name of the second general-purpose source register or stack pointer, encoded in the "Rm" field.

Operation

if source_is_sp then
    X[d] = AddPACGA(X[n], SP());
else
    X[d] = AddPACGA(X[n], X[m]);
PACIA, PACIA1716, PACIASP, PACIAZ, PACIZA

Pointer Authentication Code for Instruction address, using key A. This instruction computes and inserts a pointer authentication code for an instruction address, using a modifier and key A.

The address is:

- In the general-purpose register that is specified by <Xd> for PACIA and PACIZA.
- In X17, for PACIA1716.
- In X30, for PACIASP and PACIAZ.

The modifier is:

- In the general-purpose register or stack pointer that is specified by <Xn|SP> for PACIA.
- The value zero, for PACIZA and PACIAZ.
- In X16, for PACIA1716.
- In SP, for PACIASP.

It has encodings from 2 classes: Integer and System.

**Integer**

(ARMv8.3)

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 1  | 1  | 0  | 1  | 0  | 1  | 0  | 1  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 1  | 0  | 0  | Z  | 0  | 0  | 0  | Rn |  | | Rd |

**PACIA (Z == 0)**

PACIA <Xd>, <Xn|SP>

**PACIZA (Z == 1 && Rn == 1111)**

PACIZA <Xd>

```c
boolean source_is_sp = FALSE;
integer d = UInt(Rd);
integer n = UInt(Rn);
if !HavePACExt() then
    UNDEFINED;
if Z == '0' then // PACIA
    if n == 31 then source_is_sp = TRUE;
else // PACIZA
    if n != 31 then UNDEFINED;
if !HavePACExt() then UnallocatedEncoding();
```  

**System**

(ARMv8.3)

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 1  | 1  | 0  | 1  | 0  | 1  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 1  | 0  | 0  | 0  | 0  | x  | 1  | 0  | 0  | x  | 1  | 1  | 1  | 1  | 1  | CRm | op2 |
integer d;
integer n;
boolean source_is_sp = FALSE;

case CRm:op2 of
  when '0011 000' // PACIAZ
    d = 30;
    n = 31;
  when '0011 001' // PACIASP
    d = 30;
    source_is_sp = TRUE;
  when '0011 11x' // PACIA, PACIA1716
    n = 16;
    if HaveBtiExt() then
      BTypeCompatible = BTypeCompatible_PACIXSP();
    end
    when '0001 000' // PACIA1716
      d = 17;
      n = 16;
    when '0001 11x' // PACIAZ
        X[d] = AddPACIA (X[d], SP[]);
    else
      X[d] = AddPACIA (X[d], X[n]);

Assembler Symbols

<Xd> Is the 64-bit name of the general-purpose destination register, encoded in the "Rd" field.

<Xn|SP> Is the 64-bit name of the general-purpose source register or stack pointer, encoded in the "Rn" field.

Operation

if HavePACExt() then
  if source_is_sp then
    X(d) = AddPACIA (X[d], SP[]);
  else
    X(d) = AddPACIA (X[d], X[n]);


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PACIB, PACIB1716, PACIBSP, PACIBZ, PACIZB

Pointer Authentication Code for Instruction address, using key B. This instruction computes and inserts a pointer authentication code for an instruction address, using a modifier and key B.

The address is:
- In the general-purpose register that is specified by <Xd> for PACIB and PACIZB.
- In X17, for PACIB1716.
- In X30, for PACIBSP and PACIBZ.

The modifier is:
- In the general-purpose register or stack pointer that is specified by <Xn|SP> for PACIB.
- The value zero, for PACIZB and PACIBZ.
- In X16, for PACIB1716.
- In SP, for PACIBSP.

It has encodings from 2 classes: Integer and System

**Integer (ARMv8.3)**

```
|   | 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9  | 8  | 7  | 6  | 5  | 4  | 3  | 2  | 1  | 0  |
|---|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
|   | 1  | 1  | 0  | 1  | 0  | 1  | 0  | 0  | 0  | 0  | 0  | 1  | 0  | 0  | 0  | 0  | 0  | Z  | 0  | 0  | 1  |
```

### PACIB (Z == 0)

PACIB <Xd>, <Xn|SP>

### PACIZB (Z == 1 && Rn == 1111)

PACIZB <Xd>

```java
boolean source_is_sp = FALSE;
integer d = UInt(Rd);
integer n = UInt(Rn);
if !HavePACExt() then
    UNDEFINED;
if Z == '0' then // PACIB
    if n == 31 then source_is_sp = TRUE;
else // PACIBZ
    if n != 31 then UNDEFINED;
    if Z == '0' then // PACIB
        if n == 1 then UNDEFINED;
else // PACIBZ
    if n != 31 then UnallocatedEncoding();
```

**System (ARMv8.3)**

```
|   | 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9  | 8  | 7  | 6  | 5  | 4  | 3  | 2  | 1  | 0  |
|---|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
|   | 1  | 1  | 0  | 1  | 0  | 1  | 0  | 0  | 0  | 0  | 0  | 1  | 0  | 0  | 0  | 0  | 0  | x  | 1  | 0  | 1  | x  | 1  | 1  | 1  | 1  | 1  |
```

CRm op2
PACIB1716 (CRm == 0001 && op2 == 010)

PACIB1716

PACIBSP (CRm == 0011 && op2 == 011)

PACIBSP

PACIBZ (CRm == 0011 && op2 == 010)

PACIBZ

integer d;
integer n;
boolean source_is_sp = FALSE;

case CRm:op2 of
    when '0011 010' // PACIBZ
d = 30;
n = 31;
    when '0011 011' // PACIBSP
d = 30;
source_is_sp = TRUE;
    if when '0001 010' // PACIB1716
        d = 17;
n = 16;
        when '0001 000' SEE "PACIA";
        when '0001 100' SEE "AUTIA";
        when '0001 110' SEE "AUTIB";
        when '0011 00x' SEE "PACIA";
        when '0011 10x' SEE "AUTIA";
        when '0011 11x' SEE "AUTIB";
        when '0000 111' SEE "XPACLRI"; HaveBTIExt() then
            BTypeCompatible = BTypeCompatible PACXSP();
    when '0001 010' // PACIB1716
        d = 17;
n = 16;
        when '0001 000' SEE "PACIA";
        when '0001 100' SEE "AUTIA";
        when '0001 110' SEE "AUTIB";
        when '0011 00x' SEE "PACIA";
        when '0011 10x' SEE "AUTIA";
        when '0011 11x' SEE "AUTIB";
        when '0000 111' SEE "XPACLRI";

Assembler Symbols

<Xd> Is the 64-bit name of the general-purpose destination register, encoded in the "Rd" field.

<Xn|SP> Is the 64-bit name of the general-purpose source register or stack pointer, encoded in the "Rn" field.

Operation

if HavePACExt() then
    if source_is_sp then
        X[d] = AddPACIB(X[d], SP[]);
    else
        X[d] = AddPACIB(X[d], X[n]);


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PMUL

Polynomial Multiply. This instruction multiplies corresponding elements in the vectors of the two source SIMD&FP registers, places the results in a vector, and writes the vector to the destination SIMD&FP register.

For information about multiplying polynomials see *Polynomial arithmetic over \{0, 1\}*. 

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

Three registers of the same type

PMUL \(<Vd>.<T>, <Vn>.<T>, <Vm>.<T>\)

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
|    |   U |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| Q  | 1  | 0  | 1  | 1  | 0  | size | 1  | Rm | 1  | 0  | 0  | 1  | 1  | 1  | Rn |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |

Integer definitions:

\[\begin{align*}
\text{integer } \text{d} & = \text{UInt}(\text{Rd}); \\
\text{integer } \text{n} & = \text{UInt}(\text{Rn}); \\
\text{integer } \text{m} & = \text{UInt}(\text{Rm}); \\
\text{if } \text{U} == '1' \text{ and } \text{size} != '00' \text{ then UNDEFINED; } \\
\text{if } \text{size} == '11' \text{ then UNDEFINED; } \\
\text{integer } \text{esize} & = 8 \times \text{UInt}(\text{size}); \\
\text{integer } \text{datasize} & = \text{if } \text{Q} == '1' \text{ then 128 else 64; } \\
\text{integer } \text{elements} & = \text{datasize} \div \text{esize; } \\
\text{boolean } \text{poly} & = (\text{U} == '1'); \\
\end{align*}\]

Assembler Symbols

\(<Vd>\) Is the name of the SIMD&FP destination register, encoded in the "Rd" field.

\(<T>\) Is an arrangement specifier, encoded in “size-Q”:

\[\begin{array}{c|c|c}
\text{size} & \text{Q} & <T> \\
\hline
00 & 0 & 8B \\
00 & 1 & 16B \\
01 & x & \text{RESERVED} \\
1x & x & \text{RESERVED} \\
\end{array}\]

\(<Vn>\) Is the name of the first SIMD&FP source register, encoded in the "Rn" field.

\(<Vm>\) Is the name of the second SIMD&FP source register, encoded in the "Rm" field.
Operation

```c
CheckFPAdvSIMDEnabled64();
bits(datasize) operand1 = V[n];
bits(datasize) operand2 = V[m];
bits(datasize) result;
bits(esize) element1;
bits(esize) element2;
bits(esize) product;
for e = 0 to elements-1
  element1 = Elem[operand1, e, esize];
  element2 = Elem[operand2, e, esize];
  if poly then
    product = PolynomialMult(element1, element2)<esize-1:0>;
  else
    product = (UInt(element1) * UInt(element2))<esize-1:0>;
  Elem[result, e, esize] = product;
V[d] = result;
```

Operational information

If PSTATE.DIT is 1:
- The execution time of this instruction is independent of:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
- The response of this instruction to asynchronous exceptions does not vary based on:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
PMULL, PMULL2

Polynomial Multiply Long. This instruction multiplies corresponding elements in the lower or upper half of the vectors of the two source SIMD&FP registers, places the results in a vector, and writes the vector to the destination SIMD&FP register. The destination vector elements are twice as long as the elements that are multiplied.

For information about multiplying polynomials see *Polynomial arithmetic over \{0, 1\}.*

The PMULL instruction extracts each source vector from the lower half of each source register, while the PMULL2 instruction extracts each source vector from the upper half of each source register.

Depending on the settings in the *CPACR_EL1*, *CPTR_EL2*, and *CPTR_EL3* registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9  | 8  | 7  | 6  | 5  | 4  | 3  | 2  | 1  | 0  |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0  | Q  | 0  | 1  | 1  | 1  | 1  | 0  | size | 1  | Rm | 1  | 1  | 1  | 0  | 0  | Rn | Rd |

Three registers, not all the same type

PMULL\{2\} <Vd>,<Ta>, <Vn>,<Tb>, <Vm>,<Tb>

```plaintext
integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rm);

if size == '01' || size == '10' then UNDEFINED;
if size == '11' && size == '10' then ReservedValue();
if size == '11' && !HaveBit128PMULLExt() then UnallocatedEncoding() then UNDEFINED;
integer esize = 8 << UInt(size);
integer datasize = 64;
integer part = UInt(Q);
integer elements = datasize DIV esize;
```

**Assembler Symbols**

<table>
<thead>
<tr>
<th>2</th>
<th>0</th>
<th>[absent]</th>
<th>1</th>
<th>[present]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Is the second and upper half specifier. If present it causes the operation to be performed on the upper 64 bits of the registers holding the narrower elements, and is encoded in "Q":

\begin{align*}
0 & \quad [\text{absent}] \\
1 & \quad [\text{present}]
\end{align*}

<Vd> Is the name of the SIMD&FP destination register, encoded in the "Rd" field.

<Ta> Is an arrangement specifier, encoded in “size”:

\begin{align*}
\text{size} & \quad \langle \text{Ta} \rangle \\
00 & \quad 8H \\
01 & \quad \text{RESERVED} \\
10 & \quad \text{RESERVED} \\
11 & \quad 1Q
\end{align*}

The '1Q' arrangement is only allocated in an implementation that includes the Cryptographic Extension, and is otherwise RESERVED.

<Vn> Is the name of the first SIMD&FP source register, encoded in the "Rn" field.

<Tb> Is an arrangement specifier, encoded in “size:Q”:

\begin{align*}
\text{size} & \quad Q & \quad \langle \text{Tb} \rangle \\
00 & \quad 0 & \quad 8B \\
00 & \quad 1 & \quad 16B \\
01 & \quad x & \quad \text{RESERVED} \\
10 & \quad x & \quad \text{RESERVED} \\
11 & \quad 0 & \quad 1D \\
11 & \quad 1 & \quad 2D
\end{align*}

<Vm> Is the name of the second SIMD&FP source register, encoded in the "Rm" field.
Operation

```c
CheckFPAdvSIMEnabled64();
bits(datasize) operand1 = Vpart[n, part];
bits(datasize) operand2 = Vpart[m, part];
bits(2*datasize) result;
brightness(element1);
brightness(element2);

for e = 0 to elements-1
  element1 = Elem[operand1, e, esize];
  element2 = Elem[operand2, e, esize];
  Elem[result, e, 2*esize] = PolynomialMult(element1, element2);
V[d] = result;
```

Operational information

If PSTATE.DIT is 1:
- The execution time of this instruction is independent of:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
- The response of this instruction to asynchronous exceptions does not vary based on:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
**PRFM (immediate)**

Prefetch Memory (immediate) signals the memory system that data memory accesses from a specified address are likely to occur in the near future. The memory system can respond by taking actions that are expected to speed up the memory accesses when they do occur, such as preloading the cache line containing the specified address into one or more caches.

The effect of an `PRFM` instruction is **IMPLEMENTATION DEFINED**. For more information, see *Prefetch memory*.

For information about memory accesses, see *Load/Store addressing modes*.

<table>
<thead>
<tr>
<th>size</th>
<th>opc</th>
</tr>
</thead>
<tbody>
<tr>
<td>31</td>
<td>30</td>
</tr>
<tr>
<td>29</td>
<td>28</td>
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<td>9</td>
<td>8</td>
</tr>
<tr>
<td>7</td>
<td>6</td>
</tr>
<tr>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
</tr>
</tbody>
</table>

**Unsigned offset**

```plaintext
PRFM (<prfop>|#<imm5>), [<Xn|SP>{, #<pimm}>]
```

```plaintext
boolean wback = FALSE;
boolean postindex = FALSE;
integer scale = UInt(size);
bits(64) offset = LSL(ZeroExtend(imm12, 64), scale);
```

**Assembler Symbols**

- `<prfop>`: Is the prefetch operation, defined as `<type><target><policy>`. `<type>` is one of:
  - **PLD**: Prefetch for load, encoded in the "Rt<4:3>" field as 0b00.
  - **PLI**: Preload instructions, encoded in the "Rt<4:3>" field as 0b01.
  - **PST**: Prefetch for store, encoded in the "Rt<4:3>" field as 0b10.

- `<target>` is one of:
  - **L1**: Level 1 cache, encoded in the "Rt<2:1>" field as 0b00.
  - **L2**: Level 2 cache, encoded in the "Rt<2:1>" field as 0b01.
  - **L3**: Level 3 cache, encoded in the "Rt<2:1>" field as 0b10.

- `<policy>` is one of:
  - **KEEP**: Retained or temporal prefetch, allocated in the cache normally. Encoded in the "Rt<0>" field as 0.
  - **STRM**: Streaming or non-temporal prefetch, for data that is used only once. Encoded in the "Rt<0>" field as 1.

For more information on these prefetch operations, see *Prefetch memory*.

- For other encodings of the "Rt" field, use `<imm5>`.

- `<imm5>`: Is the prefetch operation encoding as an immediate, in the range 0 to 31, encoded in the "Rt" field.

- `<Xn|SP>`: Is the 64-bit name of the general-purpose base register or stack pointer, encoded in the "Rt" field.

- `<pimm>`: Is the optional positive immediate byte offset, a multiple of 8 in the range 0 to 32760, defaulting to 0 and encoded in the "imm12" field as `<pimm>/8`. 
integer n = Uint(Rn);
integer t = Uint(Rt);
AccType acctype = AccType_NORMAL;
MemOp memop;
boolean signed;
integer regsize;

if opc<1> == '0' then
  // store or zero-extending load
  memop = if opc<0> == '1' then MemOp_LOAD else MemOp_STORE;
  regsize = if size == '11' then 64 else 32;
  signed = FALSE;
else
  if size == '11' then
    memop = MemOp_PREFETCH;
    if opc<0> == '1' then UNDEFINED;
  else
    // sign-extending load
    if opc<0> == '1' then UnallocatedEncoding();
    else
    // sign-extending load
    memop = MemOp_LOAD;
    if opc<0> == '1' then UnallocatedEncoding();
    if size == '10' && opc<0> == '1' then UNDEFINED;
  end
  regsize = if opc<0> == '1' then 32 else 64;
  signed = TRUE;

integer datasize = 8 << scale;
if bits(64) address;
bias(datasize) data;
boolean wb_unknown = FALSE;
boolean rt_unknown = FALSE;
if memop == HaveMTEExt() then
    boolean is_load_store = memop IN {MemOp STORE, MemOp LOAD};
    SetNotTagCheckedInstruction(is_load_store && n == 31 && !wback);

bits(64) address;
bias(datasize) data;
boolean wb_unknown = FALSE;
boolean rt_unknown = FALSE;
if memop == MemOp LOAD && wback && n == t && n != 31 then
    c = ConstrainUnpredictable(Unpredictable_WBOVERLAPLD);
    assert c IN {Constraint_WBSUPPRESS, Constraint_UNKNOWN, Constraint_UNDEF, Constraint_NOP};
    case c of
        when Constraint_WBSUPPRESS wback = FALSE; // writeback is suppressed
        when Constraint_UNKNOWN wb_unknown = TRUE; // writeback is UNKNOWN
        when Constraint_UNDEF
            UnallocatedEncoding();
        when Constraint_NOP EndOfInstruction();
when

if memop == MemOp STORE && wback && n == t && n != 31 then
    c = ConstrainUnpredictable(Unpredictable_WBOVERLAPST);
    assert c IN {Constraint_NONE, Constraint_UNKNOWN, Constraint_UNDEF, Constraint_NOP};
    case c of
        when Constraint_NONE rt_unknown = FALSE; // value stored is original value
        when Constraint_UNKNOWN rt_unknown = TRUE; // value stored is UNKNOWN
        when Constraint_UNDEF
            UnallocatedEncoding();
        when Constraint_NOP EndOfInstruction();

if n == 31 then
    if memop != MemOp_PREFETCH then CheckSPAlignment();
    address = SP[ ];
else
    address = X[n];
if ! postindex then
    address = address + offset;

case memop of
    when MemOp STORE
        if rt_unknown then
            data = bits(datasize) UNKNOWN;
        else
            data = X[t];
        Mem[address, datasize DIV 8, acctype] = data;
        when MemOp LOAD
            data = Mem[address, datasize DIV 8, acctype];
            if signed then
                X[t] = SignExtend(data, regsize);
            else
                X[t] = ZeroExtend(data, regsize);
            when MemOp_PREFETCH
                Prefetch(address, t<4:0>);

if wback then
    if wb_unknown then
        address = bits(64) UNKNOWN;
    elseif postindex then
        address = address + offset;
    if n == 31 then
        SP[ ] = address;
else
X[n] = address;
PRFM (register)

Prefetch Memory (register) signals the memory system that data memory accesses from a specified address are likely to occur in the near future. The memory system can respond by taking actions that are expected to speed up the memory accesses when they do occur, such as preloading the cache line containing the specified address into one or more caches.

The effect of an PRFM instruction is IMPLEMENTATION DEFINED. For more information, see Prefetch memory.

For information about memory accesses, see Load/Store addressing modes.

```
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 1  | 1  | 1  | 1  | 0  | 0  | 0  | 1  | 0  | 1  |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
```

Integer

```
PRFM (<prfop>|#<imm5>), [<Xn|SP>, (<Wm>|<Xm>)]{, <extend> {<amount>}}
```

boolean wback = FALSE;
boolean postindex = FALSE;
integer scale = UInt(size);
if option<1> == '0' then UNDEFINED;             // sub-word index
ExtendType extend_type = DecodeRegExtend(option);
integer shift = if S == '1' then scale else 0;

Assembler Symbols

- **<prfop>**
  - Is the prefetch operation, defined as <type><target><policy>.
  - <type> is one of:
    - **PLD**
      - Prefetch for load, encoded in the "Rt<4:3>" field as 0b00.
    - **PLI**
      - Preload instructions, encoded in the "Rt<4:3>" field as 0b01.
    - **PST**
      - Prefetch for store, encoded in the "Rt<4:3>" field as 0b10.
  - <target> is one of:
    - **L1**
      - Level 1 cache, encoded in the "Rt<2:1>" field as 0b00.
    - **L2**
      - Level 2 cache, encoded in the "Rt<2:1>" field as 0b01.
    - **L3**
      - Level 3 cache, encoded in the "Rt<2:1>" field as 0b10.
  - <policy> is one of:
    - **KEEP**
      - Retained or temporal prefetch, allocated in the cache normally. Encoded in the "Rt<0>" field as 0.
    - **STRM**
      - Streaming or non-temporal prefetch, for data that is used only once. Encoded in the "Rt<0>" field as 1.

- **<imm5>**
  - Is the prefetch operation encoding as an immediate, in the range 0 to 31, encoded in the "Rt" field.
  - This syntax is only for encodings that are not accessible using <prfop>.

- **<Xn|SP>**
  - Is the 64-bit name of the general-purpose base register or stack pointer, encoded in the "Rn" field.

- **<Wm>**
  - When option<0> is set to 0, is the 32-bit name of the general-purpose index register, encoded in the "Rm" field.
When option<0> is set to 1, is the 64-bit name of the general-purpose index register, encoded in the "Rm" field.

Is the index extend/shift specifier, defaulting to LSL, and which must be omitted for the LSL option when <amount> is omitted. It is encoded in "option":

<table>
<thead>
<tr>
<th>option</th>
<th>&lt;extend&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>010</td>
<td>UXTW</td>
</tr>
<tr>
<td>011</td>
<td>LSL</td>
</tr>
<tr>
<td>110</td>
<td>SXTW</td>
</tr>
<tr>
<td>111</td>
<td>SXTX</td>
</tr>
</tbody>
</table>

Is the index shift amount, optional only when <extend> is not LSL. Where it is permitted to be optional, it defaults to #0. It is encoded in "S":

<table>
<thead>
<tr>
<th>S</th>
<th>&lt;amount&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>#0</td>
</tr>
<tr>
<td>1</td>
<td>#3</td>
</tr>
</tbody>
</table>

### Shared Decode

```cpp
integer n = Uint(Rn);
integer t = Uint(Rt);
integer m = Uint(Rm);
AccType accType = AccType_NORMAL;
MemOp memop;
boolean signed;
integer regsize;

if opc<1> == '0' then
    // store or zero-extending load
    memop = if opc<0> == '1' then MemOp_LOAD else MemOp_STORE;
    regsize = if size == '11' then 64 else 32;
    signed = FALSE;
else
    if size == '11' then
        memop = MemOp_PREFETCH;
        if opc<0> == '1' then UNDEFINED;
    else
        // sign-extending load
        memop = if opc<0> == '1' then UnallocatedEncoding();
        if size == '10' && opc<0> == '1' then UNDEFINED;
        regsize = if opc<0> == '1' then 32 else 64;
        signed = TRUE;
    end if

integer datasize = 8 << scale;
```
bits(64) offset = ExtendReg(m, extend_type, shift);

if memop == MemOp_STORE && wback && n == t && n != 31 then
    c = ConstrainUnpredictable(Unpredictable_WBOVERLAPLD);
    assert c IN {Constraint_WBSUPPRESS, Constraint_UNKNOWN, Constraint_UNDEF, Constraint_NOP};
    case c of
        when Constraint_WBSUPPRESS
            wback = FALSE; // writeback is suppressed
        when Constraint_UNKNOWN
            wb_unknown = TRUE; // writeback is UNKNOWN
        when Constraint_UNDEF
            UNDEFINED;
        when UnallocatedEncoding()
            UnallocatedEncoding();
        when Constraint_NOP
            EndOfInstruction();
    end case;

if n == 31 then
    if memop != MemOp_PREFETCH then
        CheckSPAlignment();
        address = SP[];
    else
        address = X[n];
else
    if ! postindex then
        address = address + offset;
    end case;

    case memop of
        when MemOp_STORE
            if rt_unknown then
                data = bits(datasize) UNKNOWN;
            else
                data = X[t];
                Mem[address, datasize DIV 8, acctype] = data;
            end if;
        when MemOp_LOAD
            data = Mem[address, datasize DIV 8, acctype];
            if signed then
                X[t] = SignExtend(data, regsize);
            else
                X[t] = ZeroExtend(data, regsize);
            end if;
        when MemOp_PREFETCH
            Prefetch(address, t<4:0>);
    end case;

if wback then
    if wb unknown then
        address = bits(64) UNKNOWN;
    elsif postindex then
        address = address + offset;
    if n == 31 then
        SP[] = address;
else
    X[n] = address;

Internal version only: isa v30.25-28.03. AdvSIMD v27.01-26.01, pseudocode v85-xml-00c8-rc3354; Build timestamp: 2018-06-16T09:04:45

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PRFM (unscaled offset)

Prefetch Memory (unscaled offset) signals the memory system that data memory accesses from a specified address are likely to occur in the near future. The memory system can respond by taking actions that are expected to speed up the memory accesses when they do occur, such as preloading the cache line containing the specified address into one or more caches.

The effect of an PRFM instruction is IMPLEMENTATION DEFINED. For more information, see Prefetch memory. For information about memory accesses, see Load/Store addressing modes.

### Unscaled offset

```
<table>
<thead>
<tr>
<th>imm9</th>
<th>Rn</th>
<th>Rt</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 0</td>
<td>1 0</td>
<td>0 0</td>
</tr>
<tr>
<td>size</td>
<td>opc</td>
<td></td>
</tr>
</tbody>
</table>
```

**Unscaled offset**

```
PRFM (<prfop>|#<imm5>), [<Xn|SP>{, #<simm>}]  

boolean wback = FALSE;
boolean postindex = FALSE;
integer scale = UInt(size);
bits(64) offset = SignExtend(imm9, 64);
```

### Assembler Symbols

- `<prfop>` is the prefetch operation, defined as `<type><target><policy>`. `<type>` is one of:
  - **PLD**: Prefetch for load, encoded in the "Rt<4:3>" field as 0b00.
  - **PLI**: Preload instructions, encoded in the "Rt<4:3>" field as 0b01.
  - **PST**: Prefetch for store, encoded in the "Rt<4:3>" field as 0b10.

- `<target>` is one of:
  - **L1**: Level 1 cache, encoded in the "Rt<2:1>" field as 0b00.
  - **L2**: Level 2 cache, encoded in the "Rt<2:1>" field as 0b01.
  - **L3**: Level 3 cache, encoded in the "Rt<2:1>" field as 0b10.

- `<policy>` is one of:
  - **KEEP**: Retained or temporal prefetch, allocated in the cache normally. Encoded in the "Rt<0>" field as 0.
  - **STRM**: Streaming or non-temporal prefetch, for data that is used only once. Encoded in the "Rt<0>" field as 1.

For more information on these prefetch operations, see Prefetch memory. For other encodings of the "Rt" field, use `<imm5>`.

- `<imm5>` is the prefetch operation encoding as an immediate, in the range 0 to 31, encoded in the "Rt" field.
- `<Xn|SP>` is the 64-bit name of the general-purpose base register or stack pointer, encoded in the "Rt" field.
- `<simm>` is the optional signed immediate byte offset, in the range -256 to 255, defaulting to 0 and encoded in the "imm9" field.
integer n = UInt(Rn);
integer t = UInt(Rt);
AccType acctype = AccType_NORMAL;
MemOp memop;
boolean signed;
integer regsize;

if opc<1> == '0' then
  // store or zero-extending load
  memop = if opc<0> == '1' then MemOp LOAD else MemOp STORE;
  regsize = if size == '11' then 64 else 32;
  signed = FALSE;
else
  if size == '11' then
    memop = MemOp_PREFETCH;
  if opc<0> == '1' then UNDEFINED;
  else
    // sign-extending load
    memop = if opc<0> == '1' then UnallocatedEncoding() else
    if size == '10' && opc<0> == '1' then UNDEFINED;
    if size == '10' && opc<0> == '1' then UnallocatedEncoding();
  if opc<0> == '1' then 32 else 64;
  signed = TRUE;

integer datasize = 8 << scale;
if memop == MemOp_STORE && wback && n == t && n != 31 then
    c = ConstrainUnpredictable(Unpredictable_WBOOTLAST);
    assert c IN {Constraint_NONE, Constraint_UNKNOWN, Constraint_UNDEF, Constraint_NOP};
    case c of
        when Constraint_NONE rt_unknown = FALSE; // value stored is original value
        when Constraint_UNKNOWN rt_unknown = TRUE; // value stored is UNKNOWN
        when Constraint_UNDEF UnallocatedEncoding() UNDEFINED;
        when Constraint_NOP EndOfInstruction();
if n == 31 then
    if memop != MemOp_PREFETCH then CheckSPAlignment();
    address = SP[];
else
    address = X[n];
if ! postindex then
    address = address + offset;
case memop of
    when MemOp_STORE
        if rt_unknown then
            data = bits(datasize) UNKNOWN;
        else
            data = X[t];
            Mem[address, datasize DIV 8, acctype] = data;
    when MemOp_LOAD
        data = Mem[address, datasize DIV 8, acctype];
        if signed then
            X[t] = SignExtend(data, regsize);
        else
            X[t] = ZeroExtend(data, regsize);
        when MemOp_PREFETCHPrefetch(address, t<4:0>);
if wback then
    if wb_unknown then
        address = bits(64) UNKNOWN;
    elsif postindex then
        address = address + offset;
    if n == 31 then
        SP[] = address;
else
    X[n] = address;
PSB CSYNC

Profiling Synchronization Barrier. This instruction is a barrier that ensures that all existing profiling data for the current PE has been formatted, and profiling buffer addresses have been translated such that all writes to the profiling buffer have been initiated. A following DSB instruction completes when the writes to the profiling buffer have completed.

If the Statistical Profiling Extension is not implemented, this instruction executes as a NOP.

System (ARMv8.2)

<table>
<thead>
<tr>
<th>CRm</th>
<th>op2</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
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<td>1</td>
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<tr>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

System

```
PSB CSYNC

SystemHintOp op;

case CRm:op2 of
    when '0000 000' op = SystemHintOp_NOP;
    when '0000 001' op = SystemHintOp_YIELD;
    when '0000 010' op = SystemHintOp_WFE;
    when '0000 011' op = SystemHintOp_WFI;
    when '0000 100' op = SystemHintOp_SEV;
    when '0000 101' op = SystemHintOp_SEVL;
    when '0000 111'   see "XPACLRI";
    when '0001 xxx'   see "PACIA1716, PACIB1716, AUTIA1716, AUTIB1716";
    when '0010 000'
        if !HaveRASExt() then EndOfInstruction();        // Instruction executes as NOP
        op = SystemHintOp_ESB;
    when '0010 001'
        if !HaveStatisticalProfiling() then EndOfInstruction(); // Instruction executes as NOP
        op = SystemHintOp_PSB;
    when '0010 010'
        if !HaveSelfHostedTrace() then EndOfInstruction();  // Instruction executes as NOP
        op = SystemHintOp_TSB;
    when '0010 100'
        op = SystemHintOp_CSDB;
    when '0011 xxx'
        see "PACIAZ, PACIASP, PACIBZ, PACIBSP, AUTIAZ, AUTIASP, AUTIBZ, AUTIBSP";
    when '0100 xxx'
        op = SystemHintOp_BTI;
        BTypeCompatible = BTypeCompatible_BTI(op2<2:1>);
    otherwise EndOfInstruction();                          // Instruction executes as NOP
```

PSB CSYNC
case op of
when SystemHintOp_YIELDHint_Yield();
when SystemHintOp_WFE
  if IsEventRegisterSet() then
    ClearEventRegister();
  else
    if PSTATE.EL == EL0 then
      // Check for traps described by the OS which may be EL1 or EL2.
      AArch64.CheckForWFxTrap(EL1, TRUE);
    if EL2Enabled() && PSTATE.EL in {EL0, EL1} && !IsInHost() then
      // Check for traps described by the Hypervisor.
      AArch64.CheckForWFxTrap(EL2, TRUE);
    if HaveEL(EL3) && PSTATE.EL != EL3 then
      // Check for traps described by the Secure Monitor.
      AArch64.CheckForWFxTrap(EL3, TRUE);
    WaitForEvent();
  when SystemHintOp_WFI
  if !InterruptPending() then
    if PSTATE.EL == EL0 then
      // Check for traps described by the OS which may be EL1 or EL2.
      AArch64.CheckForWFxTrap(EL1, FALSE);
    if EL2Enabled() && PSTATE.EL in {EL0, EL1} && !IsInHost() then
      // Check for traps described by the Hypervisor.
      AArch64.CheckForWFxTrap(EL2, FALSE);
    if HaveEL(EL3) && PSTATE.EL != EL3 then
      // Check for traps described by the Secure Monitor.
      AArch64.CheckForWFxTrap(EL3, FALSE);
    WaitForInterrupt();
when SystemHintOp_SEVSendEvent();
when SystemHintOp_SEVLSendEventLocal();
when SystemHintOp_ESBSynchronizeErrors();
  AArch64.ESBOperation();
  if EL2Enabled() && PSTATE.EL in {EL0, EL1} then
    AArch64.vESBOperation();
    TakeUnmaskedErrorInterrupts();
when SystemHintOp_PSBProfilingSynchronizationBarrier();
when SystemHintOp_TSB
  TraceSynchronizationBarrier();
when SystemHintOp_CSDBConsumptionOfSpeculativeDataBarrier();
|when otherwise // do nothing SystemHintOp_BTI
  BTypeNext = '00'; |
|otherwise // do nothing}

Internal version only: isa v30.25,v29.05, AdvSIMD v27.01,v26.0, pseudocode v85-xml-00b88_rc3055 ; Build timestamp: 2018-09-13T13:2018-06-16T09:04:45
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PSSBB

Physical Speculative Store Bypass Barrier is a memory barrier which prevents speculative loads from bypassing earlier stores to the same physical address.

The semantics of the Physical Speculative Store Bypass Barrier are:

- When a load to a location appears in program order after the PSSBB, then the load does not speculatively read an entry earlier in the coherence order for that location than the entry generated by the latest store satisfying all of the following conditions:
  - The store is to the same location as the load.
  - The store appears in program order before the PSSBB.
- When a load to a location appears in program order before the PSSBB, then the load does not speculatively read data from any store satisfying all of the following conditions:
  - The store is to the same location as the load.
  - The store appears in program order after the PSSBB.

```plaintext
CRm  opc
1 1 0 1 0 1 0 0 0 0 0 1 1 0 1 0 0 1 0 0 1 1 1 1
```

System

```plaintext
PSSBB

MemBarrierOp op;
MBReqDomain domain;
MBReqTypes types;

case opc of
  when '00' op = MemBarrierOp_DSB;
  when '01' op = MemBarrierOp_DMB;
  when '10' op = MemBarrierOp_ISB;
  otherwise
    if otherwise HaveSBExtUnallocatedEncoding() && CRm<3:0> == '0000' then
      op = MemBarrierOp_PSSBB;
    elsif CRm<3:2> == '00' then
      op = MemBarrierOp_SSBB;
    elsif CRm<3:2> == '01' then
      op = MemBarrierOp_PSSBB();
    else
      types = MBReqTypes_All;
      domain = MBReqDomain_FullSystem;
```
case op of
    when MemBarrierOp_DSBDataSynchronizationBarrier (domain, types);
    when MemBarrierOp_DMBDataMemoryBarrier (domain, types);
    when MemBarrierOp_ISBInstructionSynchronizationBarrier ();
    when MemBarrierOp_SSBSpeculativeSynchronizationBarrierToVA ();
    when MemBarrierOp_PSSBSpeculativeSynchronizationBarrierToPA ();
    when MemBarrierOp_SBSpeculationBarrier ();
RADDHN, RADDHN2

Rounding Add returning High Narrow. This instruction adds each vector element in the first source SIMD&FP register to the corresponding vector element in the second source SIMD&FP register, places the most significant half of the result into a vector, and writes the vector to the lower or upper half of the destination SIMD&FP register.

The results are rounded. For truncated results, see ADDHN.

The RADDHN instruction writes the vector to the lower half of the destination register and clears the upper half, while the RADDHN2 instruction writes the vector to the upper half of the destination register without affecting the other bits of the register.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

<table>
<thead>
<tr>
<th>U</th>
<th>Q</th>
<th>size</th>
<th>Rm</th>
<th>Rd</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Three registers, not all the same type

RADDHN\{2\} <Vd>.<Tb>, <Vn>.<Ta>, <Vm>.<Ta>

integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rm);

if size == '11' then UNDEFINED;
integer esize = 8 << (int(size) == '11' ? RESERVEDValue() : UInt(size));
integer datasize = 64;
integer part = UInt(Q);
integer elements = datasize DIV esize;

boolean sub_op = (o1 == '1');
boolean round = (U == '1');

Assembler Symbols

2

Is the second and upper half specifier. If present it causes the operation to be performed on the upper 64 bits of the registers holding the narrower elements, and is encoded in "Q":

<table>
<thead>
<tr>
<th>Q</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>[absent]</td>
</tr>
<tr>
<td>1</td>
<td>[present]</td>
</tr>
</tbody>
</table>

<Vd> Is the name of the SIMD&FP destination register, encoded in the "Rd" field.

<Tb> Is an arrangement specifier, encoded in “size:Q”:

<table>
<thead>
<tr>
<th>size</th>
<th>Q</th>
<th>&lt;Tb&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>0</td>
<td>8B</td>
</tr>
<tr>
<td>00</td>
<td>1</td>
<td>16B</td>
</tr>
<tr>
<td>01</td>
<td>0</td>
<td>4H</td>
</tr>
<tr>
<td>01</td>
<td>1</td>
<td>8H</td>
</tr>
<tr>
<td>10</td>
<td>0</td>
<td>2S</td>
</tr>
<tr>
<td>10</td>
<td>1</td>
<td>4S</td>
</tr>
<tr>
<td>11</td>
<td>x</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

<Vn> Is the name of the first SIMD&FP source register, encoded in the "Rn" field.

<Ta> Is an arrangement specifier, encoded in “size”:

<table>
<thead>
<tr>
<th>size</th>
<th>&lt;Ta&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>8H</td>
</tr>
<tr>
<td>01</td>
<td>4S</td>
</tr>
<tr>
<td>10</td>
<td>2D</td>
</tr>
<tr>
<td>11</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>
Operation

```plaintext
CheckFPAdvSIMDEnabled64();
bits(2*datasize) operand1 = V[n];
bits(2*datasize) operand2 = V[m];
bits(datasize)   result;
integer round_const = if round then 1 << (esize - 1) else 0;
bits(2*esize)   element1;
bits(2*esize)   element2;
bits(2*esize)   sum;
for e = 0 to elements-1
  element1 = Elem[operand1, e, 2*esize];
  element2 = Elem[operand2, e, 2*esize];
  if sub_op then
    sum = element1 - element2;
  else
    sum = element1 + element2;
  sum = sum + round_const;
  Elem[result, e, esize] = sum<2*esize-1:esize>;
Vpart[d, part] = result;
```

Operational information

If PSTATE.DIT is 1:

- The execution time of this instruction is independent of:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
- The response of this instruction to asynchronous exceptions does not vary based on:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
RAX1

Rotate and Exclusive OR rotates each 64-bit element of the 128-bit vector in a source SIMD&FP register left by 1, performs a bitwise exclusive OR of the resulting 128-bit vector and the vector in another source SIMD&FP register, and writes the result to the destination SIMD&FP register.

This instruction is implemented only when ARMv8.2-SHA is implemented.

Advanced SIMD

(ARMv8.2)

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9  | 8  | 7  | 6  | 5  | 4  | 3  | 2  | 1  | 0  |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 1  | 1  | 0  | 1  | 1  | 1  | 0  | 0  | 0  | 1  | 1  | 1  | 0  | 0  | 0  | 1  | 1  | 1  | 0  | 0  | 1  | 1  | 1  | 0  | 0  | 1  | 1  | 1  | 0  | 0  |

Advanced SIMD

RAX1 <Vd>.2D, <Vn>.2D, <Vm>.2D

if !HaveSHA3Ext() then UNDEFINED;
integer d = 1 then UnallocatedEncoding();
integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rm);

Assembler Symbols

<Vd> Is the name of the SIMD&FP destination register, encoded in the "Rd" field.
<Vn> Is the name of the first SIMD&FP source register, encoded in the "Rn" field.
<Vm> Is the name of the second SIMD&FP source register, encoded in the "Rm" field.

Operation

AArch64.CheckFPAdvSIMDEnabled();

bits(128) Vm = V[m];
bits(128) Vn = V[n];
V[d] = Vn EOR (ROL(Vm<127:64>,1):ROL(Vm<63:0>, 1));

Operational information

If PSTATE.DIT is 1:

• The execution time of this instruction is independent of:
  ◦ The values of the data supplied in any of its registers.
  ◦ The values of the NZCV flags.
• The response of this instruction to asynchronous exceptions does not vary based on:
  ◦ The values of the data supplied in any of its registers.
  ◦ The values of the NZCV flags.

Internal version only: isa v30.25, AdvSIMD v27.01, pseudocode v85-xml-00bet8_rc3; Build timestamp: 2018-09-13T13:2018-06-16T09:45

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**RET**

Return from subroutine branches unconditionally to an address in a register, with a hint that this is a subroutine return.

### Integer

**RET** `<Xn>`

```
Integer

integer n = UInt(Rn);
BranchType branch_type;
integer m = UInt(Rm);
boolean pac = (A == '1');
boolean use_key_a = (M == '0');
boolean source_is_sp = ((Z == '1') && (m == 31));
```

- If `!pac && m != 0` then `UNDEFINED`;
- If `pac && !unallocatedEncoding()` then `UNDEFINED`;
- If `pac && HavePACExt()` then `UNDEFINED`;

**Case** `op` of

- When `00` `branch_type = BranchType_INDIR` `unallocatedEncoding();`
- When `01` `branch_type = BranchType_JMP;`
- When `10` `branch_type = BranchType_CALL;`
- When `11` `branch_type = BranchType_RET;`
- Otherwise `UNDEFINED;`

- If `pac` then
  - If `Z == '0' && m != 31` then `UNDEFINED;`
  - If `branch_type = BranchType_JMP` otherwise `unallocatedEncoding();`
  - If `pac` then
    - If `Z == '0' && m != 31` then `unallocatedEncoding();`
    - If `branch_type = BranchType_RET` then
      - If `n == 31` then `unallocatedEncoding` otherwise `UNDEFINED;`
- If `branch_type = BranchType_RET` then
  - If `n == 31` then `unallocatedEncoding` otherwise `UNDEFINED;`

```
Assembler Symbols

<Xn> Is the 64-bit name of the general-purpose register holding the address to be branched to, encoded in the "Rn" field. Defaults to X30 if absent.
```
Operation

```c
bits(64) target = X[n];
case branch_type of
    when if pac then
        bits(64) modifier = if source_is_sp then BranchType_INDIR
            if InGuardedPage then
                if n == 16 || n == 17 then
                    BTypeNext = '01';
                else
                    BTypeNext = '11';
            else
                BTypeNext = '01';
        when BranchType_INDCALL
            BTypeNext = '10';
        when BranchType_RET
            BTypeNext = '00';
    if pac then
        bits(64) modifier = if source_is_sp then SP[] else X[m];
        if use_key_a then
            target = AuthIA(target, modifier);
        else
            target = AuthIB(target, modifier);
        if branch_type == BranchType_INDCALL BranchType_CALL then X[30] = PC[] + 4;
BranchTo(target, branch_type);
```

Operational information

If PSTATE.DIT is 1:

- The execution time of this instruction is independent of:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
- The response of this instruction to asynchronous exceptions does not vary based on:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.


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RETAA, RETAB

Return from subroutine, with pointer authentication. This instruction authenticates the address that is held in LR, using SP as the modifier and the specified key, branches to the authenticated address, with a hint that this instruction is a subroutine return.

Key A is used for RETAA, and key B is used for RETAB.

If the authentication passes, the PE continues execution at the target of the branch. If the authentication fails, a Translation fault is generated.

The authenticated address is not written back to LR.

Integer (ARMv8.3)

```
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 |  9 |  8 |  7 |  6 |  5 |  4 |  3 |  2 |  1 |  0 |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
|  0 |  1 |  0 |  1 |  1 |  1 |  1 |  0 |  0 |  0 |  0 |  1 |  M |  1 |  1 |  1 |  1 |  1 |  1 |  1 |  1 |  1 |  1 |  1 |  1 |  1 |  1 |  1 |  1 |  1 |  1 |

Z op A Rn Rm

RETAA (M == 0)

RETAA

RETAB (M == 1)

RETAB

integer n = UInt(Rn);
integer m = UInt(Rm);
boolean pac = (A == '1');
boolean use_key_a = (M == '0');
boolean source_is_sp = ((Z == '1') && (m == 31));

if !pac && m != 0 then
    UNDEFINED;
elsif pac && !
    UNDEFINED;
elsif pac && !
    HavePACExt()
    UNDEFINED;

case op of
    when '00' branch_type = (I then BranchType_INDIR)(UnallocatedEncoding);
    when '01' branch_type = (I then BranchType_JMP);
    case op of
        when '00' branch_type = BranchType_INDCALL;
        when '01' branch_type = BranchType_CALL;
        when '10' branch_type = BranchType_RET;
        otherwise UNDEFINED;

if pac then
    if Z == '0' && m != 31 then
        UNDEFINED;
    if branch_type ==
        otherwise UnallocatedEncoding();

if pac then
    if Z == '0' && m != 31 then
        UnallocatedEncoding();
    if branch_type == BranchType RET then
        if n != 31 then UnallocatedEncoding then
            if n != 31 then UNDEFINED;

n = 30;
source_is_sp = TRUE;
Operation

```c
bits(64) target = X[n];
case branch_type of
  when if pac then
    bits(64) modifier = if source_is_sp then BranchType_INDIR
      if InGuardedPage then
        if n == 16 || n == 17 then
          BTypeNext = '01';
        else
          BTypeNext = '11';
      else
        BTypeNext = '01';
      when BranchType_INDCALL
        BTypeNext = '10';
      when BranchType_RET
        BTypeNext = '00';
  when pac then
    bits(64) modifier = if source_is_sp then SP[] else X[m];
      if use_key_a then
        target = AuthIA(target, modifier);
      else
        target = AuthIB(target, modifier);
    if branch_type == BranchType_INDCALL BranchType_CALL then X[30] = PC[] + 4;
    BranchTo(target, branch_type);
```

Internal version only: isa v30.25-29.15, AdvSIMD v27.01-26.0, pseudocode v85-xml-00b88_rc1.3.5.5; Build timestamp: 2018-09-13T13:2018-06:16:04 045

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REV

Reverse Bytes reverses the byte order in a register.

This instruction is used by the pseudo-instruction REV64.

| sf | 1 | 0 | 1 | 1 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | x |
|----|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Rd | Rn |
| opc |

32-bit (sf == 0 && opc == 10)

REV <Wd>, <Wn>

64-bit (sf == 1 && opc == 11)

REV <Xd>, <Xn>

```plaintext
decl integer d = UInt(Rd);
decl integer n = UInt(Rn);

decl integer datattype = if sf == '1' then 64 else 32;

decl integer container_size;

case opc of
   when '00' -> Unreachable();
   when '01' -> container_size = 16;
   when '10' -> container_size = 32;
   when '11' -> if sf == '0' then UNDEFINED;

   container_size = 64;  
| if sf == '0' then UnallocatedEncoding(); |

   container_size = 64;  
| if sf == '0' then UnallocatedEncoding(); |

Assembler Symbols

<Wd> Is the 32-bit name of the general-purpose destination register, encoded in the "Rd" field.
<Wn> Is the 32-bit name of the general-purpose source register, encoded in the "Rn" field.
<Xd> Is the 64-bit name of the general-purpose destination register, encoded in the "Rd" field.
<Xn> Is the 64-bit name of the general-purpose source register, encoded in the "Rn" field.
Operation

```plaintext
bits(datasize) operand = X[n];
bits(datasize) result;

integer containers = datasize DIV container_size;
integer elements_per_container = container_size DIV 8;
integer index = 0;
integer rev_index;
for c = 0 to containers-1
  rev_index = index + ((elements_per_container - 1) * 8);
  for e = 0 to elements_per_container-1
    result<rev_index + 7:rev_index> = operand<index + 7:index>;
    index = index + 8;
    rev_index = rev_index - 8;
X[d] = result;
```

Operational information

If PSTATE.DIT is 1:

- The execution time of this instruction is independent of:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
- The response of this instruction to asynchronous exceptions does not vary based on:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
REV16 (vector)

Reverse elements in 16-bit halfwords (vector). This instruction reverses the order of 8-bit elements in each halfword of the vector in the source SIMD&FP register, places the results into a vector, and writes the vector to the destination SIMD&FP register.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

Vector

REV16 <Vd>.<T>, <Vn>.<T>

integer d = UInt(Rd);
integer n = UInt(Rn);

// size=esize:   B(0),  H(1),  S(1), D(S)
integer esize = 8 << UInt(size);
integer datasize = if Q == '1' then 128 else 64;

// op=REVx: 64(0), 32(1), 16(2)
bits(2) op = o0:U;

// => op+size:
//    64+B = 0, 64+H = 1, 64+S = 2, 64+D = X
// 32+B = 1, 32+H = 2, 32+S = X, 32+D = X
// 16+B = 2, 16+H = X, 16+S = X, 16+D = X
// 8+B = X, 8+H = X, 8+S = X, 8+D = X

// => 3-(op+size) (index bits in group)
// 64/B = 3, 64+H = 2, 64+S = 1, 64+D = X
// 32+B = 2, 32+H = 1, 32+S = X, 32+D = X
// 16+B = 1, 16+H = X, 16+S = X, 16+D = X
// 8+B = X, 8+H = X, 8+S = X, 8+D = X

// index bits within group: 1, 2, 3
if UInt(op)+UInt(size) >= 3 then UNDEFINED;

integer container_size;
case op of
    when '10' container_size = 16;
    when '01' container_size = 32;
    when '00' container_size = 64;

integer containers = datasize DIV container_size;
integer elements_per_container = container_size DIV esize;

Assembler Symbols

<Vd>       Is the name of the SIMD&FP destination register, encoded in the "Rd" field.
<T>       Is an arrangement specifier, encoded in "size:Q":

REV16 (vector)
<table>
<thead>
<tr>
<th>size</th>
<th>Q</th>
<th>&lt;T&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>0</td>
<td>8B</td>
</tr>
<tr>
<td>00</td>
<td>1</td>
<td>16B</td>
</tr>
<tr>
<td>01</td>
<td>x</td>
<td>RESERVED</td>
</tr>
<tr>
<td>1x</td>
<td>x</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

<\text{Vn}> Is the name of the SIMD&FP source register, encoded in the "Rn" field.

**Operation**

```c
CheckFPAdvSIMDEnabled64();
bits(datasize) operand = V[n];
bits(datasize) result;
integer element = 0;
integer rev_element;
for c = 0 to containers-1
    rev_element = element + elements_per_container - 1;
    for e = 0 to elements_per_container-1
        Elem[result, rev_element, esize] = Elem[operand, element, esize];
        element = element + 1;
        rev_element = rev_element - 1;
V[d] = result;
```

**Operational information**

If PSTATE.DIT is 1:

- The execution time of this instruction is independent of:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
- The response of this instruction to asynchronous exceptions does not vary based on:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.

Internal version only: isa v30.25, AdvSIMD v27.01, pseudocode v85-xml-00b0r8_rc3.2.xml; Build timestamp: 2018-09-13T13:04:45

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REV16

Reverse bytes in 16-bit halfwords reverses the byte order in each 16-bit halfword of a register.

32-bit (sf == 0)

REV16 <Wd>, <Wn>

64-bit (sf == 1)

REV16 <Xd>, <Xn>

integer d = \texttt{UInt}(Rd);
integer n = \texttt{UInt}(Rn);

integer datasize = if sf == '1' then 64 else 32;
case opc of
when '00' \texttt{Unreachable}();
when '01'
  container_size = 16;
when '10'
  container_size = 32;
when '11'
  if sf == '0' then UNDEFINED;
  container_size = 64;
if sf == '0' then \texttt{UnallocatedEncoding}();
  container_size = 64;

Assembler Symbols

<Wd> Is the 32-bit name of the general-purpose destination register, encoded in the "Rd" field.
<Wn> Is the 32-bit name of the general-purpose source register, encoded in the "Rn" field.
<Xd> Is the 64-bit name of the general-purpose destination register, encoded in the "Rd" field.
<Xn> Is the 64-bit name of the general-purpose source register, encoded in the "Rn" field.

Operation

\begin{align*}
\text{bits(datasize)} \ & \text{operand} = X[n]; \\
\text{bits(datasize)} \ & \text{result}; \\
\text{integer} \ & \text{containers} = \text{datasize} \ \text{DIV} \ \text{container}\_\text{size}; \\
\text{integer} \ & \text{elements}\_\text{per}\_\text{container} = \text{container}\_\text{size} \ \text{DIV} \ 8; \\
\text{integer} \ & \text{index} = 0; \\
\text{integer} \ & \text{rev}\_\text{index}; \\
\text{for} \ c = 0 \ \text{to} \ \text{containers}-1 \\
\ & \text{rev}\_\text{index} = \text{index} + ((\text{elements}\_\text{per}\_\text{container} - 1) \ \text{*} \ 8); \\
\text{for} \ e = 0 \ \text{to} \ \text{elements}\_\text{per}\_\text{container}-1 \\
\ & \text{result}<\text{rev}\_\text{index} + 7:rev\_\text{index}> = \text{operand}<\text{index} + 7:index>; \\
\ & \text{index} = \text{index} + 8; \\
\ & \text{rev}\_\text{index} = \text{rev}\_\text{index} - 8; \\
X[d] = \text{result}; 
\end{align*}
Operational information

If PSTATE.DIT is 1:

- The execution time of this instruction is independent of:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
- The response of this instruction to asynchronous exceptions does not vary based on:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
REV32 (vector)

Reverse elements in 32-bit words (vector). This instruction reverses the order of 8-bit or 16-bit elements in each word of the vector in the source SIMD&FP register, places the results into a vector, and writes the vector to the destination SIMD&FP register.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

```
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9  | 8  | 7  | 6  | 5  | 4  | 3  | 2  | 1  | 0  |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0  | Q  | 1  | 0  | 1  | 1  | 0  | size | 1  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 1  | 0  | Rn | | Rd | |
| U  | o0 |
```

### Vector

**REV32 <Vd>.<T>, <Vn>.<T>**

```plaintext
integer d = UInt(Rd);
integer n = UInt(Rn);

// size=esize:   B(0), H(1), S(1), D(S)
integer esize = 8 << UInt(size);
integer datasize = if Q == '1' then 128 else 64;

// op=REVx: 64(0), 32(1), 16(2)
bits(2) op = o0:U;

// => op+size:
//    64+B = 0, 64+H = 1, 64+S = 2, 64+D = X
//    32+B = 1, 32+H = 2, 32+S = X, 32+D = X
//    16+B = 2, 16+H = X, 16+S = X, 16+D = X
//    8 +B = X,  8+H = X,  8+S = X,  8+D = X
// => 3-(op+size) (index bits in group)
//    64/B = 3, 64+H = 2, 64+S = 1, 64+D = X
//    32/B = 2, 32+H = 1, 32+S = X, 32+D = X
//    16+B = 1, 16+H = X, 16+S = X, 16+D = X
//    8+B = X,  8+H = X,  8+S = X,  8+D = X

// index bits within group: 1, 2, 3
if UInt(op)+UInt(size) >= 3 then UNDEFINED;

integer container_size;
case op of
  when '10' container_size = 16;
  when '01' container_size = 32;
  when '00' container_size = 64;

integer containers = datasize DIV container_size;
integer elements_per_container = container_size DIV esize;{size} => 3 then UnallocatedEncoding();
```

### Assembler Symbols

- `<Vd>` Is the name of the SIMD&FP destination register, encoded in the "Rd" field.
- `<T>` Is an arrangement specifier, encoded in “size:Q”: 

---

Page 939
<table>
<thead>
<tr>
<th>size</th>
<th>Q</th>
<th>&lt;T&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>0</td>
<td>8B</td>
</tr>
<tr>
<td>00</td>
<td>1</td>
<td>16B</td>
</tr>
<tr>
<td>01</td>
<td>0</td>
<td>4H</td>
</tr>
<tr>
<td>01</td>
<td>1</td>
<td>8H</td>
</tr>
<tr>
<td>1x</td>
<td>x</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

<Vn> Is the name of the SIMD&FP source register, encoded in the "Rn" field.

**Operation**

```c
CheckFPAdvSIMDEnabled64();
bits(datasize) operand = V[n];
bits(datasize) result;
integer element = 0;
integer rev_element;
for c = 0 to containers-1
    rev_element = element + elements_per_container - 1;
    for e = 0 to elements_per_container-1
        Elem[result, rev_element, esize] = Elem[operand, element, esize];
        element = element + 1;
        rev_element = rev_element - 1;
V[d] = result;
```

**Operational information**

If PSTATE.DIT is 1:
- The execution time of this instruction is independent of:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
- The response of this instruction to asynchronous exceptions does not vary based on:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
REV32

Reverse bytes in 32-bit words reverses the byte order in each 32-bit word of a register.

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 1  | 1  | 0  | 1  | 0  | 1  | 1  | 0  | 0  | 0  | 0  | 0  | 0  | 1  | 0  | 1  | 0  | 1  | 0  | 1  | 0  | 1  | 0  | 1  | 0  | 0  | 0  | 1  | 0  | 1  | 0  | 1  | 0  |

sf | opc

64-bit

REV32 <Xd>, <Xn>

integer d = UInt(Rd);
integer n = UInt(Rn);

integer datasize = if sf == '1' then 64 else 32;

integer container_size;
case opc of
  when '00'
    Unreachable();
  when '01'
    container_size = 16;
  when '10'
    container_size = 32;
  when '11'
    if sf == '0' then UNDEFINED;
    container_size = 64;

Assembler Symbols

<Xd> Is the 64-bit name of the general-purpose destination register, encoded in the "Rd" field.
<Xn> Is the 64-bit name of the general-purpose source register, encoded in the "Rn" field.

Operation

bits(datasize) operand = X[n];
bits(datasize) result;

integer containers = datasize DIV container_size;
integer elements_per_container = container_size DIV 8;
integer index = 0;
integer rev_index;
for c = 0 to containers-1
  rev_index = index + ((elements_per_container - 1) * 8);
  for e = 0 to elements_per_container-1
    result<rev_index + 7:rev_index> = operand<index + 7:index>;
    index = index + 8;
    rev_index = rev_index - 8;

X[d] = result;

Operational information

If PSTATE.DIT is 1:

- The execution time of this instruction is independent of:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
- The response of this instruction to asynchronous exceptions does not vary based on:
  - The values of the data supplied in any of its registers.
The values of the NZCV flags.

Internal version only: isa v30.25, AdvSIMD v27.01, pseudocode v85-xml-00bet8_rc3_353 ; Build timestamp: 2018-06-16T09:04:45

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REV64

Reverse elements in 64-bit doublewords (vector). This instruction reverses the order of 8-bit, 16-bit, or 32-bit elements in each doubleword of the vector in the source SIMD&FP register, places the results into a vector, and writes the vector to the destination SIMD&FP register.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

\[
\begin{array}{cccccccccccccccc}
0 & 0 & 0 & 0 & 1 & 1 & 1 & 0 & \text{size} & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & \text{Rn} & \text{Rd} & o0
\end{array}
\]

Vector

REV64 \(<Vd>\).\(<T>\), \(<Vn>\).\(<T>\)

integer \(d\) = \(\text{UInt}(\text{Rd})\);
integer \(n\) = \(\text{UInt}(\text{Rn})\);

// size = esize: \(B(0), H(1), S(1), D(S)\)
integer esize = 8 << \(\text{UInt}(\text{size})\);
integer datasize = if \(Q == '1'\) then 128 else 64;

// op = REVx: 64(0), 32(1), 16(2)
bits(2) \(op\) = \(00:U\);

// => op+size:
// 64+B = 0, 64+H = 1, 64+S = 2, 64+D = X
// 32+B = 1, 32+H = 2, 32+S = X, 32+D = X
// 16+B = 2, 16+H = X, 16+S = X, 16+D = X
// 8+B = X, 8+H = X, 8+S = X, 8+D = X

// => 3-(op+size) (index bits in group)
// 64/B = 3, 64+H = 2, 64+S = 1, 64+D = X
// 32/B = 2, 32+H = 1, 32+S = X, 32+D = X
// 16/B = 1, 16+H = X, 16+S = X, 16+D = X
// 8+B = X, 8+H = X, 8+S = X, 8+D = X

// index bits within group: 1, 2, 3
if \(\text{UInt}(\text{op})+\text{UInt}(\text{size}) >= 3\) then \text{UNDEFINED};

integer \text{container\_size};
\text{case} \text{op} \\text{of}
  \text{when} '10': \text{container\_size} = 16;
  \text{when} '01': \text{container\_size} = 32;
  \text{when} '00': \text{container\_size} = 64;
\text{end};

integer \text{containers} = \text{datasize} \text{DIV} \text{container\_size};
integer \text{elements\_per\_container} = \text{container\_size} \text{DIV} \text{esize};\text{(size)} >= 3 \text{then} \text{UnallocatedEncoding};

Assembler Symbols

\(<Vd>\) Is the name of the SIMD&FP destination register, encoded in the "Rd" field.

\(<T>\) Is an arrangement specifier, encoded in "size:Q":

REV64
<Vn> is the name of the SIMD&FP source register, encoded in the "Rn" field.

**Operation**

```c
CheckFPAdvSIMDEnabled64();
bits(datasize) operand = V[n];
bits(datasize) result;
integer element = 0;
integer rev_element;
for c = 0 to containers-1
    rev_element = element + elements_per_container - 1;
    for e = 0 to elements_per_container-1
        Elem[result, rev_element, esize] = Elem[operand, element, esize];
        element = element + 1;
        rev_element = rev_element - 1;
V[d] = result;
```

**Operational information**

If PSTATE.DIT is 1:
- The execution time of this instruction is independent of:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
- The response of this instruction to asynchronous exceptions does not vary based on:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
REV64

Reverse Bytes reverses the byte order in a 64-bit general-purpose register.
When assembling for ARMv8.2, an assembler must support this pseudo-instruction. It is OPTIONAL whether an assembler supports this pseudo-instruction when assembling for an architecture earlier than ARMv8.2.

This is a pseudo-instruction of REV. This means:

• The encodings in this description are named to match the encodings of REV.
• The assembler syntax is used only for assembly, and is not used on disassembly.
• The description of REV gives the operational pseudocode for this instruction.

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9  | 8  | 7  | 6  | 5  | 4  | 3  | 2  | 1  | 0  |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 1  | 1  | 0  | 1  | 1  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 1  | 1  | Rn | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  |

sf opc

64-bit

REV64 <Xd>, <Xn>

is equivalent to

REV <Xd>, <Xn>

Assembler Symbols

<Xd>  Is the 64-bit name of the general-purpose destination register, encoded in the "Rd" field.
<Xn>  Is the 64-bit name of the general-purpose source register, encoded in the "Rn" field.

Operation

The description of REV gives the operational pseudocode for this instruction.

Operational information

IF PSTATE.DIT is 1:

• The execution time of this instruction is independent of:
  • The values of the data supplied in any of its registers.
  • The values of the NZCV flags.
• The response of this instruction to asynchronous exceptions does not vary based on:
  • The values of the data supplied in any of its registers.
  • The values of the NZCV flags.

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RMIF

Performs a rotation right of a value held in a general purpose register by an immediate value, and then inserts a selection of the bottom four bits of the result of the rotation into the PSTATE flags, under the control of a second immediate mask.

**Integer**

(ARMv8.4)

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9  | 8  | 7  | 6  | 5  | 4  | 3  | 2  | 1  | 0  |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 1  | 0  | 1  | 1  | 0  | 1  | 0  | 0  | 0  | 0  | imm6| 0  | 0  | 0  | 0  | 1  | Rn | 0  | mask|

sf

**Integer**

RMIF <Xn>, #<shift>, #<mask>

if !HaveFlagManipulateExt() || sf != '1' then UNDEFINED;
integer lsb = -1; if sf == '1' then UnallocatedEncoding();
integer lsb =UInt (imm6);
integer n = UInt (Rn);

**Assembler Symbols**

<Xn> Is the 64-bit name of the general-purpose source register, encoded in the "Rn" field.

<shift> Is the shift amount, in the range 0 to 63, defaulting to 0 and encoded in the "imm6" field.

<mask> Is the flag bit mask, an immediate in the range 0 to 15, which selects the bits that are inserted into the NZCV condition flags, encoded in the "mask" field.

**Operation**

bits(4) tmp;
bits(64) tmpreg = X[n];
tmp = (tmpreg:tmpreg)<lsb+3:lsb>;
if mask<3> == '1' then PSTATE.N = tmp<3>;
if mask<2> == '1' then PSTATE.Z = tmp<2>;
if mask<1> == '1' then PSTATE.C = tmp<1>;
if mask<0> == '1' then PSTATE.V = tmp<0>;

**Operational information**

If PSTATE.DIT is 1:

- The execution time of this instruction is independent of:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
- The response of this instruction to asynchronous exceptions does not vary based on:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
RSHRN, RSHRN2

Rounding Shift Right Narrow (immediate). This instruction reads each unsigned integer value from the vector in the source SIMD&FP register, right shifts each result by an immediate value, writes the final result to a vector, and writes the vector to the lower or upper half of the destination SIMD&FP register. The destination vector elements are half as long as the source vector elements. The results are rounded. For truncated results, see SHRN.

The RSHRN instruction writes the vector to the lower half of the destination register and clears the upper half, while the RSHRN2 instruction writes the vector to the upper half of the destination register without affecting the other bits of the register.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0

| immh | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |

Vector

RSHRN(2) <Vd>.<Tb>, <Vn>.<Ta>, #<shift>

integer d = UInt(Rd);
integer n = UInt(Rn);

if imm == '0000' then SEE(asimdimm);
if immh3 == '1' then UNDEFINED;
integer esize = 8 << if immh3 == '1' then ReservedValue();
integer esize = 8 << HighestSetBit(immh);
integer datasize = 64;
integer part = UInt(Q);
integer elements = datasize DIV esize;

integer shift = (2 * esize) - UInt(immh:immb);
boolean round = (op == '1');

Assembler Symbols

2

<table>
<thead>
<tr>
<th>Q</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>[absent]</td>
</tr>
<tr>
<td>1</td>
<td>[present]</td>
</tr>
</tbody>
</table>

<Vd> Is the second and upper half specifier. If present it causes the operation to be performed on the upper 64 bits of the registers holding the narrower elements, and is encoded in “Q”:

<Tb> Is an arrangement specifier, encoded in “immh:Q”:

<table>
<thead>
<tr>
<th>immh</th>
<th>0000</th>
<th>0001</th>
<th>0001</th>
<th>001x</th>
<th>001x</th>
<th>01xx</th>
<th>01xx</th>
<th>1xxx</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>8B</td>
<td>16B</td>
<td>4H</td>
<td>8H</td>
<td>2S</td>
<td>4S</td>
<td>RESERVERD</td>
<td></td>
</tr>
</tbody>
</table>

<Vn> Is the name of the SIMD&FP source register, encoded in the "Rn" field.

<Ta> Is an arrangement specifier, encoded in “immh”:
immh <Ta>
0000  SEE Advanced SIMD modified immediate
0001  8H
001x  4S
01xx  2D
1xxx  RESERVED

<shift>
Is the right shift amount, in the range 1 to the destination element width in bits, encoded in “immh:immb”:

immh <shift>
0000  SEE Advanced SIMD modified immediate
0001  (16-UInt(immh:immb))
001x  (32-UInt(immh:immb))
01xx  (64-UInt(immh:immb))
1xxx  RESERVED

Operation

CheckFPAdvSIMDEnabled64();
bits(datasize*2) operand = V[n];
bits(datasize) result;
integer round_const = if round then (1 << (shift - 1)) else 0;
integer element;
for e = 0 to elements-1
  element = (UInt(Elem[operand, e, 2*esize]) + round_const) >> shift;
  Elem[result, e, esize] = element<esize-1:0>;
Vpart[d, part] = result;

Operational information

If PSTATE.DIT is 1:

• The execution time of this instruction is independent of:
  ◦ The values of the data supplied in any of its registers.
  ◦ The values of the NZCV flags.
• The response of this instruction to asynchronous exceptions does not vary based on:
  ◦ The values of the data supplied in any of its registers.
  ◦ The values of the NZCV flags.
RSUBHN, RSUBHN2

Rounding Subtract returning High Narrow. This instruction subtracts each vector element of the second source SIMD&FP register from the corresponding vector element of the first source SIMD&FP register, places the most significant half of the result into a vector, and writes the vector to the lower or upper half of the destination SIMD&FP register.

The results are rounded. For truncated results, see SUBHN.

The RSUBHN instruction writes the vector to the lower half of the destination register and clears the upper half, while the RSUBHN2 instruction writes the vector to the upper half of the destination register without affecting the other bits of the register.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

<table>
<thead>
<tr>
<th>31</th>
</tr>
</thead>
<tbody>
<tr>
<td>30</td>
</tr>
<tr>
<td>29</td>
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<tr>
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<td>14</td>
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<td>13</td>
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<td>12</td>
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<td>11</td>
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<td>10</td>
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<td>9</td>
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<td>7</td>
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<tr>
<td>6</td>
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<tr>
<td>5</td>
</tr>
<tr>
<td>4</td>
</tr>
<tr>
<td>3</td>
</tr>
<tr>
<td>2</td>
</tr>
<tr>
<td>1</td>
</tr>
<tr>
<td>0</td>
</tr>
</tbody>
</table>

Three registers, not all the same type

RSUBHN{2} <Vd>.<Tb>, <Vn>.<Ta>, <Vm>.<Ta>

integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rm);

if size == 'll' then UNDEFINED;
integer esize = 8 <<< if size == 'll' then ReservedValue();
integer esize = 8 <<< UInt(size);
integer datasize = 64;
integer part = UInt(Q);
integer elements = datasize DIV esize;

boolean sub_op = (o1 == '1');
boolean round = (U == '1');

Assembler Symbols

<table>
<thead>
<tr>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 [absent]</td>
</tr>
<tr>
<td>1 [present]</td>
</tr>
</tbody>
</table>

<Vd> Is the name of the SIMD&FP destination register, encoded in the "Rd" field.

<Tb> Is an arrangement specifier, encoded in “size:Q”:

<table>
<thead>
<tr>
<th>size</th>
<th>Q</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>8B</td>
</tr>
<tr>
<td>00</td>
<td>16B</td>
</tr>
<tr>
<td>01</td>
<td>4H</td>
</tr>
<tr>
<td>01</td>
<td>8H</td>
</tr>
<tr>
<td>10</td>
<td>2S</td>
</tr>
<tr>
<td>10</td>
<td>4S</td>
</tr>
<tr>
<td>11</td>
<td>x</td>
</tr>
</tbody>
</table>

<Ta> Is an arrangement specifier, encoded in “size”:

<table>
<thead>
<tr>
<th>size</th>
<th>&lt;Ta&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>8H</td>
</tr>
<tr>
<td>01</td>
<td>4S</td>
</tr>
<tr>
<td>10</td>
<td>2D</td>
</tr>
<tr>
<td>11</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>
Is the name of the second SIMD&FP source register, encoded in the "Rm" field.

**Operation**

```c
CheckFPAdvSIMDEnabled64();
bits(2*datasize) operand1 = V[n];
bits(2*datasize) operand2 = V[m];
bits(datasize)   result;
integer round_const = if round then 1 << (esize - 1) else 0;
bits(2*esize)   element1;
bits(2*esize)   element2;
bits(2*esize)   sum;

for e = 0 to elements-1
    element1 = Elem[operand1, e, 2*esize];
    element2 = Elem[operand2, e, 2*esize];
    if sub_op then
        sum = element1 - element2;
    else
        sum = element1 + element2;
    sum = sum + round_const;
    Elem[result, e, esize] = sum<2*esize-1:esize>;
Vpart[d, part] = result;
```

**Operational information**

If PSTATE.DIT is 1:

- The execution time of this instruction is independent of:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
- The response of this instruction to asynchronous exceptions does not vary based on:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.

Internal version only: isa v30.25, AdvSIMD v27.01, pseudocode v85-xml-00bet8_rc3c352; Build timestamp: 2018-09-13T13:2018-06-16T09:45:45

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SABA

Signed Absolute difference and Accumulate. This instruction subtracts the elements of the vector of the second source SIMD&FP register from the corresponding elements of the first source SIMD&FP register, and accumulates the absolute values of the results into the elements of the vector of the destination SIMD&FP register.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

Three registers of the same type

SABA <Vd>, <T>, <Vn>, <T>, <Vm>, <T>

integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rm);
if size == '11' then UNDEFINED;
integer esize = 8 << if size == '11' then ReservedValue();
integer esize = 8 << UInt(size);
integer datasize = if Q == '1' then 128 else 64;
integer elements = datasize DIV esize;
boolean unsigned = (U == '1');
boolean accumulate = (ac == '1');

Assembler Symbols

<Vd> Is the name of the SIMD&FP destination register, encoded in the "Rd" field.
<T> Is an arrangement specifier, encoded in “size:Q”:

<table>
<thead>
<tr>
<th>size</th>
<th>Q</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>8B</td>
</tr>
<tr>
<td>00</td>
<td>16B</td>
</tr>
<tr>
<td>01</td>
<td>4H</td>
</tr>
<tr>
<td>01</td>
<td>8H</td>
</tr>
<tr>
<td>10</td>
<td>2S</td>
</tr>
<tr>
<td>10</td>
<td>4S</td>
</tr>
<tr>
<td>11</td>
<td>x</td>
</tr>
</tbody>
</table>

<Vn> Is the name of the first SIMD&FP source register, encoded in the "Rn" field.
<Vm> Is the name of the second SIMD&FP source register, encoded in the "Rm" field.

Operation

CheckFPAdvSIMDEnabled64();
bits(datasize) operand1 = V[n];
bits(datasize) operand2 = V[m];
bits(datasize) result;
integer element1;
integer element2;
bits(esize) absdiff;
result = if accumulate then V[d] else Zeros();
for e = 0 to elements-1
    element1 = Int(Elem[operand1, e, esize], unsigned);
    element2 = Int(Elem[operand2, e, esize], unsigned);
    absdiff = Abs(element1 - element2)<esize-1:0>;
    Elem[result, e, esize] = Elem[result, e, esize] + absdiff;
V[d] = result;
Operational information

If PSTATE.DIT is 1:

- The execution time of this instruction is independent of:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
- The response of this instruction to asynchronous exceptions does not vary based on:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
SABAL, SABAL2

Signed Absolute difference and Accumulate Long. This instruction subtracts the vector elements in the lower or upper half of the second source SIMD&FP register from the corresponding vector elements of the first source SIMD&FP register, and accumulates the absolute values of the results into the vector elements of the destination SIMD&FP register. The destination vector elements are twice as long as the source vector elements.

The SABAL instruction extracts each source vector from the lower half of each source register, while the SABAL2 instruction extracts each source vector from the upper half of each source register.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

Three registers, not all the same type

SABAL(2) <Vd>, <Ta>, <Vn>, <Vm>.

\[
\begin{array}{|c|}
\hline
\text{integer } d = \text{UInt}(Rd); \\
\text{integer } n = \text{UInt}(Rn); \\
\text{integer } m = \text{UInt}(Rm); \\
\text{if size == '11' then UNDEFINED; } \\
\text{integer esize = 8} << \text{if size == '11' then ReservedValue(); } \\
\text{integer datasize = 64; } \\
\text{integer part = UInt(Q); } \\
\text{integer elements = datasize DIV esize; } \\
\text{boolean accumulate = (op == '0'); } \\
\text{boolean unsigned = (U == '1'); } \\
\end{array}
\]

Assembler Symbols

<table>
<thead>
<tr>
<th>Q</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>[absent]</td>
</tr>
<tr>
<td>1</td>
<td>[present]</td>
</tr>
</tbody>
</table>

<Vd> Is the name of the SIMD&FP destination register, encoded in the "Rd" field.

<Ta> Is an arrangement specifier, encoded in "size":

<table>
<thead>
<tr>
<th>size</th>
<th>&lt;Ta&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>8H</td>
</tr>
<tr>
<td>01</td>
<td>4S</td>
</tr>
<tr>
<td>10</td>
<td>2D</td>
</tr>
<tr>
<td>11</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

<Vn> Is the name of the first SIMD&FP source register, encoded in the "Rn" field.

<Tb> Is an arrangement specifier, encoded in "size:Q":

<table>
<thead>
<tr>
<th>size</th>
<th>Q</th>
<th>&lt;Tb&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>0</td>
<td>8B</td>
</tr>
<tr>
<td>00</td>
<td>1</td>
<td>16B</td>
</tr>
<tr>
<td>01</td>
<td>0</td>
<td>4H</td>
</tr>
<tr>
<td>01</td>
<td>1</td>
<td>8H</td>
</tr>
<tr>
<td>10</td>
<td>0</td>
<td>2S</td>
</tr>
<tr>
<td>10</td>
<td>1</td>
<td>4S</td>
</tr>
<tr>
<td>11</td>
<td>x</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>
**Operation**

\[
\text{CheckFPAdvSIMDEnabled64}();
\]

- bits(datasize) operand1 = \text{Vpart}[n, part];
- bits(datasize) operand2 = \text{Vpart}[m, part];
- integer element1;
- integer element2;
- bits(2*esize) absdiff;

result = if accumulate then \text{V}[d] else \text{Zeros}();
for e = 0 to elements-1
  element1 = \text{Int(Elem[operand1, e, esize], unsigned)};
  element2 = \text{Int(Elem[operand2, e, esize], unsigned)};
  absdiff = \text{Abs(element1 - element2)}<2*esize-1:0>;
  \text{Elem[result, e, 2*esize]} = \text{Elem[result, e, 2*esize]} + absdiff;
\text{V}[d] = result;

**Operational information**

If PSTATE.DIT is 1:
- The execution time of this instruction is independent of:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
- The response of this instruction to asynchronous exceptions does not vary based on:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
SABD

Signed Absolute Difference. This instruction subtracts the elements of the vector of the second source SIMD&FP register from the corresponding elements of the first source SIMD&FP register, places the absolute values of the results into a vector, and writes the vector to the destination SIMD&FP register.

Depending on the settings in the `CPACR_EL1`, `CPTR_EL2`, and `CPTR_EL3` registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9  | 8  | 7  | 6  | 5  | 4  | 3  | 2  | 1  | 0  |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0  | 0  | 1  | 1  | 0  | 1  | 0  | 1  | 1  | 0  | 1  | 0  | 1  | 1  | 0  | 1  | 1  | 0  | 1  | 0  | 1  | 1  | 0  | 1  | 1  | 0  | 1  | 1  | 0  | 1  |

Three registers of the same type

SABD `<Vd>`, `<Vn>`, `<Vm>`

```plaintext
integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rm);
if size == '11' then UNDEFINED;
integer esize = 8 << if size == '11' then ReservedValue();
integer esize = 8 << UInt(size);
integer datasize = if Q == '1' then 128 else 64;
integer elements = datasize DIV esize;
boolean unsigned = (U == '1');
boolean accumulate = (ac == '1');
```

Assembler Symbols

- `<Vd>` Is the name of the SIMD&FP destination register, encoded in the "Rd" field.
- `<T>` Is an arrangement specifier, encoded in “size:Q”:

<table>
<thead>
<tr>
<th>size</th>
<th>Q</th>
<th>&lt;T&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>0</td>
<td>8B</td>
</tr>
<tr>
<td>00</td>
<td>1</td>
<td>16B</td>
</tr>
<tr>
<td>01</td>
<td>0</td>
<td>4H</td>
</tr>
<tr>
<td>01</td>
<td>1</td>
<td>8H</td>
</tr>
<tr>
<td>10</td>
<td>0</td>
<td>2S</td>
</tr>
<tr>
<td>10</td>
<td>1</td>
<td>4S</td>
</tr>
<tr>
<td>11</td>
<td>x</td>
<td>RESERVE</td>
</tr>
</tbody>
</table>

- `<Vn>` Is the name of the first SIMD&FP source register, encoded in the "Rn" field.
- `<Vm>` Is the name of the second SIMD&FP source register, encoded in the "Rm" field.

Operation

```plaintext
CheckFPAdvSIMDEnabled64();
bits(datasize) operand1 = V[n];
bits(datasize) operand2 = V[m];
bits(datasize) result;
integer element1;
integer element2;
bits(esize) absdiff;
result = if accumulate then V[d] else Zeros();
for e = 0 to elements-1
    element1 = Int(Elem[operand1, e, esize], unsigned);
    element2 = Int(Elem[operand2, e, esize], unsigned);
    absdiff = Abs(element1 - element2)<esize-1:0>;
    Elem[result, e, esize] = Elem[result, e, esize] + absdiff;
V[d] = result;
```
Operational information

If PSTATE.DIT is 1:

- The execution time of this instruction is independent of:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.

- The response of this instruction to asynchronous exceptions does not vary based on:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
SABDL, SABDL2

Signed Absolute Difference Long. This instruction subtracts the vector elements of the second source SIMD&FP register from the corresponding vector elements of the first source SIMD&FP register, places the absolute value of the results into a vector, and writes the vector to the lower or upper half of the destination SIMD&FP register. The destination vector elements are twice as long as the source vector elements.

The SABDL instruction writes the vector to the lower half of the destination register and clears the upper half, while the SABDL2 instruction writes the vector to the upper half of the destination register without affecting the other bits of the register.

Depending on the settings in the CPACR_EL1, CPTTR_EL2, and CPTTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

<table>
<thead>
<tr>
<th>Q</th>
<th>Rm</th>
<th>size</th>
<th>Rd</th>
<th>Rn</th>
<th>op</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>size</td>
</tr>
</tbody>
</table>

Three registers, not all the same type

SABDL{2} <Vd>, <Ta>, <Vn>, <Vm>, <Vn>, <Vm>, <Vn>

\[
\text{integer } d = \text{UInt}(Rd);
\text{integer } n = \text{UInt}(Rn);
\text{integer } m = \text{UInt}(Rm);
\]

\[\text{if size == '11' then UNDEFINED; }\]
\[\text{integer esize = 8 } \times \text{UInt(size); }\]
\[\text{integer datasize = 64; }\]
\[\text{integer part = UInt(Q); }\]
\[\text{integer elements = datasize DIV esize; }\]
\[\text{boolean accumulate = (op == '0'); }\]
\[\text{boolean unsigned = (U == '1'); }\]

Assembler Symbols

2
Is the second and upper half specifier. If present it causes the operation to be performed on the upper 64 bits of the registers holding the narrower elements, and is encoded in “Q”:

<table>
<thead>
<tr>
<th>Q</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>[absent]</td>
</tr>
<tr>
<td>1</td>
<td>[present]</td>
</tr>
</tbody>
</table>

<Vd> Is the name of the SIMD&FP destination register, encoded in the “Rd” field.

<Ta> Is an arrangement specifier, encoded in “size”:

<table>
<thead>
<tr>
<th>size</th>
<th>&lt;Ta&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>8H</td>
</tr>
<tr>
<td>01</td>
<td>4S</td>
</tr>
<tr>
<td>10</td>
<td>2D</td>
</tr>
<tr>
<td>11</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

<Vn> Is the name of the first SIMD&FP source register, encoded in the “Rn” field.

<Tb> Is an arrangement specifier, encoded in “size:Q”:

<table>
<thead>
<tr>
<th>size</th>
<th>Q</th>
<th>&lt;Tb&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>0</td>
<td>8B</td>
</tr>
<tr>
<td>00</td>
<td>1</td>
<td>16B</td>
</tr>
<tr>
<td>01</td>
<td>0</td>
<td>4H</td>
</tr>
<tr>
<td>01</td>
<td>1</td>
<td>8H</td>
</tr>
<tr>
<td>10</td>
<td>0</td>
<td>2S</td>
</tr>
<tr>
<td>10</td>
<td>1</td>
<td>4S</td>
</tr>
<tr>
<td>11</td>
<td>x</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

<Vm> Is the name of the second SIMD&FP source register, encoded in the “Rm” field.
Operation

```pseudo
checkfpadvSIM Enabled64();

bits(datasize) operand1 = Vpart[n, part];
bits(datasize) operand2 = Vpart[m, part];
bits(2*datasize) result;
integer element1;
integer element2;
bits(2*esize) absdiff;

result = if accumulate then V[d] else Zeros();
for e = 0 to elements-1
  element1 = Int(Elem[operand1, e, esize], unsigned);
  element2 = Int(Elem[operand2, e, esize], unsigned);
  absdiff = Abs(element1 - element2)<2*esize-1:0>;
  Elem[result, e, 2*esize] = Elem[result, e, 2*esize] + absdiff;
V[d] = result;
```

Operational information

If PSTATE.DIT is 1:
- The execution time of this instruction is independent of:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
- The response of this instruction to asynchronous exceptions does not vary based on:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
SADALP

Signed Add and Accumulate Long Pairwise. This instruction adds pairs of adjacent signed integer values from the vector in the source SIMD&FP register and accumulates the results into the vector elements of the destination SIMD&FP register. The destination vector elements are twice as long as the source vector elements.

Depending on the settings in the `CPACR_EL1`, `CPTR_EL2`, and `CPTR_EL3` registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

```
0 1 1 1 0 0 0 0 0 0 1 1 0 1 0
size  Rn  Rd
U  op
```

Vector

SADALP <Vd>.<Ta>, <Vn>.<Tb>

```
integer d = UInt(Rd);
integer n = UInt(Rn);
if size == '11' then UNDEFINED;
integer esize = 8 << int size == '11' then ReservedValue();
integer esize = 8 << UInt(size);
integer datasize = if Q == '1' then 128 else 64;
integer elements = datasize DIV (2*esize);
boolean acc = (op == '1');
boolean unsigned = (U == '1');
```

Assembler Symbols

- `<Vd>`: Is the name of the SIMD&FP destination register, encoded in the "Rd" field.
- `<Ta>`: Is an arrangement specifier, encoded in “size:Q”:

<table>
<thead>
<tr>
<th>size</th>
<th>Q</th>
<th>&lt;Ta&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>0</td>
<td>4H</td>
</tr>
<tr>
<td>00</td>
<td>1</td>
<td>8H</td>
</tr>
<tr>
<td>01</td>
<td>0</td>
<td>2S</td>
</tr>
<tr>
<td>01</td>
<td>1</td>
<td>4S</td>
</tr>
<tr>
<td>10</td>
<td>0</td>
<td>1D</td>
</tr>
<tr>
<td>10</td>
<td>1</td>
<td>2D</td>
</tr>
<tr>
<td>11</td>
<td>x</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

- `<Vn>`: Is the name of the SIMD&FP source register, encoded in the "Rn" field.
- `<Tb>`: Is an arrangement specifier, encoded in “size:Q”:

<table>
<thead>
<tr>
<th>size</th>
<th>Q</th>
<th>&lt;Tb&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>0</td>
<td>8B</td>
</tr>
<tr>
<td>00</td>
<td>1</td>
<td>16B</td>
</tr>
<tr>
<td>01</td>
<td>0</td>
<td>4H</td>
</tr>
<tr>
<td>01</td>
<td>1</td>
<td>8H</td>
</tr>
<tr>
<td>10</td>
<td>0</td>
<td>2S</td>
</tr>
<tr>
<td>10</td>
<td>1</td>
<td>4S</td>
</tr>
<tr>
<td>11</td>
<td>x</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>
Operation

```c
CheckFPAdvSIMDEnabled64();
bits(datasize) operand = V[n];
bins(datasize) result;

bits(2*esize) sum;
integer op1;
integer op2;

result = if acc then V[d] else Zeros();
for e = 0 to elements-1
    op1 = Int(Elem[operand, 2*e+0, esize], unsigned);
    op2 = Int(Elem[operand, 2*e+1, esize], unsigned);
    sum = (op1 + op2)<2*esize-1:0>;
    Elem[result, e, 2*esize] = Elem[result, e, 2*esize] + sum;
V[d] = result;
```

Operational information

If PSTATE.DIT is 1:

- The execution time of this instruction is independent of:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
- The response of this instruction to asynchronous exceptions does not vary based on:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.


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SADDL, SADDL2

Signed Add Long (vector). This instruction adds each vector element in the lower or upper half of the first source SIMD&FP register to the corresponding vector element of the second source SIMD&FP register, places the results into a vector, and writes the vector to the destination SIMD&FP register. The destination vector elements are twice as long as the source vector elements. All the values in this instruction are signed integer values.

The SADDL instruction extracts each source vector from the lower half of each source register, while the SADDL2 instruction extracts each source vector from the upper half of each source register.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
|    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| U  | 0  | 1  | 0  | 0  | 1  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  |

Three registers, not all the same type

SADDL[2] <Vd>.<Ta>, <Vn>.<Tb>, <Vm>.<Tb>

```plaintext
integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rm);

if size == '11' then UNDEFINED;
integer esize = 8 << if size == '11' then ReservedValue();
integer esize = 8 << UInt(size);
integer datasize = 64;
integer part = UInt(Q);
integer elements = datasize DIV esize;

boolean sub_op = (o1 == '1');
boolean unsigned = (U == '1');
```

Assembler Symbols

<table>
<thead>
<tr>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
</tr>
<tr>
<td>1</td>
</tr>
</tbody>
</table>

<Vd> Is the name of the SIMD&FP destination register, encoded in the "Rd" field.

<Ta> Is an arrangement specifier, encoded in “size”:

| 8H |
| 4S |
| 2D |
| 16B |

<Vn> Is the name of the first SIMD&FP source register, encoded in the "Rn" field.

<Tb> Is an arrangement specifier, encoded in “size:Q”:

| 2S |
| 4S |
| 8H |
| 4H |
| 16B |
| 8B |

SADDL, SADDL2  Page 961
<Vm> Is the name of the second SIMD&FP source register, encoded in the "Rm" field.

**Operation**

```plaintext
CheckFPAdvSIMDEnabled64();

bits(datasize) operand1 = Vpart[n, part];
bits(datasize) operand2 = Vpart[m, part];
bits(2*datasize) result;
integer element1;
integer element2;
integer sum;

for e = 0 to elements-1
    element1 = Int(Elem[operand1, e, esize], unsigned);
    element2 = Int(Elem[operand2, e, esize], unsigned);
    if sub_op then
        sum = element1 - element2;
    else
        sum = element1 + element2;
    Elem[result, e, 2*esize] = sum<2*esize-1:0>;
V[d] = result;
```

**Operational information**

If PSTATE.DIT is 1:

- The execution time of this instruction is independent of:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
- The response of this instruction to asynchronous exceptions does not vary based on:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
SADDLP

Signed Add Long Pairwise. This instruction adds pairs of adjacent signed integer values from the vector in the source SIMD&FP register, places
the result into a vector, and writes the vector to the destination SIMD&FP register. The destination vector elements are twice as long as the
source vector elements.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an
attempt to execute the instruction might be trapped.

```
0 | Q | 0 | 1 | size | 0 | 1 | op | Rn | Rd
---|---|---|-----|-----|---|---|-----|-----|-----
0 | 0 | 1 | 1 | 1 | 0 | 1 | 0 | 1 | 0
```

Vector

SADDLP <Vd>.<Ta>, <Vn>.<Tb>

integer d = UInt(Rd);
integer n = UInt(Rn);

```plaintext
if size == 'll' then UNDEFINED;
integer esize = 8 << if size == 'll' then ReservedValue();
integer esize = 8 << UInt(size);
integer datasize = if Q == '1' then 128 else 64;
integer elements = datasize DIV (2*esize);
boolean acc = (op == '1');
boolean unsigned = (U == '1');
```
Operation

```c
void CheckFPAdvSIMDEnabled64()
{
    bits(datasize) operand = V[n];
    bits(datasize) result;

    bits(2*esize) sum;
    integer op1;
    integer op2;

    result = if acc then V[d] else Zeros();
    for e = 0 to elements-1
        op1 = Int(Elem[operand, 2*e+0, esize], unsigned);
        op2 = Int(Elem[operand, 2*e+1, esize], unsigned);
        sum = (op1 + op2)<2*esize-1:0>;
        Elem[result, e, 2*esize] = Elem[result, e, 2*esize] + sum;
    V[d] = result;
}
```

Operational information

If PSTATE.DIT is 1:

- The execution time of this instruction is independent of:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
- The response of this instruction to asynchronous exceptions does not vary based on:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.

Internal version only: isa v30.25 28.21; AdvSIMD v27.01 26.0; pseudocode v85-xml-008cr8_rc3350; Build timestamp: 2018-09-13T13:20:45

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SADDLV

Signed Add Long across Vector. This instruction adds every vector element in the source SIMD&FP register together, and writes the scalar result to the destination SIMD&FP register. The destination scalar is twice as long as the source vector elements. All the values in this instruction are signed integer values.

Depending on the settings in the `CPACR_EL1`, `CPTR_EL2`, and `CPTR_EL3` registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

```
31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10  9  8  7  6  5  4  3  2  1  0
0 | Q | 0 | 1 | 1 | 1 | 0 | size | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | Rn | Rd |
  U
```

Advanced SIMD

```
SADDLV <V><d>, <Vn>.<T>
```

```
integer d = UInt(Rd);
integer n = UInt(Rn);
if size:Q == '100' then UNDEFINED;
if size == '11' then UNDEFINED;
integer esize = 8 << if size:Q == '100' then ReservedValue(1);
if size == '11' then ReservedValue();
integer esize = 8 << UInt(size);
integer datasize = if Q == '1' then 128 else 64;
integer elements = datasize DIV esize;
boolean unsigned = (U == '1');
```

Assembler Symbols

```
<V>
Is the destination width specifier, encoded in “size”:

<table>
<thead>
<tr>
<th>size</th>
<th>&lt;V&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>H</td>
</tr>
<tr>
<td>01</td>
<td>S</td>
</tr>
<tr>
<td>10</td>
<td>D</td>
</tr>
<tr>
<td>11</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

<d>
Is the number of the SIMD&FP destination register, encoded in the "Rd" field.

<Vn>
Is the name of the SIMD&FP source register, encoded in the "Rn" field.

<T>
Is an arrangement specifier, encoded in “size:Q”:

<table>
<thead>
<tr>
<th>size</th>
<th>Q</th>
<th>&lt;T&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>0</td>
<td>8B</td>
</tr>
<tr>
<td>00</td>
<td>1</td>
<td>16B</td>
</tr>
<tr>
<td>01</td>
<td>0</td>
<td>4H</td>
</tr>
<tr>
<td>01</td>
<td>1</td>
<td>8H</td>
</tr>
<tr>
<td>10</td>
<td>0</td>
<td>RESERVED</td>
</tr>
<tr>
<td>10</td>
<td>1</td>
<td>4S</td>
</tr>
<tr>
<td>11</td>
<td>x</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>
```
Operation

CheckFPAdvSIMDEnabled64();
bits(datasize) operand = V[n];
integer sum;

sum = \text{Int(Elem)}(operand, 0, esize, unsigned);
for e = 1 to elements-1
    sum = sum + \text{Int(Elem)}(operand, e, esize, unsigned);
V[d] = sum<2*esize-1:0>;

Operational information

If PSTATE.DIT is 1:
\begin{itemize}
  \item The execution time of this instruction is independent of:
    \begin{itemize}
      \item The values of the data supplied in any of its registers.
      \item The values of the NZCV flags.
    \end{itemize}
  \item The response of this instruction to asynchronous exceptions does not vary based on:
    \begin{itemize}
      \item The values of the data supplied in any of its registers.
      \item The values of the NZCV flags.
    \end{itemize}
\end{itemize}
SADDW, SADDW2

Signed Add Wide. This instruction adds vector elements of the first source SIMD&FP register to the corresponding vector elements in the lower or upper half of the second source SIMD&FP register, places the results in a vector, and writes the vector to the SIMD&FP destination register.

The SADDW instruction extracts the second source vector from the lower half of the second source register, while the SADDW2 instruction extracts the second source vector from the upper half of the second source register.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9  | 8  | 7  | 6  | 5  | 4  | 3  | 2  | 1  | 0  |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0  | Q  | 0  | 1  | 1  | 0  | size | 1  | Rm | 0  | 0  | 0  | 1  | 0  | Rd |
| U  |     |   |    |    |    |        |   |    |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| o1 |     |   |    |    |    |        |   |    |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |

Three registers, not all the same type

\[
\text{SADDW}(2) \ <\text{Vd}>, \ <\text{Ta}> , \ <\text{Vn}> , \ <\text{Vm}>, \ <\text{Tb}>
\]

\[
\begin{align*}
\text{integer } d &= \text{UInt}(Rd); \\
\text{integer } n &= \text{UInt}(Rn); \\
\text{integer } m &= \text{UInt}(Rm); \\
\end{align*}
\]

\[
\begin{align*}
\text{if size == '11' then UNDEFINED; } \\
\text{integer esize = } 8 & \text{ if size = '11' then ReservedValue(); } \\
\text{integer esize = } 8 & \text{ if size = '11' then ReservedValue(); } \\
\text{integer datasize = 64;} \\
\text{integer part = } \text{UInt}(Q); \\
\text{integer elements = datasize DIV esize;}
\end{align*}
\]

\[
\begin{align*}
\text{boolean sub_op = (o1 == '1'); } \\
\text{boolean unsigned = (U == '1');}
\end{align*}
\]

Assembler Symbols

2

<table>
<thead>
<tr>
<th>Q</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>[absent]</td>
</tr>
<tr>
<td>1</td>
<td>[present]</td>
</tr>
</tbody>
</table>

\(<\text{Vd}>\)

Is the second and upper half specifier. If present it causes the operation to be performed on the upper 64 bits of the registers holding the narrower elements, and is encoded in "Q":

\(<\text{Ta}>\)

Is an arrangement specifier, encoded in “size”:

\[
\begin{align*}
\text{size} & \quad \text{<Ta> } \\
00 & \quad 8H \\
01 & \quad 4S \\
10 & \quad 2D \\
11 & \quad \text{RESERVED}
\end{align*}
\]

\(<\text{Vn}>\)

Is the name of the first SIMD&FP source register, encoded in the "Rn" field.

\(<\text{Vm}>\)

Is the name of the second SIMD&FP source register, encoded in the "Rm" field.

\(<\text{Tb}>\)

Is an arrangement specifier, encoded in “size:Q”:

\[
\begin{align*}
\text{size} & \text{ Q } \text{ <Tb> } \\
00 & \quad 0 \quad 8B \\
00 & \quad 1 \quad 16B \\
01 & \quad 0 \quad 4H \\
01 & \quad 1 \quad 8H \\
10 & \quad 0 \quad 2S \\
10 & \quad 1 \quad 4S \\
11 & \quad x \quad \text{RESERVED}
\end{align*}
\]

SADDW, SADDW2
Operation

```c
CheckFPAdvSIMDEnabled64();

bits(2*datasize) operand1 = V[n];
bits(datasize) operand2 = Vpart[m, part];
bits(2*datasize) result;
integer element1;
integer element2;
integer sum;

for e = 0 to elements-1
    element1 = Int(Elem[operand1, e, 2*esize], unsigned);
    element2 = Int(Elem[operand2, e, esize], unsigned);
    if sub_op then
        sum = element1 - element2;
    else
        sum = element1 + element2;
    Elem[result, e, 2*esize] = sum<2*esize-1:0>;
V[d] = result;
```

Operational information

If PSTATE.DIT is 1:

- The execution time of this instruction is independent of:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
- The response of this instruction to asynchronous exceptions does not vary based on:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
Speculation Barrier is a barrier that controls speculation.
The semantics of the Speculation Barrier are that the execution, until the barrier completes, of any instruction that appears later in the program order than the barrier:

- Cannot be performed speculatively to the extent that such speculation can be observed through side-channels as a result of control flow speculation or data value speculation.
- Can be speculatively executed as a result of predicting that a potentially exception generating instruction has not generated an exception.

In particular, any instruction that appears later in the program order than the barrier cannot cause a speculative allocation into any caching structure where the allocation of that entry could be indicative of any data value present in memory or in the registers.

The SB instruction:

- Cannot be speculatively executed as a result of control flow speculation or data value speculation.
- Can be speculatively executed as a result of predicting that a potentially exception generating instruction has not generated an exception.

The potentially exception generating instruction can complete once it is known not to be speculative, and all data values generated by instructions appearing in program order before the SB instruction have their predicted values confirmed.

When the prediction of the instruction stream is not informed by data taken from the register outputs of the speculative execution of instructions appearing in program order after an uncompleted SB instruction, the SB instruction has no effect on the use of prediction resources to predict the instruction stream that is being fetched.

```plaintext
SB

MemBarrierOp op;
MBReqDomain domain;
MBReqTypes types;

case opc of
  when '00' op = MemBarrierOp_DSB;
  when '01' op = MemBarrierOp_DMB;
  when '10' op = MemBarrierOp_ISB;
  otherwise if HaveSBExt() && CRm<3:0> == '0000' then
    op = MemBarrierOp_SB;
  else
    UNDEFINED;

case CRm<3:2> of
  when '00' domain = MBReqDomain_OuterShareable;
  when '01' domain = MBReqDomain_Nonshareable;
  when '10' domain = MBReqDomain_InnerShareable;
  when '11' domain = MBReqDomain_FullSystem;

case CRm<1:0> of
  when '01' types = MBReqTypes_Reads;
  when '10' types = MBReqTypes_Writes;
  when '11' types = MBReqTypes_All;
  otherwise if CRm<3:2> == '01' then
    op = MemBarrierOp_PSSBB;
  elsif CRm<3:2> == '00' && opc == '00' then
    op = MemBarrierOp_SSBB;
  elsif HaveSBExt() && CRm<3:2> == '00' && opc == '11' then
    op = MemBarrierOp_SB;
  else
    types = MBReqTypes_All;
    domain = MBReqDomain_FullSystem;
```

System
case op of
    when MemBarrierOp_DSBDataSynchronizationBarrier(domain, types);
    when MemBarrierOp_DMBDataMemoryBarrier(domain, types);
    when MemBarrierOp_ISBIstructionSynchronizationBarrier();
    when MemBarrierOp_SSBSpeculativeSynchronizationBarrierToVA();
    when MemBarrierOp_PSSBSpeculativeSynchronizationBarrierToPA();
    when MemBarrierOp_SBSpeculationBarrier();
SBFM

Signed Bitfield Move is usually accessed via one of its aliases, which are always preferred for disassembly.

If \(\text{<imm>}\) is greater than or equal to \(\text{<immr>}\), this copies a bitfield of \((\text{<imm>}-\text{<immr>}+1)\) bits starting from bit position \(\text{<immr>}\) in the source register to the least significant bits of the destination register.

If \(\text{<imm>}\) is less than \(\text{<immr>}\), this copies a bitfield of \((\text{<imm>}+1)\) bits from the least significant bits of the source register to bit position \((\text{regsize}-\text{<immr>})\) of the destination register, where \(\text{regsize}\) is the destination register size of 32 or 64 bits.

In both cases the destination bits below the bitfield are set to zero, and the bits above the bitfield are set to a copy of the most significant bit of the bitfield.

This instruction is used by the aliases ASR (immediate), SBFIZ, SBFX, SXTB, SXTH, and SXTW.

<table>
<thead>
<tr>
<th>31</th>
<th>30</th>
<th>29</th>
<th>28</th>
<th>27</th>
<th>26</th>
<th>25</th>
<th>24</th>
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<th>9</th>
<th>8</th>
<th>7</th>
<th>6</th>
<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td>sf</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>N</td>
<td></td>
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</tr>
<tr>
<td>immr</td>
<td>imms</td>
<td>Rn</td>
<td>Rd</td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
</tbody>
</table>

32-bit (\(\text{sf} = 0 \&\& \text{N} = 0\))

\[
\text{SBFM <Wd>, <Wn>, #<immr>, #<imm>}
\]

64-bit (\(\text{sf} = 1 \&\& \text{N} = 1\))

\[
\text{SBFM <Xd>, <Xn>, #<immr>, #<imm>}
\]

```plaintext
integer d = UInt(Rd);
integer n = UInt(Rn);
integer datasize = if sf == '1' then 64 else 32;

boolean inzero;
boolean extend;
integer R;
integer S;
bits(datasize) wmask;
bits(datasize) tmask;

case opc of
  when '00' inzero = TRUE; extend = TRUE; // SBFM
  when '01' inzero = FALSE; extend = FALSE; // BFM
  when '10' inzero = TRUE; extend = FALSE; // UBFX
  when '11' UNDEFINED;
if sf == '1' && N != '1' then UNDEFINED;
if sf == '0' && (N != '0' || immr<5> != '0' || imms<5> != '0') then UNDEFINED;
R = when '11' UnallocatedEncoding();
if sf == '1' && N != '1' then ReservedValue();
if sf == '0' && (N != '0' || immr<5> != '0' || imms<5> != '0') then ReservedValue();
R = UInt(immr);
S = UInt(imms);
(wmask, tmask) = DecodeBitMasks(N, imms, immr, FALSE);
```

Assembler Symbols

- \(<Wd>\) Is the 32-bit name of the general-purpose destination register, encoded in the "Rd" field.
- \(<Wn>\) Is the 32-bit name of the general-purpose source register, encoded in the "Rn" field.
- \(<Xd>\) Is the 64-bit name of the general-purpose destination register, encoded in the "Rd" field.
- \(<Xn>\) Is the 64-bit name of the general-purpose source register, encoded in the "Rn" field.
For the 32-bit variant: is the right rotate amount, in the range 0 to 31, encoded in the "immr" field.
For the 64-bit variant: is the right rotate amount, in the range 0 to 63, encoded in the "immr" field.

For the 32-bit variant: is the leftmost bit number to be moved from the source, in the range 0 to 31, encoded in the "imms" field.
For the 64-bit variant: is the leftmost bit number to be moved from the source, in the range 0 to 63, encoded in the "imms" field.

**Alias Conditions**

<table>
<thead>
<tr>
<th>Alias</th>
<th>Of variant</th>
<th>Is preferred when</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASR (immediate)</td>
<td>32-bit</td>
<td>imms == '011111'</td>
</tr>
<tr>
<td>ASR (immediate)</td>
<td>64-bit</td>
<td>imms == '111111'</td>
</tr>
<tr>
<td>SBFIZ</td>
<td>64-bit</td>
<td>UInt(imms) &lt; UInt(immr)</td>
</tr>
<tr>
<td>SBFX</td>
<td></td>
<td>BFXPreferred(sf, opc&lt;1&gt;, imms, immr)</td>
</tr>
<tr>
<td>SXTB</td>
<td></td>
<td>immr == '000000' &amp; imms == '000111'</td>
</tr>
<tr>
<td>SXTH</td>
<td></td>
<td>immr == '000000' &amp; imms == '001111'</td>
</tr>
<tr>
<td>SXTW</td>
<td></td>
<td>immr == '000000' &amp; imms == '011111'</td>
</tr>
</tbody>
</table>

**Operation**

```plaintext
bits(datasize) dst = if inzero then Zeros() else X[d];
bits(datasize) src = X[n];

// perform bitfield move on low bits
bits(datasize) bot = (dst AND NOT(wmask)) OR (ROR(src, R) AND wmask);

// determine extension bits (sign, zero or dest register)
bits(datasize) top = if extend then Replicate(src<S>) else dst;

// combine extension bits and result bits
X[d] = (top AND NOT(tmask)) OR (bot AND tmask);
```

**Operational information**

If PSTATE.DIT is 1:

• The execution time of this instruction is independent of:
  ◦ The values of the data supplied in any of its registers.
  ◦ The values of the NZCV flags.
• The response of this instruction to asynchronous exceptions does not vary based on:
  ◦ The values of the data supplied in any of its registers.
  ◦ The values of the NZCV flags.
SCVTTF (vector, fixed-point)

Signed fixed-point Convert to Floating-point (vector). This instruction converts each element in a vector from fixed-point to floating-point using the rounding mode that is specified by the \( \text{FPCR} \), and writes the result to the SIMD&FP destination register.

A floating-point exception can be generated by this instruction. Depending on the settings in \( \text{FPCR} \), the exception results in either a flag being set in \( \text{FPSR} \), or a synchronous exception being generated. For more information, see \text{Floating-point exception traps}.

Depending on the settings in the \text{CPACR_EL1}, \text{CPTR_EL2}, and \text{CPTR_EL3} registers, and the Security state and Exception level in which the instruction is executed, an attempt to execute the instruction might be trapped.

It has encodings from 2 classes: \text{Scalar} and \text{Vector}.

**Scalar**

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0  | 1  | 0  | 1  | 1  | 1  | 1  | 1  | 0  | != | 0000 | immh | 1  | 1  | 1  | 0  | 0  | 1  | Rn | Rd |
| U  | immh |

**Vector**

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0  | Q  | 0  | 1  | 1  | 1  | 1  | 0  | != | 0000 | immh | 1  | 1  | 1  | 0  | 0  | 1  | Rn | Rd |
| U  | immh |

```plaintext
integer d = UInt(Rd);
integer n = UInt(Rn);

if immh == '000x' || (immh == '001x' && !HaveFP16Ext()) then UNDEFINED;
integer esize = if immh == '1xxx' then 64 else if immh == '01xx' then 32 else 16;
integer datasize = esize;
integer elements = 1;

integer frachbits = (esize * 2) -4) then ReservedValue();
integer esize = if immh == '1xxx' then 64 else if immh == '01xx' then 32 else 16;
integer datasize = esize;
integer elements = 1;

integer frachbits = (esize * 2) - UInt(immh:immb);
boolean unsigned = (U == '1');
FPRounding rounding = FPRoundingMode(FPCR);
```
Vector

SCVT

A width specifier, encoded in “immh”:

<table>
<thead>
<tr>
<th>immh</th>
<th>&lt;V&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>000x</td>
<td>RESERVED</td>
</tr>
<tr>
<td>001x</td>
<td>H</td>
</tr>
<tr>
<td>01xx</td>
<td>S</td>
</tr>
<tr>
<td>1xxx</td>
<td>D</td>
</tr>
</tbody>
</table>

The number of the SIMD&FP destination register, in the "Rd" field.

Is the number of the first SIMD&FP source register, encoded in the "Rn" field.

Is an arrangement specifier, encoded in “immh:Q”:

<table>
<thead>
<tr>
<th>immh</th>
<th>Q</th>
<th>&lt;T&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0000</td>
<td>x</td>
<td>SEE Advanced SIMD modified immediate</td>
</tr>
<tr>
<td>0001</td>
<td>x</td>
<td>RESERVED</td>
</tr>
<tr>
<td>001x</td>
<td>0</td>
<td>4H</td>
</tr>
<tr>
<td>001x</td>
<td>1</td>
<td>8H</td>
</tr>
<tr>
<td>01xx</td>
<td>0</td>
<td>2S</td>
</tr>
<tr>
<td>01xx</td>
<td>1</td>
<td>4S</td>
</tr>
<tr>
<td>1xxx</td>
<td>0</td>
<td>RESERVED</td>
</tr>
<tr>
<td>1xxx</td>
<td>1</td>
<td>2D</td>
</tr>
</tbody>
</table>

Is the name of the SIMD&FP source register, encoded in the "Rn" field.

For the scalar variant: is the number of fractional bits, in the range 1 to the operand width, encoded in “immh:immb”:

<table>
<thead>
<tr>
<th>immh</th>
<th>&lt;fbits&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>000x</td>
<td>RESERVED</td>
</tr>
<tr>
<td>001x</td>
<td>(32-UInt(immh:immb))</td>
</tr>
<tr>
<td>01xx</td>
<td>(64-UInt(immh:immb))</td>
</tr>
<tr>
<td>1xxx</td>
<td>(128-UInt(immh:immb))</td>
</tr>
</tbody>
</table>

For the vector variant: is the number of fractional bits, in the range 1 to the element width, encoded in “immh:immb”:

<table>
<thead>
<tr>
<th>immh</th>
<th>&lt;fbits&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0000</td>
<td>SEE Advanced SIMD modified immediate</td>
</tr>
<tr>
<td>0001</td>
<td>RESERVED</td>
</tr>
<tr>
<td>001x</td>
<td>(32-UInt(immh:immb))</td>
</tr>
<tr>
<td>01xx</td>
<td>(64-UInt(immh:immb))</td>
</tr>
<tr>
<td>1xxx</td>
<td>(128-UInt(immh:immb))</td>
</tr>
</tbody>
</table>
Operation

```c
CheckFPAdvSIMDEnabled64();

bits(datasize) operand = V[n];
bits(datasize) result;
bits(esize) element;

for e = 0 to elements-1
    element = Elem[operand, e, esize];
    Elem[result, e, esize] = FixedToFP(element, fracbits, unsigned, FPCR, rounding);

V[d] = result;
```


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SCVT F (vector, integer)

Signed integer Convert to Floating-point (vector). This instruction converts each element in a vector from signed integer to floating-point using the rounding mode that is specified by the FPCR, and writes the result to the SIMD&FP destination register.

A floating-point exception can be generated by this instruction. Depending on the settings in FPCR, the exception results in either a flag being set in FPSR, or a synchronous exception being generated. For more information, see Floating-point exception traps.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the Security state and Exception level in which the instruction is executed, an attempt to execute the instruction might be trapped.

It has encodings from 4 classes: Scalar half-precision, Scalar single-precision and double-precision, Vector half-precision and Vector single-precision and double-precision

Scalar half precision

(ARMv8.2)

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0  | 1  | 0  | 1  | 1  | 1  | 0  | 0  | 1  | 1  | 1  | 0  | 0  | 1  | 1  | 1  | 0  | 1  | 1  | 0  | 1  | 0  | 0  | 0  | 0  | 0  | 0  | 0  |

U

Scalar half precision

SCVT F <Hd>, <Hn>

if !HaveFP16Ext() then UNDEFINED;
integer d = Int(Rd);
integer n = Int(Rn);

integer esize = 16;
integer datasize = esize;
integer elements = 1;
boolean unsigned = (U == '1');

Scalar single-precision and double-precision

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0  | 1  | 0  | 1  | 1  | 1  | 0  | 0  | sz|1  | 0  | 0  | 0  | 0  | 1  | 1  | 1  | 0  | 1  | 1  | 0  | 1  | 0  | 0  | 0  | 0  | 0  |

U

Scalar single-precision and double-precision

SCVT F<V>d, <V>n

integer d = UInt(Rd);
integer n = UInt(Rn);

integer esize = 32 << UInt(sz);
integer datasize = esize;
integer elements = 1;
boolean unsigned = (U == '1');

Vector half precision

(ARMv8.2)

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0  | 1  | 0  | 1  | 1  | 1  | 0  | 0  | Q |0  | 1  | 1  | 1  | 0  | 0  | 0  | 1  | 1  | 1  | 0  | 1  | 1  | 0  | 1  | 0  | 0  | 0  |

U
Vector half precision

SCVTF \(<V_d>.<T>, <V_n>.<T>\)

```cpp
if !HaveFP16Ext() then UNDEFINED;
integer d = if UnallocatedEncoding() then UnallocatedEncoding();
integer n = UnallocatedEncoding();
integer dsize = 16;
integer datasize = if Q == '1' then 128 else 64;
integer elements = datasize DIV esize;
boolean unsigned = (U == '1');
```

Vector single-precision and double-precision

SCVTF \(<V_d>.<T>, <V_n>.<T>\)

```cpp
integer d = UInt(Rd);
integer n = UInt(Rn);

if sz:Q == '10' then UNDEFINED;
integer esize = 32 << if sz:Q == '10' then ReservedValue() else UInt(sz);
integer datasize = if Q == '1' then 128 else 64;
integer elements = datasize DIV esize;
boolean unsigned = (U == '1');
```

Assembler Symbols

- `<Hd>` is the 16-bit name of the SIMD&FP destination register, encoded in the "Rd" field.
- `<Hn>` is the 16-bit name of the SIMD&FP source register, encoded in the "Rn" field.
- `<V>` is a width specifier, encoded in "sz":
  ```
  \[
  \begin{array}{c|c}
  sz & <V> \\
  \hline
  0 & S \\
  1 & D \\
  \end{array}
  \]
  ```
- `<d>` is the number of the SIMD&FP destination register, encoded in the "Rd" field.
- `<n>` is the number of the SIMD&FP source register, encoded in the "Rn" field.
- `<Vd>` is the name of the SIMD&FP destination register, encoded in the "Rd" field.
- `<T>` For the vector half precision variant: is an arrangement specifier, encoded in "Q":
  ```
  \[
  \begin{array}{c|c}
  Q & <T> \\
  \hline
  0 & 4H \\
  1 & 8H \\
  \end{array}
  \]
  ```
  For the vector single-precision and double-precision variant: is an arrangement specifier, encoded in "sz:Q":
  ```
  \[
  \begin{array}{c|c|c}
  sz & Q & <T> \\
  \hline
  0 & 0 & 2S \\
  0 & 1 & 4S \\
  1 & 0 & RESERVED \\
  1 & 1 & 2D \\
  \end{array}
  \]
  ```
- `<Vn>` is the name of the SIMD&FP source register, encoded in the "Rn" field.
Operation

```c
CheckFPAdvSIMEnabled64();
bits(datasize) operand = V[n];
bits(datasize) result;
FPRounding rounding = FPRoundingMode(FPCR);
bits(esize) element;
for e = 0 to elements-1
    element = Elem[operand, e, esize];
    Elem[result, e, esize] = FixedToFP(element, 0, unsigned, FPCR, rounding);
V[d] = result;
```
SCVTF (scalar, fixed-point)

Signed fixed-point Convert to Floating-point (scalar). This instruction converts the signed value in the 32-bit or 64-bit general-purpose source register to a floating-point value using the rounding mode that is specified by the FPCR, and writes the result to the SIMD&FP destination register.

A floating-point exception can be generated by this instruction. Depending on the settings in FPCR, the exception results in either a flag being set in FPSR, or a synchronous exception being generated. For more information, see Floating-point exception traps.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the Security state and Exception level in which the instruction is executed, an attempt to execute the instruction might be trapped.

```
<table>
<thead>
<tr>
<th>31</th>
<th>30</th>
<th>29</th>
<th>28</th>
<th>27</th>
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<th>21</th>
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<th>12</th>
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<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
</tr>
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<tbody>
<tr>
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<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
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<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>scale</td>
<td>Rn</td>
<td>Rd</td>
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<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
```

SCVTF (scalar, fixed-point)  Page 979
32-bit to half-precision (sf == 0 && type == 11) (ARMv8.2)

SCVTF <Hd>, <Wn>, #<fbits>

32-bit to single-precision (sf == 0 && type == 00)

SCVTF <Sd>, <Wn>, #<fbits>

32-bit to double-precision (sf == 0 && type == 01)

SCVTF <Dd>, <Wn>, #<fbits>

64-bit to half-precision (sf == 1 && type == 11) (ARMv8.2)

SCVTF <Hd>, <Xn>, #<fbits>

64-bit to single-precision (sf == 1 && type == 00)

SCVTF <Sd>, <Xn>, #<fbits>

64-bit to double-precision (sf == 1 && type == 01)

SCVTF <Dd>, <Xn>, #<fbits>
integer d = \texttt{UInt}(Rd);  
integer n = \texttt{UInt}(Rn);  

integer intsize = if \texttt{sf} == '1' then 64 else 32;  
integer fltsize;  
FPConvOp op;  
FPRounding \texttt{rounding};  
boolean unsigned;  

case type of  
when '00' fltsize = 32;  
when '01' fltsize = 64;  
when '10' UNDEFINED;  
when '11'  
  if \texttt{scale} == '0' then UNDEFINED;  
  \texttt{fracbits} = 64 - \texttt{ UInt}(scale);  
when '10'  
  \texttt{UnallocatedEncoding}();  
when '11'  
  if \texttt{HaveFP16Ext}() then  
    fltsize = 16;  
  \texttt{UnallocatedEncoding}();  
if \texttt{sf} == '0' && \texttt{scale} == '0' then UNDEFINED;  
integer \text{fracbits} = 64 - \texttt{UInt}(scale);  

case \text{opcode}:\text{rmode} of  
when '00 11' // FCVTZ  
  \texttt{rounding} = \texttt{FPRounding\_ZERO};  
  \texttt{unsigned} = (\text{opcode} == '1');  
  \texttt{op} = \texttt{FPConvOp\_CVT\_FtoI};  
when '01 00' // [US]CVTF  
  \texttt{rounding} = \texttt{FPRounding\_Mode}(\text{FPCR});  
  \texttt{unsigned} = (\text{opcode} == '1');  
  \texttt{op} = \texttt{FPConvOp\_CVT\_ItoF};  
otherwise \texttt{UnallocatedEncoding}();  
otherwise UNDEFINED();  

\textbf{Assembler Symbols}  

<\text{Dd}> Is the 64-bit name of the SIMD&FP destination register, encoded in the "Rd" field.  
<\text{Hd}> Is the 16-bit name of the SIMD&FP destination register, encoded in the "Rd" field.  
<\text{Sd}> Is the 32-bit name of the SIMD&FP destination register, encoded in the "Rd" field.  
<\text{Xn}> Is the 64-bit name of the general-purpose source register, encoded in the "Rn" field.  
<\text{Wn}> Is the 32-bit name of the general-purpose source register, encoded in the "Rn" field.  
<\text{fbits}> For the 32-bit to double-precision, 32-bit to half-precision and 32-bit to single-precision variant: is the number of bits after the binary point in the fixed-point source, in the range 1 to 32, encoded as 64 minus "scale".  
For the 64-bit to double-precision, 64-bit to half-precision and 64-bit to single-precision variant: is the number of bits after the binary point in the fixed-point source, in the range 1 to 64, encoded as 64 minus "scale".
Operation

```c
CheckFPAdvSIMDEnabled64();

bits(fltsize) fltval;
b bits(intsize) intval;

case op of
    when FPConvOp_CVT_FtoI
        fltval = V[n];
        intval = FPToFixed(fltval, fracbits, unsigned, FPCR, rounding);
        X[d] = intval;
    when FPConvOp_CVT_ItoF
        intval = X[n];
        fltval = FixedToFP(intval, fracbits, unsigned, FPCR, rounding);
        V[d] = fltval;
```

Internal version only: isa v30.25 v29.05, AdvSIMD v27.01 v26.0, pseudocode v85-xml-00bet8_rc322 ; Build timestamp: 2018-09-13T13:20:45

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SCVTF (scalar, integer)

Signed integer Convert to Floating-point (scalar). This instruction converts the signed integer value in the general-purpose source register to a floating-point value using the rounding mode that is specified by the FPCR, and writes the result to the SIMD&FP destination register.

A floating-point exception can be generated by this instruction. Depending on the settings in FPCR, the exception results in either a flag being set in FPSR, or a synchronous exception being generated. For more information, see Floating-point exception traps.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

<table>
<thead>
<tr>
<th>sf</th>
<th>0</th>
<th>0</th>
<th>1</th>
<th>1</th>
<th>1</th>
<th>0</th>
<th>type</th>
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<th>0</th>
<th>0</th>
<th>0</th>
<th>Rn</th>
<th>Rd</th>
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</thead>
<tbody>
<tr>
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<td></td>
<td></td>
<td></td>
<td></td>
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<td>opcode</td>
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</tr>
</tbody>
</table>
32-bit to half-precision (sf == 0 && type == 11)
(ARMv8.2)

SCVTF <Hd>, <Wn>

32-bit to single-precision (sf == 0 && type == 00)

SCVTF <Sd>, <Wn>

32-bit to double-precision (sf == 0 && type == 01)

SCVTF <Dd>, <Wn>

64-bit to half-precision (sf == 1 && type == 11)
(ARMv8.2)

SCVTF <Hd>, <Xn>

64-bit to single-precision (sf == 1 && type == 00)

SCVTF <Sd>, <Xn>

64-bit to double-precision (sf == 1 && type == 01)

SCVTF <Dd>, <Xn>
integer d = UInt(Rd);
integer n = UInt(Rn);

integer intsize = if sf == '1' then 64 else 32;
integer fltsize;

FPConvOp op;
FPRounding rounding;
boolean unsigned;
integer part;

case type of
    when '00'
        fltsize = 32;
    when '01'
        fltsize = 64;
    when '10'
        if opcode<2:1>:rmode != '11 01' then UNDEFINED;
        fltsize = 128;
    when '11'
        if HaveFP16Ext() then
            fltsize = 16;
        else
            UNDEFINED;

case opcode<2:1>:rmode of
    when '00 xx'        // FCVT[NPMZ][US]
        rounding = FPDecodeRounding(rmode);
        unsigned = (opcode<0> == '1');
        op = FPConvOp_CVT_FtoI;
    when '01 00'        // [US]CVTF
        rounding = FPRounding_MODE(FPCR);
        unsigned = (opcode<0> == '1');
        op = FPConvOp_CVT_FtoI;
    when '10 00'        // FCVTA[US]
        rounding = FPRounding_TIEAWAY;
        unsigned = (opcode<0> == '1');
        op = FPConvOp_CVT_FtoI;
    when '11 00'        // FMOV
        if fltsize != 16 && fltsize != intsize then UNDEFINED;
        if opcode<0> == '1' then
            op = FPConvOp_MOV_FtoI;
        else
            op = FPConvOp_MOV_ItoF;
        part = 0;
    when '11 01'        // FMOV D[1]
        if intsize != 64 || fltsize != 128 then UNDEFINED;
        if opcode<0> == '1' then
            op = FPConvOp_MOV_FtoI;
        else
            op = FPConvOp_MOV_ItoF;
        part = 1;
        fltsize = 64; // size of D[1] is 64
    when '11 11'        // FJCVTZS
        if HaveFJCVTZSExt() then UNDEFINED;
        rounding = FPRounding_ZERO;
        unsigned = (opcode<0> == '1');
        op = FPConvOp_CVT_FtoI_JS;
        otherwise
            UNDEFINED;
        otherwise
            UNDEFINED;

Assembler Symbols

<Dd> Is the 64-bit name of the SIMD&FP destination register, encoded in the "Rd" field.
Is the 16-bit name of the SIMD&FP destination register, encoded in the "Rd" field.

Is the 32-bit name of the SIMD&FP destination register, encoded in the "Rd" field.

Is the 64-bit name of the general-purpose source register, encoded in the "Rn" field.

Is the 32-bit name of the general-purpose source register, encoded in the "Rn" field.

Operation

```c
CheckFPAdvSIMDEnabled64();

bits(fltsize) fltval;
bits(intsize) intval;

case op of
    when FPConvOp_CVT_FtoI
        fltval = V[n];
        intval = FToFixed(fltval, 0, unsigned, FPCR, rounding);
        X[d] = intval;
    when FPConvOp_CVT_ItoF
        intval = X[n];
        fltval = FixedToFP(intval, 0, unsigned, FPCR, rounding);
        V[d] = fltval;
    when FPConvOp_MOV_FtoI
        fltval = Vpart[n,part];
        intval = ZeroExtend(fltval, intsize);
        X[d] = intval;
    when FPConvOp_MOV_ItoF
        intval = X[n];
        fltval = intval<fltsize-1:0>;
        Vpart[d,part] = fltval;
    when FPConvOp_CVT_FtoI_JS
        fltval = V[n];
        intval = FPtoFixedJS(fltval, FPCR, TRUE);
        X[d] = ZeroExtend(intval<31:0>, 64);
```

Internal version only: isa v30.25 | v29.05, AdvSIMD v27.0 | v26.0, pseudocode v85-xml-00bet8_rc3b5; Build timestamp: 2018-09-13T13:45:00

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SDOT (by element)

Dot Product signed arithmetic (vector, by element). This instruction performs the dot product of the four 8-bit elements in each 32-bit element of the first source register with the four 8-bit elements of an indexed 32-bit element in the second source register, accumulating the result into the corresponding 32-bit element of the destination register.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

In ARMv8.2 and ARMv8.3, this is an OPTIONAL instruction. From ARMv8.4 it is mandatory for all implementations to support it.

ID_AA64ISAR0_EL1.DP indicates whether this instruction is supported.

Vector
(ARMv8.2)

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 |  9 |  8 |  7 |  6 |  5 |  4 |  3 |  2 |  1 |  0 |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
|  0 |  Q |  0 |  1 |  1 |  1 |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
|    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    | U |    |

Vector

SDOT <Vd>,<Ta>,<Vn>,<Tb>,<Vm>.4B[index]

if !HaveDOTPExt() then UNDEFINED;
if size != '10' then UNDEFINED;
boolean signed = (U=='0');

integer d = if size  != '10' then ReservedValue();
boolean signed = (U=='0');
integer d = UInt(Rd);
integer n  = UInt(Rn);
integer m  = UInt(M:Rm);
integer index = UInt(H:L);

integer esize = 8 << UInt(size);
integer datasize = if Q == '1' then 128 else 64;
integer elements = datasize DIV esize;

Assembler Symbols

<Vd> Is the name of the SIMD&FP destination register, encoded in the "Rd" field.

<Ta> Is an arrangement specifier, encoded in “Q”:

<table>
<thead>
<tr>
<th>Q</th>
<th>&lt;Ta&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>2S</td>
</tr>
<tr>
<td>1</td>
<td>4S</td>
</tr>
</tbody>
</table>

<Vn> Is the name of the first SIMD&FP source register, encoded in the "Rn" field.

<Tb> Is an arrangement specifier, encoded in “Q”:

<table>
<thead>
<tr>
<th>Q</th>
<th>&lt;Tb&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>8B</td>
</tr>
<tr>
<td>1</td>
<td>16B</td>
</tr>
</tbody>
</table>

<Vm> Is the name of the second SIMD&FP source register, encoded in the "M:Rm" fields.

<index> Is the element index, encoded in the "H:L" fields.
Operation

```c
CheckFPAdvSIMDEnabled64();
bits(datasize) operand1 = V[n];
bits(128) operand2 = V[m];
bits(datasize) result = V[d];
for e = 0 to elements-1
    integer res = 0;
    integer element1, element2;
    for i = 0 to 3
        if signed then
            element1 = SInt(16[operand1, 4 * e + i, esize DIV 4]);
            element2 = SInt(16[operand2, 4 * index + i, esize DIV 4]);
        else
            element1 = UInt(16[operand1, 4 * e + i, esize DIV 4]);
            element2 = UInt(16[operand2, 4 * index + i, esize DIV 4]);
        res = res + element1 * element2;
    Elem[result, e, esize] = Elem[result, e, esize] + res;
V[d] = result;
```
SDOT (vector)

Dot Product signed arithmetic (vector). This instruction performs the dot product of the four 8-bit elements in each 32-bit element of the first source register with the four 8-bit elements of the corresponding 32-bit element in the second source register, accumulating the result into the corresponding 32-bit element of the destination register.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

In ARMv8.2 and ARMv8.3, this is an OPTIONAL instruction. From ARMv8.4 it is mandatory for all implementations to support it.

ID_AA64ISAR0_EL1.DP indicates whether this instruction is supported.

Three registers of the same type
(ARMv8.2)

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9  | 8  | 7  | 6  | 5  | 4  | 3  | 2  | 1  | 0  |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| U  | Q  | 0  | 1  | 1  | 1  | 0  | size | 0  | Rm | 1  | 0  | 1  | 0  | 1  | Rn | 1  | 0  | 0  | 1  | 0  | 0  | 1  | 0  | 1  | 0  | 0  | 1  | 0  |

Three registers of the same type

\[
\text{SDOT} \ <Vd>.<Ta>, \ <Vn>.<Tb>, \ <Vm>.<Tb>
\]

\[
\text{if} \ !\text{HaveDOTPExt()} \text{then UNDEFINED;}
\]
\[
\text{if size}!= \ '10' \text{then UNDEFINED;}
\]
\[
\text{boolean signed} = (U=='0');
\]
\[
\text{integer d} = \text{if size}!= \ '10' \text{then reservedValue();}
\]
\[
\text{boolean signed} = (U=='0');
\]
\[
\text{integer d} = \text{UInt}(Rd);
\]
\[
\text{integer n} = \text{UInt}(Rn);
\]
\[
\text{integer m} = \text{UInt}(Rm);
\]
\[
\text{integer esize} = 8 << \text{UInt}(size);
\]
\[
\text{integer datasize} = \text{if Q == '1' then 128 else 64;}
\]
\[
\text{integer elements} = \text{datasize} \text{DIV esize};
\]

Assembler Symbols

\[
<\text{Vd}> \quad \text{Is the name of the SIMD&FP destination register, encoded in the "Rd" field.}
\]
\[
<\text{Ta}> \quad \text{Is an arrangement specifier, encoded in “Q”:}
\]
\[
\begin{array}{c|c}
Q & <\text{Ta}> \\
\hline
0 & 2S \\
1 & 4S \\
\end{array}
\]
\[
<\text{Vn}> \quad \text{Is the name of the first SIMD&FP source register, encoded in the "Rn" field.}
\]
\[
<\text{Tb}> \quad \text{Is an arrangement specifier, encoded in “Q”:}
\]
\[
\begin{array}{c|c}
Q & <\text{Tb}> \\
\hline
0 & 8B \\
1 & 16B \\
\end{array}
\]
\[
<\text{Vm}> \quad \text{Is the name of the second SIMD&FP source register, encoded in the "Rm" field.}
\]
Operation

```c
CheckFPAdvSIMEnabled64();
bits(datasize) operand1 = V[n];
bits(datasize) operand2 = V[m];
bits(datasize) result;

result = V[d];
for e = 0 to elements-1
    integer res = 0;
    integer element1, element2;
    for i = 0 to 3
        if signed then
            element1 = SInt(Elem[operand1, 4 * e + i, esize DIV 4]);
            element2 = SInt(Elem[operand2, 4 * e + i, esize DIV 4]);
        else
            element1 = UInt(Elem[operand1, 4 * e + i, esize DIV 4]);
            element2 = UInt(Elem[operand2, 4 * e + i, esize DIV 4]);
        res = res + element1 * element2;
    Elem[result, e, esize] = Elem[result, e, esize] + res;
V[d] = result;
```

Internal version only: isa v30.25, AdvSIMD v27.0, pseudocode v85-xml-00bet8 rc30.25 ; Build timestamp: 2018-09-13T13:11:54.045

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SETF8, SETF16

Set the PSTATE.NZV flags based on the value in the specified general-purpose register. **SETF8** treats the value as an 8 bit value, and **SETF16** treats the value as an 16 bit value.

The PSTATE.C flag is not affected by these instructions.

**Integer**

(ARMv8.4)

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0  | 0  | 1  | 1  | 1  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  |

**sf**

**SETF8 (sz == 0)**

SETF8 <Wn>

**SETF16 (sz == 1)**

SETF16 <Wn>

```plaintext
if !HaveFlagManipulateExt() || sf != '0' then UNDEFINED;
integer msb = if sz=='1' then 15 else 7;
integer n = (); () || sf != '0' then Int(Rn);
```

**Assembler Symbols**

<Wn> Is the 32-bit name of the general-purpose source register, encoded in the "Rn" field.

**Operation**

```plaintext
bits(32) tmpreg = X[n];
PSTATE.N = tmpreg<msb>;
PSTATE.Z = if (tmpreg<msb>=0) == Zeros(msb+1) then '1' else '0';
PSTATE.V = tmpreg<msb+1> EOR tmpreg<msb>;
//PSTATE.C unchanged;
```

**Operational information**

If PSTATE.DIT is 1:

- The execution time of this instruction is independent of:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
- The response of this instruction to asynchronous exceptions does not vary based on:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
Send Event is a hint instruction. It causes an event to be signaled to all PEs in the multiprocessor system. For more information, see *Wait for Event mechanism* and *Send event*. 

```
<table>
<thead>
<tr>
<th>CRm</th>
<th>op2</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>1</td>
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<tr>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>
```

**System**

```
SystemHintOp op;

case CRm:op2 of
  when '0000 000' op = SystemHintOp_NOP;
  when '0000 001' op = SystemHintOp_YIELD;
  when '0000 010' op = SystemHintOp_WFE;
  when '0000 011' op = SystemHintOp_WFI;
  when '0000 100' op = SystemHintOp_SEV;
  when '0000 101' op = SystemHintOp_SEVL;
  when '0000 111' SEE "XPACLRI";
  when '0001 xxx' SEE "PACIA1716, PACIB1716, AUTIA1716, AUTIB1716";
  when '0010 000'
    if !HaveRASExt() then EndOfInstruction();       // Instruction executes as NOP
    op = SystemHintOp_ESE;
  when '0010 001'
    if !HaveStatisticalProfiling() then EndOfInstruction(); // Instruction executes as NOP
    op = SystemHintOp_PSE;
  when '0010 100'
    op = SystemHintOp_TSDB;
  when '0011 xxx'
    SEE "PACIAZ, PACIASP, PACIBZ, PACIBSP, AUTIAZ, AUTIASP, AUTIBZ, AUTIBSP";
  when '0100 xx0'
    op = SystemHintOp_BTI;
  otherwise op = SystemHintOp_BT1;
    BTypeCompatible = BTypeCompatible_BT1(op2<2:1>);
  otherwise EndOfInstruction();                    // Instruction executes as NOP
```
case op of
  when SystemHintOp_YIELDHint_Yield();
  when SystemHintOp_WFE
    if IsEventRegisterSet() then
      ClearEventRegister();
    else
      if PSTATE.EL == EL0 then
        // Check for traps described by the OS which may be EL1 or EL2.
        AArch64.CheckForWfxTrap(EL1, TRUE);
      if EL2Enabled() && PSTATE.EL IN {EL0,EL1} && !IsHost() then
        // Check for traps described by the Hypervisor.
        AArch64.CheckForWfxTrap(EL2, TRUE);
      if HaveEL(EL3) && PSTATE.EL != EL3 then
        // Check for traps described by the Secure Monitor.
        AArch64.CheckForWfxTrap(EL3, TRUE);
      WaitForEvent();
  when SystemHintOp_WFI
    if !InterruptPending() then
      if PSTATE.EL == EL0 then
        // Check for traps described by the OS which may be EL1 or EL2.
        AArch64.CheckForWfxTrap(EL1, FALSE);
      if EL2Enabled() && PSTATE.EL IN {EL0,EL1} && IsHost() then
        // Check for traps described by the Hypervisor.
        AArch64.CheckForWfxTrap(EL2, FALSE);
      if HaveEL(EL3) && PSTATE.EL != EL3 then
        // Check for traps described by the Secure Monitor.
        AArch64.CheckForWfxTrap(EL3, FALSE);
      WaitForInterrupt();
  when SystemHintOp_SEVSendEvent();
  when SystemHintOp_SEVLSendEventLocal();
  when SystemHintOp_ESBSynchronizeErrors();
    AArch64.ESBOperation();
    if EL2Enabled() && PSTATE.EL IN {EL0,EL1} then
      AArch64.vESBOperation();
    TakeUnmaskedErrorInterrupts();
  when SystemHintOp_PSBProfilingSynchronizationBarrier();
  when SystemHintOp_TSB
    TraceSynchronizationBarrier();
  when SystemHintOp_CSDBCConsumptionOfSpeculativeDataBarrier();
    when otherwise // do nothing SystemHintOp_BTI
      BTypeNext = '00';
    otherwise // do nothing

SEVL

Send Event Local is a hint instruction that causes an event to be signaled locally without requiring the event to be signaled to other PEs in the multiprocessor system. It can prime a wait-loop which starts with a WFE instruction.

System

SEVL

```c
SystemHintOp op;

case CRm:op2 of
    when '0000 000' op = SystemHintOp_NOP;
    when '0000 001' op = SystemHintOp_YIELD;
    when '0000 010' op = SystemHintOp_WFE;
    when '0000 011' op = SystemHintOp_WFI;
    when '0000 100' op = SystemHintOp_SEV;
    when '0000 101' op = SystemHintOp_SEVL;
    when '0000 111'
        SEE "XPACLRI";
    when '0001 xxx'
        SEE "PACIA1716, PACIB1716, AUTIA1716, AUTIB1716";
    when '0010 000'
        if ! HaveRASExt() then EndOfInstruction(); // Instruction executes as NOP
        op = SystemHintOp_ESB;
    when '0010 001'
        if ! HaveStatisticalProfiling() then EndOfInstruction(); // Instruction executes as NOP
        op = SystemHintOp_PSB;
    when '0010 010'
        if ! HaveSelfHostedTrace() then EndOfInstruction(); // Instruction executes as NOP
        op = SystemHintOp_TSB;
    when '0010 100'
        op = SystemHintOp_CSDB;
    when '0011 xxx'
        SEE "PACIAZ, PACIAZP, PACIBZ, PACIBZP, AUTIAZ, AUTIASP, AUTIBZ, AUTIBZP";
    when '0100 xx0'
        op = SystemHintOp_BTI;
        BTypeCompatible = BTypeCompatible_BTI(op2<2:1>);
    otherwise EndOfInstruction(); // Instruction executes as NOP
```

Page 994
case op of
  when SystemHintOp_YIELDHint_Yield();

  when SystemHintOp_WFE
    if IsEventRegisterSet() then
      ClearEventRegister();
    else
      if PSTATE.EL == EL0 then
        // Check for traps described by the OS which may be EL1 or EL2.
        AArch64.CheckForWFxTrap(EL1, TRUE);
      if EL2Enabled() && PSTATE.EL IN {EL0, EL1} && !IsInHost() then
        // Check for traps described by the Hypervisor.
        AArch64.CheckForWFxTrap(EL2, TRUE);
      if HaveEL(EL3) && PSTATE.EL != EL3 then
        // Check for traps described by the Secure Monitor.
        AArch64.CheckForWFxTrap(EL3, TRUE);
      WaitForEvent();
    
  when SystemHintOp_WFI
    if !InterruptPending() then
      if PSTATE.EL == EL0 then
        // Check for traps described by the OS which may be EL1 or EL2.
        AArch64.CheckForWFxTrap(EL1, FALSE);
      if EL2Enabled() && PSTATE.EL IN {EL0, EL1} && !IsInHost() then
        // Check for traps described by the Hypervisor.
        AArch64.CheckForWFxTrap(EL2, FALSE);
      if HaveEL(EL3) && PSTATE.EL != EL3 then
        // Check for traps described by the Secure Monitor.
        AArch64.CheckForWFxTrap(EL3, FALSE);
      WaitForInterrupt();
  
  when SystemHintOp_SEVSendEvent();

  when SystemHintOp_SEVLSendEventLocal();

  when SystemHintOp_ESBSynchronizeErrors();
      AArch64.ESBOperation();
  
    if EL2Enabled() && PSTATE.EL IN {EL0, EL1} then AArch64.vESBOperation();
    TakeUnmaskedErrorInterrupts();

  when SystemHintOp_PSBProfilingSynchronizationBarrier();

  when SystemHintOp_TSB
      TraceSynchronizationBarrier();

  when SystemHintOp_CSDBConsumptionOfSpeculativeDataBarrier();

  when SystemHintOp_BTI
    BTypeNext = '00';

  otherwise // do nothing

Internal version only: isa v30.25 v29.05, AdvSIMD v27.01, uSimd v26.0, pseudocode v85-xml-00bet8_rc105 ; Build timestamp: 2018-09-13T13:2018-06-16T02:04:45
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SHA1C

SHA1 hash update (choose).

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9  | 8  | 7  | 6  | 5  | 4  | 3  | 2  | 1  | 0  |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0  | 1  | 0  | 1  | 1  | 1  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  |

Advanced SIMD

SHA1C $<Qd>$, $<Sn>$, $<Vm>$.4S

integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rm);
if !HaveSHA1Ext() then UNDEFINED;() then UnallocatedEncoding();

Assembler Symbols

$<Qd>$ Is the 128-bit name of the SIMD&FP source and destination, encoded in the "Rd" field.
$<Sn>$ Is the 32-bit name of the second SIMD&FP source register, encoded in the "Rn" field.
$<Vm>$ Is the name of the third SIMD&FP source register, encoded in the "Rm" field.

Operation

AArch64.CheckFPAdvSIMDEnabled();

bits(128) X = V[d];
bits(32)  Y = V[n];  // Note: 32 not 128 bits wide
bits(128) W = V[m];
bits(32)  t;
for e = 0 to 3
  t = SHAChoose(X<63:32>, X<95:64>, X<127:96>);
  Y = Y + ROL(X<31:0>, 5) + t + Elem[W, e, 32];
  X<63:32> = ROL(X<63:32>, 30);
  <Y, X> = ROL(Y : X, 32);
V[d] = X;

Operational information

If PSTATE.DIT is 1:
- The execution time of this instruction is independent of:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
- The response of this instruction to asynchronous exceptions does not vary based on:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
SHA1H

SHA1 fixed rotate.

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0  | 1  | 0  | 1  | 1  | 1  | 1  | 0  | 0  | 0  | 1  | 0  | 1  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 1  | 0  | 1  | 0  | 0  | 0  | 0  | 0  | 1  | 0  |

Rn Rd

Advanced SIMD

SHA1H <Sd>, <Sn>

```java
integer d = UInt(Rd);
integer n = UInt(Rn);
if !HaveSHA1Ext() then UNDEFINED();
```

Assembler Symbols

- `<Sd>` is the 32-bit name of the SIMD&FP destination register, encoded in the "Rd" field.
- `<Sn>` is the 32-bit name of the SIMD&FP source register, encoded in the "Rn" field.

Operation

```java
AArch64.CheckFPAdvSIMDEnabled();

bits(32) operand = V[n];        // read element [0] only, [1-3] zeroed
V[d] = ROL(operand, 30);
```

Operational information

If PSTATE.DIT is 1:

- The execution time of this instruction is independent of:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
- The response of this instruction to asynchronous exceptions does not vary based on:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.

Internal version only: isa v30.25 v29.05 v27.01 v26.0 pseudocode v85-xml-00bet8_rc3_v35.3 Build timestamp: 2018-09-13T13:2018-06-16T09:04:45
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SHA1M

SHA1 hash update (majority).

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9  | 8  | 7  | 6  | 5  | 4  | 3  | 2  | 1  | 0  |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0  | 1  | 0  | 1  | 1  | 1  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  |

Advanced SIMD

SHA1M \(<Q_d>, <S_n>, <V_m>.4S\)

integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rm);
if !HaveSHA1Ext() then UNDEFINED(); then UnallocatedEncoding();

Assembler Symbols

\(<Q_d>\)  Is the 128-bit name of the SIMD&FP source and destination, encoded in the "Rd" field.
\(<S_n>\)  Is the 32-bit name of the second SIMD&FP source register, encoded in the "Rn" field.
\(<V_m>\)  Is the name of the third SIMD&FP source register, encoded in the "Rm" field.

Operation

\[\text{AArch64.CheckFPAdvSIMDEnabled}();\]

\[
\begin{align*}
\text{bits}(128) & \quad X = V[d]; \\
\text{bits}(32) & \quad Y = V[n]; \quad \text{// Note: 32 not 128 bits wide} \\
\text{bits}(128) & \quad W = V[m]; \\
\text{bits}(32) & \quad t;
\end{align*}
\]

for e = 0 to 3
  \[
  t = \text{SHA}majority(X<63:32>, X<95:64>, X<127:96>);
  Y = Y + \text{ROL}(X<31:0>, 5) + t + \text{Elem}[W, e, 32];
  X<63:32> = \text{ROL}(X<63:32>, 30);
  \langle Y, X \rangle = \text{ROL}(Y : X, 32);
  V[d] = X;
\]

Operational information

If PSTATE.DIT is 1:

- The execution time of this instruction is independent of:
  \* The values of the data supplied in any of its registers.
  \* The values of the NZCV flags.

- The response of this instruction to asynchronous exceptions does not vary based on:
  \* The values of the data supplied in any of its registers.
  \* The values of the NZCV flags.

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SHA1P

SHA1 hash update (parity).

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9  | 8  | 7  | 6  | 5  | 4  | 3  | 2  | 1  | 0  |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0  | 1  | 0  | 1  | 1  | 1  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  |

Advanced SIMD

SHA1P <Qd>, <Sn>, <Vm>.4S

```plaintext
integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rm);
if !HaveSHA1Ext() then UNDEFINED();

Assembler Symbols

<Qd> Is the 128-bit name of the SIMD&FP source and destination, encoded in the "Rd" field.
<Sn> Is the 32-bit name of the second SIMD&FP source register, encoded in the "Rn" field.
<Vm> Is the name of the third SIMD&FP source register, encoded in the "Rm" field.

Operation

AArch64.CheckFPAdvSIMDEnabled();

bits(128) X = V[d];
bits(32) Y = V[n];      // Note: 32 not 128 bits wide
bits(128) W = V[m];
bits(32) t;
for e = 0 to 3
    t = SHAparity(X<63:32>, X<95:64>, X<127:96>);
    Y = Y + ROL(X<31:0>, 5) + t + Elem[W, e, 32];
    X<63:32> = ROL(X<63:32>, 30);
    <Y, X> = ROL(Y : X, 32);
V[d] = X;
```

Operational information

If PSTATE.DIT is 1:

- The execution time of this instruction is independent of:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
- The response of this instruction to asynchronous exceptions does not vary based on:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.

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SHA1SU0

SHA1 schedule update 0.

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9  | 8  | 7  | 6  | 5  | 4  | 3  | 2  | 1  | 0  |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0  | 1  | 0  | 1  | 1  | 1  | 1  | 0  | 0  | 0  | 0  | 0  | 1  | 0  | 1  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 1  | 1  | 0  | 0  | 0  | 0  | 0  | 0  |

Advanced SIMD

SHA1SU0 <Vd>.4S, <Vn>.4S, <Vm>.4S

integer d = UInt (Rd);
integer n = UInt (Rn);
integer m = UInt (Rm);
if !HaveSHA1Ext() then UNDEFINED(); UnallocatedEncoding();

Assembler Symbols

<Vd> Is the name of the SIMD&FP source and destination register, encoded in the "Rd" field.
<Vn> Is the name of the second SIMD&FP source register, encoded in the "Rn" field.
<Vm> Is the name of the third SIMD&FP source register, encoded in the "Rm" field.

Operation

AArch64.CheckFPAdvSIMDEnabled();

bits(128) operand1 = V[d];
bits(128) operand2 = V[n];
bits(128) operand3 = V[m];
bits(128) result;
result = operand2<63:0> : operand1<127:64>;
result = result EOR operand1 EOR operand3;
V[d] = result;

Operational information

If PSTATE.DIT is 1:

• The execution time of this instruction is independent of:
  ◦ The values of the data supplied in any of its registers.
  ◦ The values of the NZCV flags.

• The response of this instruction to asynchronous exceptions does not vary based on:
  ◦ The values of the data supplied in any of its registers.
  ◦ The values of the NZCV flags.


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The SHA1SU1 is a schedule update 1 for SHA1.

### Advanced SIMD

**SHA1SU1**<Vd>.4S, <Vn>.4S

```c
int d = UInt(Rd);
int n = UInt(Rn);
if ![HaveSHA1Ext()]() then UNDEFINED();
```

**Assembler Symbols**

- `<Vd>`: Is the name of the SIMD&FP source and destination register, encoded in the "Rd" field.
- `<Vn>`: Is the name of the second SIMD&FP source register, encoded in the "Rn" field.

**Operation**

```c
AArch64.CheckFPAvSIMDEnabled();

bits(128) operand1 = V[d];
bites(128) operand2 = V[n];
bites(128) result;
bites(128) T = operand1 EOR LSR(operand2, 32);
result<31:0> = ROL(T<31:0>, 1);
result<63:32> = ROL(T<63:32>, 1);
result<95:64> = ROL(T<95:64>, 1);
result<127:96> = ROL(T<127:96>, 1) EOR ROL(T<31:0>, 2);
V[d] = result;
```

**Operational Information**

If `PSTATE.DIT` is 1:
- The execution time of this instruction is independent of:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
- The response of this instruction to asynchronous exceptions does not vary based on:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
SHA256H2

SHA256 hash update (part 2).

<table>
<thead>
<tr>
<th>31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 1 0 1 1 1 0 0 0 0 1 0 0 1 0 0</td>
</tr>
</tbody>
</table>

Advanced SIMD

SHA256H2 \(<Qd>, <Qn>, <Vm>.4S\)

```
integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rm);
if !HaveSHA256Ext() then UNDEFINED;

boolean part1 = (P == '0');
boolean part1 = (P == '0');
```

Assembler Symbols

- \(<Qd>\): Is the 128-bit name of the SIMD&FP source and destination, encoded in the "Rd" field.
- \(<Qn>\): Is the 128-bit name of the second SIMD&FP source register, encoded in the "Rn" field.
- \(<Vm>\): Is the name of the third SIMD&FP source register, encoded in the "Rm" field.

Operation

```
AArch64.CheckFPAdvSIMDEnabled();

bits(128) result;
if part1 then
    result = SHA256hash(V[d], V[n], V[m], TRUE);
else
    result = SHA256hash(V[n], V[d], V[m], FALSE);
V[d] = result;
```

Operational information

If PSTATE.DIT is 1:

- The execution time of this instruction is independent of:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
- The response of this instruction to asynchronous exceptions does not vary based on:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
SHA256H

SHA256 hash update (part 1).

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9  | 8  | 7  | 6  | 5  | 4  | 3  | 2  | 1  | 0  |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0  | 1  | 0  | 1  | 1  | 1  | 0  | 0  | 0  | 0  | 1  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  |

Advanced SIMD

SHA256H \(<Q_d>, <Q_n>, <V_m>\).

integer \(d\) = UInt(Rd);
integer \(n\) = UInt(Rn);
integer \(m\) = UInt(Rm);
if !HaveSHA256Ext() then UNDEFINED;
boolean part1 = (P == '0');
boolean part1 = (P == '0');

Assembler Symbols

\(<Q_d>\) is the 128-bit name of the SIMD&FP source and destination, encoded in the "Rd" field.
\(<Q_n>\) is the 128-bit name of the second SIMD&FP source register, encoded in the "Rn" field.
\(<V_m>\) is the name of the third SIMD&FP source register, encoded in the "Rm" field.

Operation

\(\text{AArch64.CheckFPAdvSIMDEnabled}()\);

bits(128) result;
if part1 then
result = SHA256hash(\(V[d]\), \(V[n]\), \(V[m]\), TRUE);
else
result = SHA256hash(\(V[n]\), \(V[d]\), \(V[m]\), FALSE);
\(V[d]\) = result;

Operational information

If PSTATE.DIT is 1:
- The execution time of this instruction is independent of:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
- The response of this instruction to asynchronous exceptions does not vary based on:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.


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SHA256SU0

SHA256 schedule update 0.

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9  | 8  | 7  | 6  | 5  | 4  | 3  | 2  | 1  | 0  |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0  | 1  | 0  | 1  | 1  | 1  | 0  | 0  | 0  | 0  | 1  | 0  | 0  | 0  | 0  | 1  | 0  | 1  | 0  | 0  | 0  | 0  | 0  | 1  | 1  | 0  | 1  | 0  | 0  | 0  | 0  |

Advanced SIMD

SHA256SU0 <Vd>.4S, <Vn>.4S

integer d = UInt(Rd);
integer n = UInt(Rn);
if !HaveSHA256Ext() then UNDEFINED(); then UnallocatedEncoding();

Assembler Symbols

<Vd> Is the name of the SIMD&FP source and destination register, encoded in the "Rd" field.
<Vn> Is the name of the second SIMD&FP source register, encoded in the "Rn" field.

Operation

```
AArch64.CheckFPAdvSIMDEnabled();

bits(128) operand1 = V[d];
bits(128) operand2 = V[n];

bits(128) result;

bits(128) T = operand2<31:0> : operand1<127:32>;
bits(32) elt;

for e = 0 to 3
  elt = Elem[T, e, 32];
  elt = ROR(elt, 7) EOR ROR(elt, 18) EOR LSR(elt, 3);  
  Elem[result, e, 32] = elt + Elem[operand1, e, 32];

V[d] = result;
```

Operational information

If PSTATE.DIT is 1:

- The execution time of this instruction is independent of:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.

- The response of this instruction to asynchronous exceptions does not vary based on:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
SHA256SU1

SHA256 schedule update 1.

31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
0 1 0 1 1 1 0 0 0 0 Rm 0 1 1 0 0 0 Rn Rd

Advanced SIMD

SHA256SU1 <Vd>.4S, <Vn>.4S, <Vm>.4S

integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rm);
if !HaveSHA256Ext() then UNDEFINED;

Assembler Symbols

<Vd> Is the name of the SIMD&FP source and destination register, encoded in the "Rd" field.
<Vn> Is the name of the second SIMD&FP source register, encoded in the "Rn" field.
<Vm> Is the name of the third SIMD&FP source register, encoded in the "Rm" field.

Operation

AArch64.CheckFPAdvSIMDEnabled();

bits(128) operand1 = V[d];
b fête (128) operand2 = V[n];
b fête (128) operand3 = V[m];
bits(128) result;
bits(128) T0 = operand3<31:0> : operand2<127:32>;
b fête (64) T1;
b fête (32) elt;
T1 = operand3<127:64>;
for e = 0 to 1
    elt = Elem[T1, e, 32];
    elt = ROR(elt, 17) EOR ROR(elt, 19) EOR LSR(elt, 10);
    elt = elt + Elem[operand1, e, 32] + Elem[T0, e, 32];
    Elem[result, e, 32] = elt;
T1 = result<63:0>;
for e = 2 to 3
    elt = Elem[T1, e - 2, 32];
    elt = ROR(elt, 17) EOR ROR(elt, 19) EOR LSR(elt, 10);
    elt = elt + Elem[operand1, e, 32] + Elem[T0, e, 32];
    Elem[result, e, 32] = elt;
V[d] = result;

Operational information

If PSTATE.DIT is 1:
- The execution time of this instruction is independent of:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
- The response of this instruction to asynchronous exceptions does not vary based on:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
SHA512H2

SHA512 Hash update part 2 takes the values from the three 128-bit source SIMD&FP registers and produces a 128-bit output value that combines the sigma0 and majority functions of two iterations of the SHA512 computation. It returns this value to the destination SIMD&FP register.

This instruction is implemented only when \texttt{ARMv8.2-SHA} is implemented.

**Advanced SIMD**

\texttt{SHA512H2 <Qd>, <Qn>, <Vm>.2D}

```plaintext
if !HaveSHA512Ext() then UNDEFINED;
inger
d = \texttt{UInt}(Rd);
inger
n = \texttt{UInt}(Rn);
inger
m = \texttt{UInt}(Rm);
```

**Assembler Symbols**

- \texttt{<Qd>}: Is the 128-bit name of the SIMD&FP source and destination register, encoded in the "Rd" field.
- \texttt{<Qn>}: Is the 128-bit name of the second SIMD&FP source register, encoded in the "Rn" field.
- \texttt{<Vm>}: Is the name of the third SIMD&FP source register, encoded in the "Rm" field.

**Operation**

```plaintext
AArch64.CheckFPAdvSIMDEnabled();

\texttt{bits}(128) Vtmp;
\texttt{bits}(64) NSigma0;
\texttt{bits}(64) tmp;
\texttt{bits}(128) X = V[n];
\texttt{bits}(128) Y = V[m];
\texttt{bits}(128) W = V[d];

NSigma0 = \texttt{ROR}(Y<63:0>, 28) \texttt{EOR} \texttt{ROR}(Y<63:0>, 34) \texttt{EOR} \texttt{ROR}(Y<63:0>, 39);
Vtmp<127:64> = (X<63:0> AND Y<127:64>) \texttt{EOR} (X<63:0> AND Y<63:0>) \texttt{EOR} (Y<127:64> AND Y<63:0>);
Vtmp<127:64> = (Vtmp<127:64> + NSigma0 + W<127:64>);
Vtmp<127:64> = (Vtmp<127:64>, 28) \texttt{EOR} \texttt{ROR}(Vtmp<127:64>, 34) \texttt{EOR} \texttt{ROR}(Vtmp<127:64>, 39);
Vtmp<127:64> = (Vtmp<127:64> AND Y<63:0>) \texttt{EOR} (Vtmp<127:64> AND Y<127:64>) \texttt{EOR} (Y<127:64> AND Y<63:0>);
Vtmp<127:64> = (Vtmp<127:64> + NSigma0 + W<127:64>);
V[d] = Vtmp;
```

**Operational information**

If \texttt{PSTATE.DIT} is 1:
- The execution time of this instruction is independent of:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
- The response of this instruction to asynchronous exceptions does not vary based on:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
SHA512H

SHA512 Hash update part 1 takes the values from the three 128-bit source SIMD&FP registers and produces a 128-bit output value that combines the sigma1 and chi functions of two iterations of the SHA512 computation. It returns this value to the destination SIMD&FP register. This instruction is implemented only when ARMv8.2-SHA is implemented.

**Advanced SIMD (ARMv8.2)**

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9  | 8  | 7  | 6  | 5  | 4  | 3  | 2  | 1  | 0  |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 1  | 1  | 0  | 1  | 1  | 0  | 1  | 1  | 0  | 1  | 1  | 0  | 1  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  |

**Assembler Symbols**

- `<Qd>`: Is the 128-bit name of the SIMD&FP source and destination register, encoded in the "Rd" field.
- `<Qn>`: Is the 128-bit name of the second SIMD&FP source register, encoded in the "Rn" field.
- `<Vm>`: Is the name of the third SIMD&FP source register, encoded in the "Rm" field.

**Operation**

```assembly
AArch64.CheckFPAdvSIMDEnabled();

bits(128) Vtmp;
bits(64) MSigma1;
bits(64) tmp;
bits(128) X = V[<Qn>];
bits(128) Y = V[<Vm>];
bits(128) W = V[<Qd>];

MSigma1 = ROR(Y<127:64>,14) EOR ROR(Y<127:64>,18) EOR ROR(Y<127:64>,41);
Vtmp<127:64> = (X<127:64> AND Y<63:0>) EOR (NOT(X<127:64>) AND Y<127:64>);
Vtmp<127:64> = (Vtmp<127:64> + MSigma1 + W<127:64>);
tmp = Vtmp<127:64> + Y<63:0>;

MSigma1 = ROR(tmp,14) EOR ROR(tmp,18) EOR ROR(tmp,41);
Vtmp<63:0> = (tmp AND Y<127:64>) EOR (NOT(tmp) AND X<63:0>);
Vtmp<63:0> = (Vtmp<63:0> + MSigma1 + W<63:0>);
V[<Qd>] = Vtmp;
```

**Operational information**

If PSTATE.DIT is 1:
- The execution time of this instruction is independent of:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
- The response of this instruction to asynchronous exceptions does not vary based on:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
(old) htmldiff from- (new)
SHA512SU0

SHA512 Schedule Update 0 takes the values from the two 128-bit source SIMD&FP registers and produces a 128-bit output value that combines the gamma0 functions of two iterations of the SHA512 schedule update that are performed after the first 16 iterations within a block. It returns this value to the destination SIMD&FP register.

This instruction is implemented only when ARMv8.2-SHA is implemented.

Advanced SIMD
(ARMv8.2)

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 1  | 1  | 0  | 1  | 1  | 1  | 0  | 1  | 1  | 0  | 0  | 0  | 0  | 0  | 0  | 1  | 0  | 0  | 0  | 0  | 0  | Rn |    |   |   |   |
|    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| 1  | 1  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | Rd |    |   |   |   |

Advanced SIMD

SHA512SU0 <Vd>.2D, <Vn>.2D

if !HaveSHA512Ext() then UNDEFINED;
integer d = 0 then unallocatedEncoding();
integer d = UInt(Rd);
integer n = UInt(Rn);

Assembler Symbols

<Vd> Is the name of the SIMD&FP source and destination register, encoded in the "Rd" field.

<Vn> Is the name of the second SIMD&FP source register, encoded in the "Rn" field.

Operation

```assembly
AArch64.CheckFPAdvSIMDEnabled();
bits(64) sig0;
bits(128) Vtmp;
bits(128) X = V[n];
bits(128) W = V[d];
sig0 = ROR(W<127:64>, 1) EOR ROR(W<127:64>, 8) EOR ('0000000':W<127:71>);
Vtmp<63:0> = W<63:0> + sig0;
sig0 = ROR(X<63:0>, 1) EOR ROR(X<63:0>, 8) EOR ('0000000':X<63:7>);
Vtmp<127:64> = W<127:64> + sig0;
V[d] = Vtmp;
```

Operational information

If PSTATE.DIT is 1:

- The execution time of this instruction is independent of:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
- The response of this instruction to asynchronous exceptions does not vary based on:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.

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SHA512SU1

SHA512 Schedule Update 1 takes the values from the three source SIMD&FP registers and produces a 128-bit output value that combines the gamma1 functions of two iterations of the SHA512 schedule update that are performed after the first 16 iterations within a block. It returns this value to the destination SIMD&FP register.

This instruction is implemented only when ARMv8.2-SHA is implemented.

Advanced SIMD (ARMv8.2)

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9  | 8  | 7  | 6  | 5  | 4  | 3  | 2  | 1  | 0  |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 1  | 1  | 0  | 1  | 1  | 0  | 0  | 1  | 1  | 0  | 0  | 1  | 1  | 0  | 0  | 1  | 0  | 0  | 0  | 1  | 0  | 1  | 1  | 0  | 0  | 1  | 0  | 1  | 0  | 1  | 0  |

Advanced SIMD

SHA512SU1 <Vd>.2D, <Vn>.2D, <Vm>.2D

if !HaveSHA512Ext() then UNDEFINED;
integer d = 1; then UnallocatedEncoding();
integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rm);

Assembler Symbols

<Vd> Is the name of the SIMD&FP source and destination register, encoded in the "Rd" field.
<Vn> Is the name of the second SIMD&FP source register, encoded in the "Rn" field.
<Vm> Is the name of the third SIMD&FP source register, encoded in the "Rm" field.

Operation

AArch64.CheckFPAdvSIMDEnabled();

bits(64) sig1;
bits(128) Vtmp;
bits(128) X = V[n];
bits(128) Y = V[m];
bits(128) W = V[d];
sig1 = ROR(X<127:64>, 19) EOR ROR(X<127:64>, 61) EOR ('000000':X<127:70>);
Vtmp<127:64> = W<127:64> + sig1 + Y<127:64>;
sig1 = ROR(X<63:0>, 19) EOR ROR(X<63:0>, 61) EOR ('000000':X<63:6>);
Vtmp<63:0> = W<63:0> + sig1 + Y<63:0>;
V[d] = Vtmp;

Operational information

If PSTATE.DIT is 1:
- The execution time of this instruction is independent of:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
- The response of this instruction to asynchronous exceptions does not vary based on:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
**SHADD**

Signed Halving Add. This instruction adds corresponding signed integer values from the two source SIMD&FP registers, shifts each result right one bit, places the results into a vector, and writes the vector to the destination SIMD&FP register.

The results are truncated. For rounded results, see **SRHADD**.

Depending on the settings in the `CPACR_EL1`, `CPTR_EL2`, and `CPTR_EL3` registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

### Three registers of the same type

**SHADD** `<Vd>`, `<Vn>`, `<Vm>`

```plaintext
integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rm);
```

```plaintext
if size == '11' then UNDEFINED;
integer esize = 8 << if size == '11' then ReservedValue();
integer esize = 8 << UInt(size);
```

```plaintext
integer datasize = if Q == '1' then 128 else 64;
integer elements = datasize DIV esize;
boolean unsigned = (U == '1');
```

### Assembler Symbols

**<Vd>**

Is the name of the SIMD&FP destination register, encoded in the "Rd" field.

**<T>**

Is an arrangement specifier, encoded in “size:Q”:

<table>
<thead>
<tr>
<th>size</th>
<th>Q</th>
<th>&lt;T&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>0</td>
<td>8B</td>
</tr>
<tr>
<td>00</td>
<td>1</td>
<td>16B</td>
</tr>
<tr>
<td>01</td>
<td>0</td>
<td>4H</td>
</tr>
<tr>
<td>01</td>
<td>1</td>
<td>8H</td>
</tr>
<tr>
<td>10</td>
<td>0</td>
<td>2S</td>
</tr>
<tr>
<td>10</td>
<td>1</td>
<td>4S</td>
</tr>
<tr>
<td>11</td>
<td>x</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

**<Vn>**

Is the name of the first SIMD&FP source register, encoded in the "Rn" field.

**<Vm>**

Is the name of the second SIMD&FP source register, encoded in the "Rm" field.

### Operation

```plaintext
CheckFPAdvSIMDEnabled64();
bits(datasize) operand1 = V[n];
bits(datasize) operand2 = V[m];
bits(datasize) result;
integer element1;
integer element2;
integer sum;
for e = 0 to elements-1
    element1 = Int(Elem[operand1, e, esize], unsigned);
    element2 = Int(Elem[operand2, e, esize], unsigned);
    sum = element1 + element2;
    Elem[result, e, esize] = sum<esize:1>;
V[d] = result;
```
Operational information

If PSTATE.DIT is 1:

• The execution time of this instruction is independent of:
  ◦ The values of the data supplied in any of its registers.
  ◦ The values of the NZCV flags.

• The response of this instruction to asynchronous exceptions does not vary based on:
  ◦ The values of the data supplied in any of its registers.
  ◦ The values of the NZCV flags.
SHL

Shift Left (immediate). This instruction reads each value from a vector, left shifts each result by an immediate value, writes the final result to a vector, and writes the vector to the destination SIMD&FP register.

Depending on the settings in the $CPACR_EL1$, $CPTR_EL2$, and $CPTR_EL3$ registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

It has encodings from 2 classes: **Scalar** and **Vector**

### Scalar

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9  | 8  | 7  | 6  | 5  | 4  | 3  | 2  | 1  | 0  |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0  | 1  | 0  | 1  | 1  | 1  | 0  | != '0000' | immh | 0  | 1  | 0  | 1  | 0  | 1  | Rn  |
|    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| immh |

### Vector

<table>
<thead>
<tr>
<th>31</th>
<th>30</th>
<th>29</th>
<th>28</th>
<th>27</th>
<th>26</th>
<th>25</th>
<th>24</th>
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<th>16</th>
<th>15</th>
<th>14</th>
<th>13</th>
<th>12</th>
<th>11</th>
<th>10</th>
<th>9</th>
<th>8</th>
<th>7</th>
<th>6</th>
<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Q</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>!= '0000'</td>
<td>immh</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>Rn</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>immh</td>
<td></td>
<td></td>
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<td></td>
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</tr>
</tbody>
</table>

### Assembler Symbols

$<V>$ is a width specifier, encoded in “immh”:

```plaintext
integer d = UInt(Rd);
integer n = UInt(Rn);

if immh<3> != '1' then UNDEFINED;
integer esize = 8 << 3;
integer datasize = esize;
integer elements = 1;
integer shift = UInt(immh:immb) - esize;
```
<table>
<thead>
<tr>
<th>immh</th>
<th>&lt;V&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0xxx</td>
<td>RESERVED</td>
</tr>
<tr>
<td>1xxx</td>
<td>D</td>
</tr>
</tbody>
</table>

<d>
Is the number of the SIMD&FP destination register, in the "Rd" field.

<n>
Is the number of the first SIMD&FP source register, encoded in the "Rn" field.

<Vd>
Is the name of the SIMD&FP destination register, encoded in the "Rd" field.

<T>
Is an arrangement specifier, encoded in “immh:Q”:

<table>
<thead>
<tr>
<th>immh</th>
<th>Q</th>
</tr>
</thead>
<tbody>
<tr>
<td>0000</td>
<td>x</td>
</tr>
<tr>
<td>0001</td>
<td>0</td>
</tr>
<tr>
<td>0001</td>
<td>1</td>
</tr>
<tr>
<td>001x</td>
<td>0</td>
</tr>
<tr>
<td>001x</td>
<td>1</td>
</tr>
<tr>
<td>01xx</td>
<td>0</td>
</tr>
<tr>
<td>01xx</td>
<td>1</td>
</tr>
<tr>
<td>1xxx</td>
<td>0</td>
</tr>
<tr>
<td>1xxx</td>
<td>1</td>
</tr>
</tbody>
</table>

<Vn>
Is the name of the SIMD&FP source register, encoded in the "Rn" field.

<shift>
For the scalar variant: is the left shift amount, in the range 0 to 63, encoded in “immh:immb”:

<table>
<thead>
<tr>
<th>immh</th>
<th>&lt;shift&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0xxx</td>
<td>RESERVED</td>
</tr>
<tr>
<td>1xxx</td>
<td>(UInt(immh:immb)-64)</td>
</tr>
</tbody>
</table>

For the vector variant: is the left shift amount, in the range 0 to the element width in bits minus 1, encoded in “immh:immb”:

<table>
<thead>
<tr>
<th>immh</th>
<th>&lt;shift&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0000</td>
<td>SEE Advanced SIMD modified immediate</td>
</tr>
<tr>
<td>0001</td>
<td>(UInt(immh:immb)-8)</td>
</tr>
<tr>
<td>001x</td>
<td>(UInt(immh:immb)-16)</td>
</tr>
<tr>
<td>01xx</td>
<td>(UInt(immh:immb)-32)</td>
</tr>
<tr>
<td>1xxx</td>
<td>(UInt(immh:immb)-64)</td>
</tr>
</tbody>
</table>

Operation

```c
CheckFPAdvSIMDEnabled64();
bits(datasize) operand = V[n];
bits(datasize) result;
for e = 0 to elements-1
    Elem[result, e, esize] = LSL(Elem[operand, e, esize], shift);
V[d] = result;
```

Operational information

If PSTATE.DIT is 1:
- The execution time of this instruction is independent of:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
- The response of this instruction to asynchronous exceptions does not vary based on:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
SHLL, SHLL2

Shift Left Long (by element size). This instruction reads each vector element in the lower or upper half of the source SIMD&FP register, left shifts each result by the element size, writes the final result to a vector, and writes the vector to the destination SIMD&FP register. The destination vector elements are twice as long as the source vector elements.

The SHLL instruction extracts vector elements from the lower half of the source register, while the SHLL2 instruction extracts vector elements from the upper half of the source register.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

Vector

\[
\text{SHLL}(2) \ <Vd>, \ <Ta>, \ <Vn>, \ <Rd>, \ #<shift>
\]

\[
\begin{aligned}
\text{integer } d &= \text{UInt}(Rd); \\
\text{integer } n &= \text{UInt}(Rn); \\
\text{if size == '11' then UNDEFINED;}
\end{aligned}
\]

\[
\begin{aligned}
\text{integer esize} &= 8 << \text{UInt}(\text{size}); \\
\text{integer datasize} &= 64; \\
\text{integer part} &= \text{UInt}(Q); \\
\text{integer elements} &= \text{datasize} \text{ DIV esize}; \\
\text{integer shift} &= \text{esize}; \\
\text{boolean unsigned} &= \text{FALSE}; // \text{Or TRUE without change of functionality}
\end{aligned}
\]

Assembler Symbols

2

<table>
<thead>
<tr>
<th>Q</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>[absent]</td>
</tr>
<tr>
<td>1</td>
<td>[present]</td>
</tr>
</tbody>
</table>

<Vd> Is the name of the SIMD&FP destination register, encoded in the "Rd" field.

<Ta> Is an arrangement specifier, encoded in “size”:

<table>
<thead>
<tr>
<th>size</th>
<th>&lt;Ta&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>8H</td>
</tr>
<tr>
<td>01</td>
<td>4S</td>
</tr>
<tr>
<td>10</td>
<td>2D</td>
</tr>
<tr>
<td>11</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

<Vn> Is the name of the SIMD&FP source register, encoded in the "Rn" field.

<Tb> Is an arrangement specifier, encoded in “size:Q”:

<table>
<thead>
<tr>
<th>size</th>
<th>Q</th>
<th>&lt;Tb&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>0</td>
<td>8B</td>
</tr>
<tr>
<td>00</td>
<td>1</td>
<td>16B</td>
</tr>
<tr>
<td>01</td>
<td>0</td>
<td>4H</td>
</tr>
<tr>
<td>01</td>
<td>1</td>
<td>8H</td>
</tr>
<tr>
<td>10</td>
<td>0</td>
<td>2S</td>
</tr>
<tr>
<td>10</td>
<td>1</td>
<td>4S</td>
</tr>
<tr>
<td>11</td>
<td>x</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

<shift> Is the left shift amount, which must be equal to the source element width in bits, encoded in “size”: 31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0 0 1 1 1 0 0 1 1 1 0 size 1 0 0 0 0 1 0 1 1 1 0 Rn Rd
### Operation

```c
CheckFPAdvSIMDEnabled64();
bits(datasize) operand = Vpart[n, part];
bits(2*datasize) result;
integer element;
for e = 0 to elements-1
    element = Int(Elem[operand, e, esize], unsigned) << shift;
    Elem[result, e, 2*esize] = element<2*esize-1:0>;
V[d] = result;
```

### Operational information

If PSTATE.DIT is 1:
- The execution time of this instruction is independent of:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
- The response of this instruction to asynchronous exceptions does not vary based on:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
Shift Right Narrow (immediate). This instruction reads each unsigned integer value from the source SIMD&FP register, right shifts each result by an immediate value, puts the final result into a vector, and writes the vector to the lower or upper half of the destination SIMD&FP register.

The destination vector elements are half as long as the source vector elements. The results are truncated. For rounded results, see RSHRN.

The RSHRN instruction writes the vector to the lower half of the destination register and clears the upper half, while the RSHRN2 instruction writes the vector to the upper half of the destination register without affecting the other bits of the register.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

### Assembler Symbols

2

Is the second and upper half specifier. If present it causes the operation to be performed on the upper 64 bits of the registers holding the narrower elements, and is encoded in "Q":

<table>
<thead>
<tr>
<th>Q</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>[absent]</td>
</tr>
<tr>
<td>1</td>
<td>[present]</td>
</tr>
</tbody>
</table>

**<Vd>**

Is the name of the SIMD&FP destination register, encoded in the "Rd" field.

**<Ta>**

Is an arrangement specifier, encoded in “immh:Q”:

<table>
<thead>
<tr>
<th>immh</th>
<th>Q</th>
<th>&lt;Ta&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0000</td>
<td>x</td>
<td>SEE Advanced SIMD modified immediate</td>
</tr>
<tr>
<td>0001</td>
<td>0</td>
<td>8B</td>
</tr>
<tr>
<td>0001</td>
<td>1</td>
<td>16B</td>
</tr>
<tr>
<td>001x</td>
<td>0</td>
<td>4H</td>
</tr>
<tr>
<td>001x</td>
<td>1</td>
<td>8H</td>
</tr>
<tr>
<td>01xx</td>
<td>0</td>
<td>2S</td>
</tr>
<tr>
<td>01xx</td>
<td>1</td>
<td>4S</td>
</tr>
<tr>
<td>1xxx</td>
<td>x</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

**<Vn>**

Is the name of the SIMD&FP source register, encoded in the "Rn" field.

**<Ta>**

Is an arrangement specifier, encoded in “immh”:

<table>
<thead>
<tr>
<th>immh</th>
<th>&lt;Ta&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0000</td>
<td>SEE Advanced SIMD modified immediate</td>
</tr>
<tr>
<td>0001</td>
<td>8H</td>
</tr>
<tr>
<td>01xx</td>
<td>4S</td>
</tr>
<tr>
<td>01xx</td>
<td>2D</td>
</tr>
<tr>
<td>1xxx</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>
Is the right shift amount, in the range 1 to the destination element width in bits, encoded in “immh:immb”:

<table>
<thead>
<tr>
<th>immh</th>
<th>&lt;shift&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0000</td>
<td>SEE Advanced SIMD modified immediate</td>
</tr>
<tr>
<td>0001</td>
<td>(16-UInt(immh:immb))</td>
</tr>
<tr>
<td>001x</td>
<td>(32-UInt(immh:immb))</td>
</tr>
<tr>
<td>01xx</td>
<td>(64-UInt(immh:immb))</td>
</tr>
<tr>
<td>1xxx</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

Operation

```c
CheckFPAdvSIMDEnabled64();
baby(datassize*2) operand = V[n];
baby(datassize) result;
integer round_const = if round then (1 << (shift - 1)) else 0;
integer element;

for e = 0 to elements-1
    element = (UInt(Elem[operand, e, 2*esize]) + round_const) >> shift;
    Elem[result, e, esize] = element<esize-1:0>;

Vpart[d, part] = result;
```

Operational information

If PSTATE.DIT is 1:

- The execution time of this instruction is independent of:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
- The response of this instruction to asynchronous exceptions does not vary based on:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
**SHSUB**

Signed Halving Subtract. This instruction subtracts the elements in the vector in the second source SIMD&FP register from the corresponding elements in the vector in the first source SIMD&FP register, shifts each result right one bit, places each result into elements of a vector, and writes the vector to the destination SIMD&FP register.

Depending on the settings in the `CPACR_EL1`, `CPTR_EL2`, and `CPTR_EL3` registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9  | 8  | 7  | 6  | 5  | 4  | 3  | 2  | 1  | 0  |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|    |
| 0  | Q  | 0  | 0  | 1  | 1  | 0  | size | 1  |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |

### Three registers of the same type

- **SHSUB** `<Vd>..<T>`, `<Vn>..<T>`, `<Vm>..<T>`

```
integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rm);
if size == '11' then UNDEFINED;
integer esize = 8 << if size == '11' then ReservedValue();
integer esize = 8 << UInt(size);
integer datasize = if Q == '1' then 128 else 64;
integer elements = datasize DIV esize;
boolean unsigned = (U == '1');
```

### Assembler Symbols

- `<Vd>` Is the name of the SIMD&FP destination register, encoded in the "Rd" field.
- `<T>` Is an arrangement specifier, encoded in “size:Q”:

```
<table>
<thead>
<tr>
<th>size</th>
<th>Q</th>
<th>&lt;T&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>0</td>
<td>8B</td>
</tr>
<tr>
<td>00</td>
<td>1</td>
<td>16B</td>
</tr>
<tr>
<td>01</td>
<td>0</td>
<td>4H</td>
</tr>
<tr>
<td>01</td>
<td>1</td>
<td>8H</td>
</tr>
<tr>
<td>10</td>
<td>0</td>
<td>2S</td>
</tr>
<tr>
<td>10</td>
<td>1</td>
<td>4S</td>
</tr>
<tr>
<td>11</td>
<td>x</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>
```

- `<Vn>` Is the name of the first SIMD&FP source register, encoded in the "Rn" field.
- `<Vm>` Is the name of the second SIMD&FP source register, encoded in the "Rm" field.

### Operation

```
CheckFPAdvSIMDEnabled64();
bits(datasize) operand1 = V[n];
bits(datasize) operand2 = V[m];
bits(datasize) result;
integer element1;
integer element2;
integer diff;
for e = 0 to elements-1
    element1 = Int(Elem[operand1, e, esize], unsigned);
    element2 = Int(Elem[operand2, e, esize], unsigned);
    diff = element1 - element2;
    Elem[result, e, esize] = diff<esize:1>;
V[d] = result;
```
Operational information

If PSTATE.DIT is 1:

- The execution time of this instruction is independent of:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
- The response of this instruction to asynchronous exceptions does not vary based on:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
SLI

Shift Left and Insert (immediate). This instruction reads each vector element in the source SIMD&FP register, left shifts each vector element by an immediate value, and inserts the result into the corresponding vector element in the destination SIMD&FP register such that the new zero bits created by the shift are not inserted but retain their existing value. Bits shifted out of the left of each vector element in the source register are lost.

The following figure shows an example of the operation of shift left by 3 for an 8-bit vector element.

\[
\begin{array}{c}
\text{Vn.B[7] before operation} \\
\text{Vn.B[7] after operation}
\end{array}
\]

\[
\begin{array}{c}
63 & 5655 & 0 \\
63 & 5655 & 0
\end{array}
\]

Depending on the settings in the `CPACR_EL1`, `CPTR_EL2`, and `CPTR_EL3` registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

It has encodings from 2 classes: Scalar and Vector

**Scalar**

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0  | 1  | 1  | 1  | 1  | 1  | 1  | 0  | != 0000 | immh | 0  | 1  | 0  | 1  | 0  | 1  | Rn | Rd |

If `immh<3>` != '1' then UNDEFINED;

\[
\begin{array}{c}
\text{integer esize = 8} \ll 3; \\
\text{integer datasize = esize}; \\
\text{integer elements = 1}; \\
\text{integer shift = if immh<3> != '1' then ReservedValue();} \\
\text{integer esize = 8} \ll 3; \\
\text{integer datasize = esize}; \\
\text{integer elements = 1}; \\
\text{integer shift = UInt(immh:immb) - esize};
\end{array}
\]

**Vector**

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0  | Q  | I  | 0  | 1  | 1  | 1  | 1  | 0  | != 0000 | immh | 0  | 1  | 0  | 1  | 0  | 1  | Rn | Rd |

integer d = UInt(Rd);
integer n = UInt(Rn);

\[
\begin{array}{c}
\text{if immh<3> != '1' then UNDEFINED;}
\end{array}
\]
Vector

SLI <Vd>.<T>, <Vn>.<T>, #<shift>

integer d = UInt(Rd);
integer n = UInt(Rn);

if immh == '0000' then SEE(asimdimm);
if immh<3>:Q == '10' then UNDEFINED;
integer esize = 8 <<<if immh<3>:Q == '10' then ReservedValue(1);
integer esize = 8 <<HighestSetBit(immh);
integer datasize = if Q == '1' then 128 else 64;
integer elements = datasize DIV esize;
integer shift = UInt(immh:immb) - esize;

Assembler Symbols

<V> Is a width specifier, encoded in “immh”:

<table>
<thead>
<tr>
<th>immh</th>
<th>&lt;V&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0xxx</td>
<td>RESERVED</td>
</tr>
<tr>
<td>1xxx</td>
<td>D</td>
</tr>
</tbody>
</table>

<d> Is the number of the SIMD&FP destination register, in the "Rd" field.

<n> Is the number of the first SIMD&FP source register, encoded in the "Rn" field.

<Vd> Is the name of the SIMD&FP destination register, encoded in the "Rd" field.

<T> Is an arrangement specifier, encoded in “immh:Q”:

<table>
<thead>
<tr>
<th>immh</th>
<th>Q</th>
<th>&lt;T&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0000</td>
<td>x</td>
<td>SEE Advanced SIMD modified immediate</td>
</tr>
<tr>
<td>0001</td>
<td>0</td>
<td>8B</td>
</tr>
<tr>
<td>0001</td>
<td>1</td>
<td>16B</td>
</tr>
<tr>
<td>001x</td>
<td>0</td>
<td>4H</td>
</tr>
<tr>
<td>001x</td>
<td>1</td>
<td>8H</td>
</tr>
<tr>
<td>01xx</td>
<td>0</td>
<td>2S</td>
</tr>
<tr>
<td>01xx</td>
<td>1</td>
<td>4S</td>
</tr>
<tr>
<td>1xxx</td>
<td>0</td>
<td>Reserved</td>
</tr>
<tr>
<td>1xxx</td>
<td>1</td>
<td>2D</td>
</tr>
</tbody>
</table>

<Vn> Is the name of the SIMD&FP source register, encoded in the "Rn" field.

<shift> For the scalar variant: is the left shift amount, in the range 0 to 63, encoded in “immh:immb”:

<table>
<thead>
<tr>
<th>immh</th>
<th>&lt;shift&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0xxx</td>
<td>RESERVED</td>
</tr>
<tr>
<td>1xxx</td>
<td>(UInt(immh:immb) - 64)</td>
</tr>
</tbody>
</table>

For the vector variant: is the left shift amount, in the range 0 to the element width in bits minus 1, encoded in “immh:immb”:

<table>
<thead>
<tr>
<th>immh</th>
<th>&lt;shift&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0000</td>
<td>SEE Advanced SIMD modified immediate</td>
</tr>
<tr>
<td>0001</td>
<td>(UInt(immh:immb) - 8)</td>
</tr>
<tr>
<td>001x</td>
<td>(UInt(immh:immb) - 16)</td>
</tr>
<tr>
<td>01xx</td>
<td>(UInt(immh:immb) - 32)</td>
</tr>
<tr>
<td>1xxx</td>
<td>(UInt(immh:immb) - 64)</td>
</tr>
</tbody>
</table>
Operation

```
CheckFPAdvSIMEnabled64();
bits(datasize) operand = V[n];
bits(datasize) operand2 = V[d];
bits(datasize) result;
bits(esize) mask = LSL(Ones(esize), shift);
bits(esize) shifted;
for e = 0 to elements-1
    shifted = LSL(Elem[operand, e, esize], shift);
    Elem[result, e, esize] = (Elem[operand2, e, esize] AND NOT(mask)) OR shifted;
V[d] = result;
```

Operational information

If PSTATE.DIT is 1:

- The execution time of this instruction is independent of:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
- The response of this instruction to asynchronous exceptions does not vary based on:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
SM3PARTW1

SM3PARTW1 takes three 128-bit vectors from the three source SIMD&FP registers and returns a 128-bit result in the destination SIMD&FP register. The result is obtained by a three-way exclusive OR of the elements within the input vectors with some fixed rotations, see the Operation pseudocode for more information.

This instruction is implemented only when ARMv8.2-SM is implemented.

Advanced SIMD
(ARMv8.2)

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9  | 8  | 7  | 6  | 5  | 4  | 3  | 2  | 1  | 0  |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 1  | 1  | 1  | 0  | 1  | 1  | 0  | 0  | 1  | 1  | 1  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  |
| Rd | Rn | Rm |

Advanced SIMD

SM3PARTW1 <Vd>.4S, <Vn>.4S, <Vm>.4S

if !HaveSM3Ext() then UNDEFINED;
integer d = 1 then UnallocatedEncoding();
integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rm);

Assembler Symbols

<Vd> Is the name of the SIMD&FP source and destination register, encoded in the "Rd" field.
<Vn> Is the name of the second SIMD&FP source register, encoded in the "Rn" field.
<Vm> Is the name of the third SIMD&FP source register, encoded in the "Rm" field.

Operation

AArch64.CheckFPAdvSIMDEnabled();

bits(128) Vm = V[m];
bits(128) Vn = V[n];
bits(128) Vd = V[d];
bits(128) result;

result<95:0> = (Vd EOR Vn)<95:0> EOR (ROL(Vm<127:96>,15):ROL(Vm<95:64>,15):ROL(Vm<63:32>,15));

for i = 0 to 3
    if i == 3 then
        result<127:96> = (Vd EOR Vn)<127:96> EOR (ROL(result<31:0>,15));
        result<(32*i)+31:(32*i)> = result<(32*i)+31:(32*i)> EOR ROL(result<(32*i)+31:(32*i)>,15) EOR ROL[result<(32*i)+31:(32*i)>,23];
    V[d] = result;

Operational information

If PSTATE.DIT is 1:

- The execution time of this instruction is independent of:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
- The response of this instruction to asynchronous exceptions does not vary based on:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
SM3PARTW2

SM3PARTW2 takes three 128-bit vectors from three source SIMD&FP registers and returns a 128-bit result in the destination SIMD&FP register. The result is obtained by a three-way exclusive OR of the elements within the input vectors with some fixed rotations, see the Operation pseudocode for more information.

This instruction is implemented only when Armv8.2-SM is implemented.

Advanced SIMD

(ARMv8.2)

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 1  | 1  | 0  | 1  | 1  | 0  | 0  | 1  | 1  | 1  | 0  | 0  | 1  | 1  | 1  | 0  | 0  | 1  | 1  | 1  | 0  | 0  | 1  | 1  | 1  | 0  |

Advanced SIMD

SM3PARTW2 <Vd>.4S, <Vn>.4S, <Vm>.4S

if !HaveSM3Ext() then UNDEFINED;
  integer d = UInt(Rd);
  integer n = UInt(Rn);
  integer m = UInt(Rm);

Assembler Symbols

<Vd>  Is the name of the SIMD&FP source and destination register, encoded in the "Rd" field.

<Vn>  Is the name of the second SIMD&FP source register, encoded in the "Rn" field.

<Vm>  Is the name of the third SIMD&FP source register, encoded in the "Rm" field.

Operation

AArch64.CheckFPAdvSIMDEnabled();

bits(128) Vm = V[m];
bits(128) Vn = V[n];
bits(128) Vd = V[d];
bits(128) result;
bits(128) tmp;
bits(32) tmp2;
tmp<127:0> = Vn EOR (ROL(Vm<127:96>,7):ROL(Vm<95:64>,7):ROL(Vm<63:32>,7):ROL(Vm<31:0>,7));
result<127:0> = Vd<127:0> EOR tmp<127:0>;
tmp2 = ROL(tmp<31:0>,15);
tmp2 = tmp2 EOR ROL(tmp2,15) EOR ROL(tmp2,23);
result<127:96> = result<127:96> EOR tmp2;
V[d]= result;

Operational information

If PSTATE.DIT is 1:
  • The execution time of this instruction is independent of:
    ◦ The values of the data supplied in any of its registers.
    ◦ The values of the NZCV flags.
  • The response of this instruction to asynchronous exceptions does not vary based on:
    ◦ The values of the data supplied in any of its registers.
    ◦ The values of the NZCV flags.

Internal version only: isa v30.25l29.25, AdvSIMD v27.01l26.0, pseudocode v85/xml-00be87_re35353 ; Build timestamp: 2018-09-13T13:2018-06-16T09:45:45

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SM3SS1

SM3SS1 rotates the top 32 bits of the 128-bit vector in the first source SIMD&FP register by 12, and adds that 32-bit value to the two other
32-bit values held in the top 32 bits of each of the 128-bit vectors in the second and third source SIMD&FP registers, rotating this result left by 7
and writing the final result into the top 32 bits of the vector in the destination SIMD&FP register, with the bottom 96 bits of the vector being
written to 0.

This instruction is implemented only when ARMv8.2-SM is implemented.

Advanced SIMD

(ARMv8.2)

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9  | 8  | 7  | 6  | 5  | 4  | 3  | 2  | 1  | 0  |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 1  | 1  | 0  | 1  | 1  | 0  | 0  | 1  | 0  | 1  | 0  | Rm | 0  | Ra | Rn | Rd |

Advanced SIMD

SM3SS1 <Vd>.4S, <Vn>.4S, <Vm>.4S, <Va>.4S

if !HaveSM3Ext() then UNDEFINED;
integer d = UnallocatedEncoding();
integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rm);
integer a = UInt(Ra);

Assembler Symbols

<Vd> Is the name of the SIMD&FP destination register, encoded in the "Rd" field.
<Vn> Is the name of the first SIMD&FP source register, encoded in the "Rn" field.
<Vm> Is the name of the second SIMD&FP source register, encoded in the "Rm" field.
<Va> Is the name of the third SIMD&FP source register, encoded in the "Ra" field.

Operation

AArch64.CheckFPAdvSIMDEnabled();

bits(128) Vm = V[m];
bits(128) Vn = V[n];
bits(128) Vd = V[d];
bits(128) Va = V[a];
Vd<127:96> = ROL((ROL(Vn<127:96>,12) + Vm<127:96> + Va<127:96>) , 7);
Vd<95:0> = Zeros();
V[d] = Vd;

Operational information

If PSTATE.DIT is 1:

• The execution time of this instruction is independent of:
  ◦ The values of the data supplied in any of its registers.
  ◦ The values of the NZCV flags.
• The response of this instruction to asynchronous exceptions does not vary based on:
  ◦ The values of the data supplied in any of its registers.
  ◦ The values of the NZCV flags.
SM3TT1A

SM3TT1A takes three 128-bit vectors from three source SIMD&FP registers and a 2-bit immediate index value, and returns a 128-bit result in the destination SIMD&FP register. It performs a three-way exclusive OR of the three 32-bit fields held in the upper three elements of the first source vector, and adds the resulting 32-bit value and the following three other 32-bit values:

- The bottom 32-bit element of the first source vector, Vd, that was used for the three-way exclusive OR.
- The result of the exclusive OR of the top 32-bit element of the second source vector, Vn, with a rotation left by 12 of the top 32-bit element of the first source vector.
- A 32-bit element indexed out of the third source vector,Vm.

The result of this addition is returned as the top element of the result. The other elements of the result are taken from elements of the first source vector, with the element returned in bits<63:32> being rotated left by 9.

This instruction is implemented only when ARMv8.2-SM is implemented.

**Advanced SIMD**

(ARMv8.2)

```
Advanced SIMD

SM3TT1A <Vd>.4S, <Vn>.4S, <Vm>.S[<imm2>]

if !HaveSM3Ext() then UNDEFINED;
integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rm);
integer i = UInt(<imm2>);
```

**Assembler Symbols**

- `<Vd>` Is the name of the SIMD&FP source and destination register, encoded in the "Rd" field.
- `<Vn>` Is the name of the second SIMD&FP source register, encoded in the "Rn" field.
- `<Vm>` Is the name of the third SIMD&FP source register, encoded in the "Rm" field.
- `<imm2>` Is a 32-bit element indexed out of `<Vm>`, encoded in "imm2".

**Operation**

```
AArch64.CheckFPAdvSIMDEnabled();

bits(128) Vm = V[m];
bits(128) Vn = V[n];
bits(128) Vd = V[d];
bits(32) WjPrime;
bits(128) result;
bits(32) TT1;
bits(32) SS2;

WjPrime = Elem[Vm,i,32];
SS2 = Vn<127:96> EOR ROL(Vd<127:96>,12);
TT1 = Vd<63:32> EOR (Vd<127:96> EOR Vd<95:64>);
TT1 = (TT1 + Vd<31:0> + SS2 + WjPrime)<31:0>;
result<31:0> = Vd<63:32>;
result<63:32> = ROL(Vd<95:64>,9);
result<95:64> = Vd<127:96>;
result<127:96> = TT1;
V[d] = result;
```
Operational information

If PSTATE.DIT is 1:

- The execution time of this instruction is independent of:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.

- The response of this instruction to asynchronous exceptions does not vary based on:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
SM3TT1B

SM3TT1B takes three 128-bit vectors from three source SIMD&FP registers and a 2-bit immediate index value, and returns a 128-bit result in the destination SIMD&FP register. It performs a 32-bit majority function between the three 32-bit fields held in the upper three elements of the first source vector, and adds the resulting 32-bit value and the following three other 32-bit values:

- The bottom 32-bit element of the first source vector, \( V_d \), that was used for the 32-bit majority function.
- The result of the exclusive OR of the top 32-bit element of the second source vector, \( V_n \), with a rotation left by 12 of the top 32-bit element of the first source vector.
- A 32-bit element indexed out of the third source vector, \( V_m \).

The result of this addition is returned as the top element of the result. The other elements of the result are taken from elements of the first source vector, with the element returned in bits<63:32> being rotated left by 9.

This instruction is implemented only when ARMv8.2-SM is implemented.

Advanced SIMD (ARMv8.2)

<table>
<thead>
<tr>
<th>Bit</th>
<th>Rm</th>
<th>imm2</th>
<th>Rd</th>
</tr>
</thead>
<tbody>
<tr>
<td>31</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>30</td>
<td>1</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>29</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>28</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>27</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>26</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>25</td>
<td>1</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>24</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>23</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>22</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>21</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>20</td>
<td>1</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>19</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>18</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>17</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>16</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>15</td>
<td>1</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>14</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>13</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>12</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>11</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>10</td>
<td>1</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>9</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>8</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>7</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>6</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>5</td>
<td>1</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>4</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>3</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Assembler Symbols

- \( \langle V_d \rangle \): Is the name of the SIMD&FP source and destination register, encoded in the "Rd" field.
- \( \langle V_n \rangle \): Is the name of the second SIMD&FP source register, encoded in the "Rn" field.
- \( \langle V_m \rangle \): Is the name of the third SIMD&FP source register, encoded in the "Rm" field.
- \( \langle \text{imm2} \rangle \): Is a 32-bit element indexed out of \( \langle V_m \rangle \), encoded in "imm2".

Operation

```assembly
AArch64.CheckFPAdvSIMDEnabled();

bits(128) Vm = V[m];
bits(128) Vn = V[n];
bits(128) Vd = V[d];
bits(32) WjPrime;
bits(128) result;
bits(32) TT1;
bits(32) SS2;

WjPrime = Elem[Vm,i,32];
SS2 = Vn<127:96> EOR ROL(Vd<127:96>,12);
TT1 = (Vd<127:96> AND Vn<63:32>) OR (Vd<127:96> AND Vd<95:64>) OR (Vd<63:32> AND Vd<95:64>);
TT1 = (TT1 + Vd<31:0> + SS2 + WjPrime)<31:0>;
result<31:0> = Vd<63:32>;
result<63:32> = ROL(Vd<95:64>,9);
result<95:64> = Vd<127:96>;
result<127:96> = TT1;
V[d] = result;
```
Operational information

If PSTATE.DIT is 1:

- The execution time of this instruction is independent of:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
- The response of this instruction to asynchronous exceptions does not vary based on:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
SM3TT2A

SM3TT2A takes three 128-bit vectors from three source SIMD&FP register and a 2-bit immediate index value, and returns a 128-bit result in the destination SIMD&FP register. It performs a three-way exclusive OR of the three 32-bit fields held in the upper three elements of the first source vector, and adds the resulting 32-bit value and the following three other 32-bit values:

- The bottom 32-bit element of the first source vector, Vd, that was used for the three-way exclusive OR.
- The 32-bit element held in the top 32 bits of the second source vector, Vn.
- A 32-bit element indexed out of the third source vector, Vm.

A three-way exclusive OR is performed of the result of this addition, the result of the addition rotated left by 9, and the result of the addition rotated left by 17. The result of this exclusive OR is returned as the top element of the returned result. The other elements of this result are taken from elements of the first source vector, with the element returned in bits<63:32> being rotated left by 19.

This instruction is implemented only when ARMv8.2-SM is implemented.

Advanced SIMD

(ARMv8.2)

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9  | 8  | 7  | 6  | 5  | 4  | 3  | 2  | 1  | 0  |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 1  | 1  | 0  | 0  | 1  | 1  | 0  | 0  | 1  | 0  | Rm | 1  | 0  | imm2 | 1 | 0  | Rn | Rd |

Advanced SIMD

SM3TT2A <Vd>.4S, <Vn>.4S, <Vm>.S[<imm2>]

if !HaveSM3Ext() then UNDEFINED;
integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rm);
integer i = UInt(imm2);

Assembler Symbols

<Vd> Is the name of the SIMD&FP source and destination register, encoded in the "Rd" field.

<Vn> Is the name of the second SIMD&FP source register, encoded in the "Rn" field.

<Vm> Is the name of the third SIMD&FP source register, encoded in the "Rm" field.

<imm2> Is a 32-bit element indexed out of <Vm>, encoded in "imm2".

Operation

AArch64.CheckFPAdvSIMDEnabled();

bits(128) Vm = V[m];
bits(128) Vn = V[n];
bits(128) Vd = V[d];
bits(32) Wj;
bits(128) result;
bits(32) TT1;

Wj = Elem[Vm,i,32];
TT2 = Vd<63:32> EOR (Vd<127:96> EOR Vd<95:64>);
TT2 = (TT2 + Vd<31:0> + Vn<127:96> + Wj)<31:0>;

result<31:0> = Vd<63:32>;
result<63:32> = ROL(Vd<95:64>,19);
result<95:64> = Vd<127:96>;
result<127:96> = TT2 EOR ROL(TT2,9) EOR ROL(TT2,17);
V[d] = result;
Operational information

If PSTATE.DIT is 1:
- The execution time of this instruction is independent of:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
- The response of this instruction to asynchronous exceptions does not vary based on:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
SM3TT2B takes three 128-bit vectors from three source SIMD&FP registers, and a 2-bit immediate index value, and returns a 128-bit result in the destination SIMD&FP register. It performs a 32-bit majority function between the three 32-bit fields held in the upper three elements of the first source vector, and adds the resulting 32-bit value and the following three other 32-bit values:

- The bottom 32-bit element of the first source vector, Vd, that was used for the 32-bit majority function.
- The 32-bit element held in the top 32 bits of the second source vector, Vn.
- A 32-bit element indexed out of the third source vector, Vm.

A three-way exclusive OR is performed of the result of this addition, the result of the addition rotated left by 9, and the result of the addition rotated left by 17. The result of this exclusive OR is returned as the top element of the returned result. The other elements of this result are taken from elements of the first source vector, with the element returned in bits<63:32> being rotated left by 19.

This instruction is implemented only when ARMv8.2-SM is implemented.

Advanced SIMD
(ARMv8.2)

|    | 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 |  9 |  8 |  7 |  6 |  5 |  4 |  3 |  2 |  1 |  0 |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| Rd |  1 |  0 |  1 |  0 |  0 |  1 |  1 |  1 |  0 |  0 |  1 |  0 |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| Rm |    |    |    |    |    |    |    |    |    |    |    |    |  1 |  0 | imm2 |  1 |  1 |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| Vd |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |  63 |    |    |    |    |    |    |    |    |    |    |
| Vn |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |  95 |    |    |    |    |    |    |    |    |    |
| Vm |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |  127 |    |    |    |    |    |    |    |    |    |    |
| imm2 |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |

Assembled Symbols

- `<Vd>` Is the name of the SIMD&FP source and destination register, encoded in the "Rd" field.
- `<Vn>` Is the name of the second SIMD&FP source register, encoded in the "Rn" field.
- `<Vm>` Is the name of the third SIMD&FP source register, encoded in the "Rm" field.
- `<imm2>` Is a 32-bit element indexed out of `<Vm>`, encoded in "imm2".

Operation

```plaintext
AArch64.CheckFPAdvSIMDEnabled();

bits(128) Vm = V[m];
bits(128) Vn = V[n];
bits(128) Vd = V[d];
bits(32) Wj;
bits(128) result;
bits(32) TT2;

Wj = Elem[Vm, i, 32];
TT2 = (Vd<127:96> AND Vd<95:64>) OR (NOT(Vd<127:96>) AND Vd<63:32>);
TT2 = (TT2 + Vd<31:0> + Vn<127:96> + Wj)<31:0>;
result<31:0> = Vd<63:32>;
result<63:32> = ROL(Vd<95:64>, 19);
result<95:64> = Vd<127:96>;
result<127:96> = TT2 EOR ROL(TT2, 9) EOR ROL(TT2, 17);
V[d] = result;
```
Operational information

If PSTATE.DIT is 1:

- The execution time of this instruction is independent of:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
- The response of this instruction to asynchronous exceptions does not vary based on:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
SM4E

SM4 Encode takes input data as a 128-bit vector from the first source SIMD&FP register, and four iterations of the round key held as the elements of the 128-bit vector in the second source SIMD&FP register. It encrypts the data by four rounds, in accordance with the SM4 standard, returning the 128-bit result to the destination SIMD&FP register.

This instruction is implemented only when ARMv8.2-SM is implemented.

Advanced SIMD

(ARMv8.2)

SM4E <Vd>.4S, <Vn>.4S

if !HaveSM4Ext() then UNDEFINED;
integer d = UInt(Rd);
integer n = UInt(Rn);

Assembler Symbols

<Vd> Is the name of the SIMD&FP source and destination register, encoded in the "Rd" field.
<Vn> Is the name of the second SIMD&FP source register, encoded in the "Rn" field.

Operation

AArch64.CheckFPAdvSIMDEnabled();

bits(128) Vn = V[n];
bits(32) intval;
bits(8) sboxout;
bits(128) roundresult;
bits(32) roundkey;
integer index;

roundresult=V[d];
for index = 0 to 3
    roundkey = Elem[Vn,index,32];
    intval = roundresult<127:96> EOR roundresult<95:64> EOR roundresult<63:32> EOR roundkey;
    for i = 0 to 3
        Elem[intval,i,8] = Sbox(Elem[intval,i,8]);
    intval = intval EOR ROL(intval,2) EOR ROL(intval,10) EOR ROL(intval,18) EOR ROL(intval,24);
    intval = intval EOR ROL(intval,2) EOR ROL(intval,10) EOR ROL(intval,18) EOR ROL(intval,24);
    roundresult<31:0> = roundresult<63:32>;
    roundresult<63:32> = roundresult<95:64>;
    roundresult<95:64> = roundresult<127:96>;
    roundresult<127:96> = intval;
    V[d] = roundresult;

Operational information

If PSTATE.DIT is 1:

- The execution time of this instruction is independent of:
- The values of the data supplied in any of its registers.
- The values of the NZCV flags.

- The response of this instruction to asynchronous exceptions does not vary based on:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
SM4EKEY

SM4 Key takes an input as a 128-bit vector from the first source SIMD&FP register and a 128-bit constant from the second SIMD&FP register. It derives four iterations of the output key, in accordance with the SM4 standard, returning the 128-bit result to the destination SIMD&FP register.

This instruction is implemented only when ARMv8.2-SM is implemented.

Advanced SIMD

(ARMv8.2)

| 31  | 30  | 29  | 28  | 27  | 26  | 25  | 24  | 23  | 22  | 21  | 20  | 19  | 18  | 17  | 16  | 15  | 14  | 13  | 12  | 11  | 10  | 9   | 8   | 7   | 6   | 5   | 4   | 3   | 2   | 1   | 0   |
|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| 1   | 1   | 0   | 0   | 1   | 1   | 0   | 0   | 1   | 1   | 0   | 0   | 1   | 0   | 0   | 1   | 1   | 0   | 0   | 1   | 1   | 0   | 0   | 1   | 1   | 0   | 0   | 1   | 1   | 0   | 0   | 1   | 1   | 0   | 0   | 1   | 1   | 0   | 0   | 1   | 1   |

Assembler Symbols

<Vd> Is the name of the SIMD&FP destination register, encoded in the "Rd" field.
<Vn> Is the name of the first SIMD&FP source register, encoded in the "Rn" field.
<Vm> Is the name of the second SIMD&FP source register, encoded in the "Rm" field.

Operation

```assembly
AArch64.CheckFPAdvSIMDEnabled();

bits(128) Vm = V[m];
bits(32) intval;
bits(8) sboxout;
bits(128) result;
bits(32) const;
bits(128) roundresult;
integer index;

roundresult = V[n];
for index = 0 to 3
    const = Elem[Vm,index,32];
    intval = roundresult<127:96> EOR roundresult<95:64> EOR roundresult<63:32> EOR const;
    for i = 0 to 3
        Elem[intval,i,8] = Sbox(Elem[intval,i,8]);
    intval = intval EOR ROl(intval,13) EOR ROl(intval,23);
    intval = intval EOR roundresult<31:0>;
roundresult<31:0> = roundresult<63:32>;
roundresult<63:32> = roundresult<95:64>;
roundresult<95:64> = roundresult<127:96>;
roundresult<127:96> = intval;
V[d] = roundresult;
```
Operational information

If PSTATE.DIT is 1:

- The execution time of this instruction is independent of:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.

- The response of this instruction to asynchronous exceptions does not vary based on:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
Signed Maximum (vector). This instruction compares corresponding elements in the vectors in the two source SIMD&FP registers, places the larger of each pair of signed integer values into a vector, and writes the vector to the destination SIMD&FP register.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

### Three registers of the same type

**SMAX** <Vd>.<T>, <Vn>.<T>, <Vm>.<T>

```plaintext
integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rm);
if size == '11' then UNDEFINED;
integer esize = 8 << if size == '11' then ReservedValue() else UInt(size);
integer datasize = if Q == '1' then 128 else 64;
integer elements = datasize DIV esize;

boolean unsigned = (U == '1');
boolean minimum = (o1 == '1');
```

### Assembler Symbols

**<Vd>**

Is the name of the SIMD&FP destination register, encoded in the "Rd" field.

**<T>**

Is an arrangement specifier, encoded in “size:Q”:

<table>
<thead>
<tr>
<th>size</th>
<th>Q</th>
<th>&lt;T&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>0</td>
<td>8B</td>
</tr>
<tr>
<td>00</td>
<td>1</td>
<td>16B</td>
</tr>
<tr>
<td>01</td>
<td>0</td>
<td>4H</td>
</tr>
<tr>
<td>01</td>
<td>1</td>
<td>8H</td>
</tr>
<tr>
<td>10</td>
<td>0</td>
<td>2S</td>
</tr>
<tr>
<td>10</td>
<td>1</td>
<td>4S</td>
</tr>
<tr>
<td>11</td>
<td>x</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

**<Vn>**

Is the name of the first SIMD&FP source register, encoded in the "Rn" field.

**<Vm>**

Is the name of the second SIMD&FP source register, encoded in the "Rm" field.

### Operation

```plaintext
CheckFPAdvSIMDEnabled64();
bits(datasize) operand1 = V[n];
bits(datasize) operand2 = V[m];
bits(datasize) result;
integer element1;
integer element2;
integer maxmin;
for e = 0 to elements-1
    element1 = Int(Elem[operand1, e, esize], unsigned);
    element2 = Int(Elem[operand2, e, esize], unsigned);
    maxmin = if minimum then Min(element1, element2) else Max(element1, element2);
    Elem[result, e, esize] = maxmin<esize-1:0>;
V[d] = result;
```

SMAX
Operational information

If PSTATE.DIT is 1:

- The execution time of this instruction is independent of:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
- The response of this instruction to asynchronous exceptions does not vary based on:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
Signed Maximum Pairwise. This instruction creates a vector by concatenating the vector elements of the first source SIMD&FP register after the vector elements of the second source SIMD&FP register, reads each pair of adjacent vector elements in the two source SIMD&FP registers, writes the largest of each pair of signed integer values into a vector, and writes the vector to the destination SIMD&FP register.

Depending on the settings in the \texttt{CPACR_EL1}, \texttt{CPTR_EL2}, and \texttt{CPTR_EL3} registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

Three registers of the same type

\begin{verbatim}
SMAXP \texttt{<Vd>}, \texttt{<T>}, \texttt{<Vn>}, \texttt{<T>}, \texttt{<Vm>}, \texttt{<T>}

integer d = \texttt{UInt}(Rd);
integer n = \texttt{UInt}(Rn);
integer m = \texttt{UInt}(Rm);
if size == '11' then UNDEFINED;
integer esize = 8 << if size == '11' then \
ReservedValue();
integer esize = 8 << \texttt{UInt}(size);
integer datasize = if Q == '1' then 128 else 64;
integer elements = datasize DIV esize;
boolean unsigned = (U == '1');
boolean minimum = (o1 == '1');
\end{verbatim}

Assembler Symbols

\begin{itemize}
\item \texttt{<Vd>}: Is the name of the SIMD&FP destination register, encoded in the "Rd" field.
\item \texttt{<T>}: Is an arrangement specifier, encoded in “size:Q”:
\begin{table}[h]
\begin{tabular}{|c|c|}
\hline
size & Q \\
\hline
00 & 8B \\
00 & 16B \\
01 & 4H \\
01 & 8H \\
10 & 2S \\
10 & 4S \\
11 & RESERVED \\
\hline
\end{tabular}
\end{table}
\item \texttt{<Vn>}: Is the name of the first SIMD&FP source register, encoded in the "Rn" field.
\item \texttt{<Vm>}: Is the name of the second SIMD&FP source register, encoded in the "Rm" field.
\end{itemize}
Operation

```c
CheckFPAdvSIMDEnabled64();
bits(datasize) operand1 = V[n];
bits(datasize) operand2 = V[m];
bits(datasize) result;
bits(2*datasize) concat = operand2:operand1;
integer element1;
integer element2;
integer maxmin;
for e = 0 to elements-1
    element1 = Int(Elem[concat, 2*e, esize], unsigned);
    element2 = Int(Elem[concat, (2*e)+1, esize], unsigned);
    maxmin = if minimum then Min(element1, element2) else Max(element1, element2);
    Elem[result, e, esize] = maxmin<esize-1:0>;
V[d] = result;
```

Operational information

If PSTATE.DIT is 1:

- The execution time of this instruction is independent of:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
- The response of this instruction to asynchronous exceptions does not vary based on:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.


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S MAXV

Signed Maximum across Vector. This instruction compares all the vector elements in the source SIMD&FP register, and writes the largest of the values as a scalar to the destination SIMD&FP register. All the values in this instruction are signed integer values.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9  | 8  | 7  | 6  | 5  | 4  | 3  | 2  | 1  | 0  |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| U  | Q  | 0  | 0  | 1  | 1  | 1  | 0  | size| 1  | 1  | 0  | 0  | 0  | 0  | 0  | 0  | 1  | 0  | 1  | 0  | 1  | 0  | Rn | Rd |

Advanced SIMD

S MAXV <V><d>, <Vn>.<T>

integer d = UInt(Rd);
integer n = UInt(Rn);

if size:Q == '100' then UNDEFINED;
if size == '11' then UNDEFINED;
integer esize = 8 << if size:Q == '100' then ReservedValue(1);
                      if size == '11' then ReservedValue(1);
integer esize = 8 << UInt(size);
integer datasize = if Q == '1' then 128 else 64;
integer elements = datasize DIV esize;

boolean unsigned = (U == '1');
boolean min = (op == '1');

Assembler Symbols

<V> Is the destination width specifier, encoded in “size”:

<table>
<thead>
<tr>
<th>size</th>
<th>&lt;V&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>B</td>
</tr>
<tr>
<td>01</td>
<td>H</td>
</tr>
<tr>
<td>10</td>
<td>S</td>
</tr>
<tr>
<td>11</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

<d> Is the number of the SIMD&FP destination register, encoded in the "Rd" field.

<Vn> Is the name of the SIMD&FP source register, encoded in the "Rn" field.

<T> Is an arrangement specifier, encoded in “size:Q”:

<table>
<thead>
<tr>
<th>size</th>
<th>Q</th>
<th>&lt;T&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>0</td>
<td>8B</td>
</tr>
<tr>
<td>00</td>
<td>1</td>
<td>16B</td>
</tr>
<tr>
<td>01</td>
<td>0</td>
<td>4H</td>
</tr>
<tr>
<td>01</td>
<td>1</td>
<td>8H</td>
</tr>
<tr>
<td>10</td>
<td>0</td>
<td>RESERVED</td>
</tr>
<tr>
<td>10</td>
<td>1</td>
<td>4S</td>
</tr>
<tr>
<td>11</td>
<td>x</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>
Operation

```c
CheckFPAdvSIMDEnabled64();
bits(datasize) operand = V[n];
integer maxmin;
integer element;

maxmin = int(Elem[operand, 0, esize], unsigned);
for e = 1 to elements-1
    element = int(Elem[operand, e, esize], unsigned);
    maxmin = if min then min(maxmin, element) else max(maxmin, element);
V[d] = maxmin<esize-1:0>;
```

Operational information

If PSTATE.DIT is 1:

- The execution time of this instruction is independent of:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
- The response of this instruction to asynchronous exceptions does not vary based on:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
SMIN

Signed Minimum (vector). This instruction compares corresponding elements in the vectors in the two source SIMD&FP registers, places the smaller of each of the two signed integer values into a vector, and writes the vector to the destination SIMD&FP register.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

```
<table>
<thead>
<tr>
<th>0</th>
<th>Q</th>
<th>0</th>
<th>0</th>
<th>1</th>
<th>1</th>
<th>1</th>
<th>0</th>
<th>size</th>
<th>1</th>
</tr>
</thead>
<tbody>
<tr>
<td>U</td>
<td>Rm</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>Rn</td>
<td>Rd</td>
</tr>
<tr>
<td>o1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
```

Three registers of the same type

SMIN <Vd>.<T>, <Vn>.<T>, <Vm>.<T>

```
integer d = UInt(Rd);
dergentient n = UInt(Rn);
dergentient m = UInt(Rm);
if size == '11' then UNDEFINED;
dergentient esize = 8 << if size == '11' then ReservedValue() |
dergentient esize = 8 << UInt(size);
dergentient datasize = if Q == '1' then 128 else 64;
dergentient elements = datasize DIV esize;
boolean unsigned = (U == '1');
dergentient minimum = (o1 == '1');
```

Assembler Symbols

```
size:Q<T>
<table>
<thead>
<tr>
<th>size</th>
<th>Q</th>
<th>&lt;T&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>0</td>
<td>8B</td>
</tr>
<tr>
<td>00</td>
<td>1</td>
<td>16B</td>
</tr>
<tr>
<td>01</td>
<td>0</td>
<td>4H</td>
</tr>
<tr>
<td>01</td>
<td>1</td>
<td>8H</td>
</tr>
<tr>
<td>10</td>
<td>0</td>
<td>2S</td>
</tr>
<tr>
<td>10</td>
<td>1</td>
<td>4S</td>
</tr>
<tr>
<td>11</td>
<td>x</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>
```

```
<Vd> Is the name of the SIMD&FP destination register, encoded in the "Rd" field.
<T> Is an arrangement specifier, encoded in “size:Q”:
```

```
<Vn> Is the name of the first SIMD&FP source register, encoded in the "Rn" field.
<Vm> Is the name of the second SIMD&FP source register, encoded in the "Rm" field.

Operation

```
CheckFPAdvSIMDEnabled64();
bits(datasize) operand1 = V[n];
bits(datasize) operand2 = V[m];
bits(datasize) result;
dergentient element1;
dergentient element2;
dergentient maxmin;
for e = 0 to elements-1
   element1 = Int(Elem[operand1, e, esize], unsigned);
dergentient element2 = Int(Elem[operand2, e, esize], unsigned);
dergentient maxmin = if minimum then Min(element1, element2) else Max(element1, element2);
   Elem[result, e, esize] = maxmin<esize-1:0>;
V[d] = result;
```
Operational information

If PSTATE.DIT is 1:

- The execution time of this instruction is independent of:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.

- The response of this instruction to asynchronous exceptions does not vary based on:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
**SMINP**

Signed Minimum Pairwise. This instruction creates a vector by concatenating the vector elements of the first source SIMD&FP register after the vector elements of the second source SIMD&FP register, reads each pair of adjacent vector elements in the two source SIMD&FP registers, writes the smallest of each pair of signed integer values into a vector, and writes the vector to the destination SIMD&FP register.

Depending on the settings in the `CPACR_EL1`, `CPTR_EL2`, and `CPTR_EL3` registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

```
31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
U   Q 0 0 1 1 0 size 1   Rm 1 0 1 0 1 1   Rn  Rd o1
```

### Three registers of the same type

```
SMINP <Vd>.<T>, <Vn>.<T>, <Vm>.<T>
```

```
integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rm);
if size == '11' then UNDEFINED;
integer esize = 8 << if size == '11' then ReservedValue() ;
integer esize = 8 << UInt(size);
integer datasize = if Q == '1' then 128 else 64;
integer elements = datasize DIV esize;
boolean unsigned = (U == '1');
boolean minimum = (o1 == '1');
```

### Assembler Symbols

- `<Vd>` Is the name of the SIMD&FP destination register, encoded in the "Rd" field.
- `<T>` Is an arrangement specifier, encoded in “size:Q”:
  ```
  size  Q  |  <T>
  00 0 8B
  00 1 16B
  01 0 4H
  01 1 8H
  10 0 2S
  10 1 4S
  11 x RESERVED
  ```
- `<Vn>` Is the name of the first SIMD&FP source register, encoded in the "Rn" field.
- `<Vm>` Is the name of the second SIMD&FP source register, encoded in the "Rm" field.
Operation

```c
CheckFPAdvSIMDEnabled64();
bits(datasize) operand1 = V[n];
bits(datasize) operand2 = V[m];
bits(datasize) result;
bits(2*datasize) concat = operand2:operand1;
integer element1;
integer element2;
integer maxmin;
for e = 0 to elements-1
    element1 = Int(Elem[concat, 2*e, esize], unsigned);
    element2 = Int(Elem[concat, (2*e)+1, esize], unsigned);
    maxmin = if minimum then Min(element1, element2) else Max(element1, element2);
    Elem[result, e, esize] = maxmin<esize-1:0>;
V[d] = result;
```

Operational information

If PSTATE.DIT is 1:

- The execution time of this instruction is independent of:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
- The response of this instruction to asynchronous exceptions does not vary based on:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.


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SMINV

Signed Minimum across Vector. This instruction compares all the vector elements in the source SIMD&FP register, and writes the smallest of the values as a scalar to the destination SIMD&FP register. All the values in this instruction are signed integer values.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9  | 8  | 7  | 6  | 5  | 4  | 3  | 2  | 1  | 0  |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| U  | Q  | 0  | 0  | 1  | 1  | 0  | size| 1  | 1  | 0  | 0  | 1  | 1  | 0  | 1  | 0  | Rn | Rd |

Advanced SIMD

SMINV <V><d>, <Vn>.

integer d = UInt(Rd);
integer n = UInt(Rn);
if size:Q == '100' then UNDEFINED;
if size == '11' then UNDEFINED;
integer esize = 8 << if size:Q == '100' then ReservedValue(1);
if size == '11' then ReservedValue(1);
integer esize = 8 << UInt(size);
integer datasize = if Q == '1' then 128 else 64;
integer elements = datasize DIV esize;
boolean unsigned = (U == '1');
boolean min = (op == '1');

Assembler Symbols

<V> Is the destination width specifier, encoded in “size”:

<table>
<thead>
<tr>
<th>size</th>
<th>&lt;V&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>B</td>
</tr>
<tr>
<td>01</td>
<td>H</td>
</tr>
<tr>
<td>10</td>
<td>S</td>
</tr>
<tr>
<td>11</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

<d> Is the number of the SIMD&FP destination register, encoded in the "Rd" field.

<Vn> Is the name of the SIMD&FP source register, encoded in the "Rn" field.

<T> Is an arrangement specifier, encoded in “size:Q”:

<table>
<thead>
<tr>
<th>size</th>
<th>Q</th>
<th>&lt;T&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>0</td>
<td>8B</td>
</tr>
<tr>
<td>00</td>
<td>1</td>
<td>16B</td>
</tr>
<tr>
<td>01</td>
<td>0</td>
<td>4H</td>
</tr>
<tr>
<td>01</td>
<td>1</td>
<td>8H</td>
</tr>
<tr>
<td>10</td>
<td>0</td>
<td>RESERVED</td>
</tr>
<tr>
<td>10</td>
<td>1</td>
<td>4S</td>
</tr>
<tr>
<td>11</td>
<td>x</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>
Operation

```c
CheckFPAdvSIMDEnabled64();
bits(datasize) operand = V[n];
integer maxmin;
integer element;

maxmin = int(Elem[operand, 0, esize], unsigned);
for e = 1 to elements-1
    element = int(Elem[operand, e, esize], unsigned);
    maxmin = if min then Min(maxmin, element) else Max(maxmin, element);
V[d] = maxmin<esize-1:0>;
```

Operational information

If PSTATE.DIT is 1:

- The execution time of this instruction is independent of:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
- The response of this instruction to asynchronous exceptions does not vary based on:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.


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SMLAL, SMLAL2 (by element)

Signed Multiply-Add Long (vector, by element). This instruction multiplies each vector element in the lower or upper half of the first source SIMD&FP register by the specified vector element in the second source SIMD&FP register, and accumulates the results with the vector elements of the destination SIMD&FP register. The destination vector elements are twice as long as the elements that are multiplied. All the values in this instruction are signed integer values.

The SMLAL instruction extracts vector elements from the lower half of the first source register, while the SMLAL2 instruction extracts vector elements from the upper half of the first source register.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

```
| 31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0 |
|------------------------------------------|------------------------------------------|------------------|
| 0 | Q | 0 | 0 | 1 | 1 | 1 | size | L | M | Rm | 0 | 0 | 1 | 0 | H | 0 | Rn | Rd |
|------------------------------------------|------------------------------------------|------------------|
```

**Vector**

SMLAL[2] <Vd>.<Ta>, <Vn>.<Tb>, <Vm>.<Ts>[<index>]

```
integer idxdsize = if H == '1' then 128 else 64;
integer index;
bit Rmhi;

case size of
  when '01' index = UInt(H:L:M); Rmhi = '0';
  when '10' index = UInt(H:L);   Rmhi = M;
otherwise UNDEFINED;

integer d = otherwise UnallocatedEncoding();
integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rmhi:Rm);

integer esize = 8 << UInt(size);
integer datasize = 64;
integer part = UInt(Q);
integer elements = datasize DIV esize;

boolean unsigned = (U == '1');
boolean sub_op = (o2 == '1');
```

**Assembler Symbols**

2

Is the second and upper half specifier. If present it causes the operation to be performed on the upper 64 bits of the registers holding the narrower elements, and is encoded in “Q”:

```
+-----+-----+
<table>
<thead>
<tr>
<th>Q</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>[absent]</td>
</tr>
<tr>
<td>1</td>
<td></td>
</tr>
</tbody>
</table>
```

<Vd> Is the name of the SIMD&FP destination register, encoded in the "Rd" field.

<Ta> Is an arrangement specifier, encoded in “size”:

```
+-----+-----+
<table>
<thead>
<tr>
<th>size</th>
<th>&lt;Ta&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>RESERVED</td>
</tr>
<tr>
<td>01</td>
<td>4S</td>
</tr>
<tr>
<td>10</td>
<td>2D</td>
</tr>
<tr>
<td>11</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>
```

<Vn> Is the name of the first SIMD&FP source register, encoded in the "Rn" field.

<Tb> Is an arrangement specifier, encoded in “size-Q”:
<table>
<thead>
<tr>
<th>size</th>
<th>Q</th>
<th>&lt;Tb&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>x</td>
<td>RESERVED</td>
</tr>
<tr>
<td>01</td>
<td>0</td>
<td>4H</td>
</tr>
<tr>
<td>01</td>
<td>1</td>
<td>8H</td>
</tr>
<tr>
<td>10</td>
<td>0</td>
<td>2S</td>
</tr>
<tr>
<td>10</td>
<td>1</td>
<td>4S</td>
</tr>
<tr>
<td>11</td>
<td>x</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

**<Vm>**
Is the name of the second SIMD&FP source register, encoded in “size:M:Rm”:

<table>
<thead>
<tr>
<th>size</th>
<th>&lt;Vm&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>RESERVED</td>
</tr>
<tr>
<td>01</td>
<td>0:Rm</td>
</tr>
<tr>
<td>10</td>
<td>M:Rm</td>
</tr>
<tr>
<td>11</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

Restricted to V0-V15 when element size <Ts> is H.

**<Ts>**
Is an element size specifier, encoded in “size”:

<table>
<thead>
<tr>
<th>size</th>
<th>&lt;Ts&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>RESERVED</td>
</tr>
<tr>
<td>01</td>
<td>H</td>
</tr>
<tr>
<td>10</td>
<td>S</td>
</tr>
<tr>
<td>11</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

**<index>**
Is the element index, encoded in “size:L:H:M”:

<table>
<thead>
<tr>
<th>size</th>
<th>&lt;index&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>RESERVED</td>
</tr>
<tr>
<td>01</td>
<td>H:L:M</td>
</tr>
<tr>
<td>10</td>
<td>H:L</td>
</tr>
<tr>
<td>11</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

**Operation**

```c
CheckFPAdvSIMDEnabled64();
bits(datasize) operand1 = Vpart[n, part];
bits(idxdsize) operand2 = V[m];
bits(2*datasize) operand3 = V[d];
bits(2*datasize) result;
integer element1;
integer element2;
bias(2*esize) product;

element2 = Int(Elem[operand2, index, esize], unsigned);
for e = 0 to elements-1
  element1 = Int(Elem[operand1, e, esize], unsigned);
  product = (element1 * element2)<2*esize=1:0>;
  if sub_op then
    Elem[result, e, 2*esize] = Elem[operand3, e, 2*esize] - product;
  else
    Elem[result, e, 2*esize] = Elem[operand3, e, 2*esize] + product;
V[d] = result;
```

**Operational information**

If PSTATE.DIT is 1:

- The execution time of this instruction is independent of:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
- The response of this instruction to asynchronous exceptions does not vary based on:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
SMLAL, SMLAL2 (vector)

Signed Multiply-Add Long (vector). This instruction multiplies corresponding signed integer values in the lower or upper half of the vectors of the two source SIMD&FP registers, and accumulates the results with the vector elements of the destination SIMD&FP register. The destination vector elements are twice as long as the elements that are multiplied.

The SMLAL instruction extracts each source vector from the lower half of each source register, while the SMLAL2 instruction extracts each source vector from the upper half of each source register.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

Three registers, not all the same type

SMLAL[2] <Vd>,<Ta>, <Vn>,<Tb>, <Vm>,<Tb>

```plaintext
integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rm);

if size == '11' then UNDEFINED;
integer esize = 8 << if size == '11' then ReservedValue();
integer esize = 8 << UInt(size);
integer datasize = 64;
integer part = UInt(Q);
integer elements = datasize DIV esize;
boolean sub_op = (o1 == '1');
boolean unsigned = (U == '1');
```

Assembler Symbols

2

Is the second and upper half specifier. If present it causes the operation to be performed on the upper 64 bits of the registers holding the narrower elements, and is encoded in “Q”:

```
<table>
<thead>
<tr>
<th>Q</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>[absent]</td>
</tr>
<tr>
<td>1</td>
<td>[present]</td>
</tr>
</tbody>
</table>
```

<Vd> Is the name of the SIMD&FP destination register, encoded in the “Rd” field.

<Ta> Is an arrangement specifier, encoded in “size”:

```
<table>
<thead>
<tr>
<th>size</th>
<th>&lt;Ta&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>8H</td>
</tr>
<tr>
<td>01</td>
<td>4S</td>
</tr>
<tr>
<td>10</td>
<td>2D</td>
</tr>
<tr>
<td>11</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>
```

<Vn> Is the name of the first SIMD&FP source register, encoded in the “Rn” field.

<Tb> Is an arrangement specifier, encoded in “size:Q”:

```
<table>
<thead>
<tr>
<th>size</th>
<th>Q</th>
<th>&lt;Tb&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>0</td>
<td>8B</td>
</tr>
<tr>
<td>00</td>
<td>1</td>
<td>16B</td>
</tr>
<tr>
<td>01</td>
<td>0</td>
<td>4H</td>
</tr>
<tr>
<td>01</td>
<td>1</td>
<td>8H</td>
</tr>
<tr>
<td>10</td>
<td>0</td>
<td>2S</td>
</tr>
<tr>
<td>10</td>
<td>1</td>
<td>4S</td>
</tr>
<tr>
<td>11</td>
<td>x</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>
```

<Vm> Is the name of the second SIMD&FP source register, encoded in the “Rm” field.
Operation

```c
CheckFPAdvSIMDEnabled64();
bits(datasize) operand1 = Vpart[n, part];
bits(datasize) operand2 = Vpart[m, part];
bits(2*datasize) operand3 = V[d];
bits(2*datasize) result;
integer element1;
integer element2;
bits(2*esize) product;
bits(2*esize) accum;

for e = 0 to elements-1
    element1 = Int(Elem[operand1, e, esize], unsigned);
    element2 = Int(Elem[operand2, e, esize], unsigned);
    product = (element1 * element2) < 2*esize-1:0>;
    if sub_op then
        accum = Elem[operand3, e, 2*esize] - product;
    else
        accum = Elem[operand3, e, 2*esize] + product;
    Elem[result, e, 2*esize] = accum;
V[d] = result;
```

Operational information

If PSTATE.DIT is 1:

- The execution time of this instruction is independent of:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
- The response of this instruction to asynchronous exceptions does not vary based on:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.

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SMLSL, SMLSL2 (by element)

Signed Multiply-Subtract Long (vector, by element). This instruction multiplies each vector element in the lower or upper half of the first source SIMD&FP register by the specified vector element of the second source SIMD&FP register and subtracts the results from the vector elements of the destination SIMD&FP register. The destination vector elements are twice as long as the elements that are multiplied.

The SMLSL instruction extracts vector elements from the lower half of the first source register, while the SMLSL2 instruction extracts vector elements from the upper half of the first source register.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

<table>
<thead>
<tr>
<th>U</th>
<th>0</th>
<th>Q</th>
<th>0</th>
<th>1</th>
<th>1</th>
<th>1</th>
<th>size</th>
<th>L</th>
<th>M</th>
<th>Rm</th>
<th>0</th>
<th>1</th>
<th>1</th>
<th>0</th>
<th>H</th>
<th>0</th>
<th>Rn</th>
<th>Rd</th>
</tr>
</thead>
<tbody>
<tr>
<td>o2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Vector

SMLSL[2] \(<Vd>.,<Ta>.,<Vn>.,<Tb>.,<Vm>.,<Ts>[<index>]\)

```plaintext
integer idxdsiz = if H == '1' then 128 else 64;
integer index;
bit Rmhi;
case size of
  when '01' index = UInt(H:L:M); Rmhi = '0';
  when '10' index = UInt(H:L);   Rmhi = M;
  otherwise UNDEFINED;

integer d = otherwise UnallocatedEncoding(A);
integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rmhi:Rm);

integer esize = 8 << UInt(size);
integer datasize = 64;
integer part = UInt(Q);
integer elements = datasize DIV esize;

boolean unsigned = (U == '1');
boolean sub_op = (o2 == '1');
```

Assembler Symbols

2

Is the second and upper half specifier. If present it causes the operation to be performed on the upper 64 bits of the registers holding the narrower elements, and is encoded in "Q":

<table>
<thead>
<tr>
<th>Q</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>[absent]</td>
</tr>
<tr>
<td>1</td>
<td>[present]</td>
</tr>
</tbody>
</table>

\(<Vd>\)

Is the name of the SIMD&FP destination register, encoded in the "Rd" field.

\(<Ta>\)

Is an arrangement specifier, encoded in “size”:

<table>
<thead>
<tr>
<th>size</th>
<th>&lt;Ta&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>RESERVED</td>
</tr>
<tr>
<td>01</td>
<td>4S</td>
</tr>
<tr>
<td>10</td>
<td>2D</td>
</tr>
<tr>
<td>11</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

\(<Vn>\)

Is the name of the first SIMD&FP source register, encoded in the "Rn" field.

\(<Tb>\)

Is an arrangement specifier, encoded in “size:Q”:
<Vm>

Is the name of the second SIMD&FP source register, encoded in “size:M:Rm”:

<table>
<thead>
<tr>
<th>size</th>
<th>&lt;Vm&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>RESERVED</td>
</tr>
<tr>
<td>01</td>
<td>0:Rm</td>
</tr>
<tr>
<td>10</td>
<td>M:Rm</td>
</tr>
<tr>
<td>11</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

Restricted to V0-V15 when element size <Ts> is H.

<Ts>

Is an element size specifier, encoded in “size”:

<table>
<thead>
<tr>
<th>size</th>
<th>&lt;Ts&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>RESERVED</td>
</tr>
<tr>
<td>01</td>
<td>H</td>
</tr>
<tr>
<td>10</td>
<td>S</td>
</tr>
<tr>
<td>11</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

<index>

Is the element index, encoded in “size:L:H:M”:

<table>
<thead>
<tr>
<th>size</th>
<th>&lt;index&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>RESERVED</td>
</tr>
<tr>
<td>01</td>
<td>H:L:M</td>
</tr>
<tr>
<td>10</td>
<td>H:L</td>
</tr>
<tr>
<td>11</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

Operation

```c
CheckFPAdvSIMDEnabled64();
bits(datasize) operand1 = Vpart[n, part];
bits(idxdsize) operand2 = V[m];
bits(2*datasize) operand3 = V[d];
bits(2*datasize) result;
integer element1;
integer element2;
broadcast(product);
element2 = Int(Elem[operand2, index, esize], unsigned);
for e = 0 to elements-1
   element1 = Int(Elem[operand1, e, esize], unsigned);
   product = (element1 * element2)<2*esize-1:0>;
   if sub_op then
      Elem[result, e, 2*esize] = Elem[operand3, e, 2*esize] - product;
   else
      Elem[result, e, 2*esize] = Elem[operand3, e, 2*esize] + product;
V[d] = result;
```

Operational information

If PSTATE.DIT is 1:

- The execution time of this instruction is independent of:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
- The response of this instruction to asynchronous exceptions does not vary based on:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
SMLSL, SMLSL2 (vector)

Signed Multiply-Subtract Long (vector). This instruction multiplies corresponding signed integer values in the lower or upper half of the vectors of the two source SIMD&FP registers, and subtracts the results from the vector elements of the destination SIMD&FP register. The destination vector elements are twice as long as the elements that are multiplied.

The SMLSL instruction extracts each source vector from the lower half of each source register, while the SMLSL2 instruction extracts each source vector from the upper half of each source register.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

**Table:**

<table>
<thead>
<tr>
<th>Q</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>[absent]</td>
</tr>
<tr>
<td>1</td>
<td>[present]</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>size</th>
<th>&lt;Ta&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>8H</td>
</tr>
<tr>
<td>01</td>
<td>4S</td>
</tr>
<tr>
<td>10</td>
<td>2D</td>
</tr>
<tr>
<td>11</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>size</th>
<th>&lt;Q&gt;</th>
<th>&lt;Tb&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>0</td>
<td>8B</td>
</tr>
<tr>
<td>00</td>
<td>1</td>
<td>16B</td>
</tr>
<tr>
<td>01</td>
<td>0</td>
<td>4H</td>
</tr>
<tr>
<td>01</td>
<td>1</td>
<td>8H</td>
</tr>
<tr>
<td>10</td>
<td>0</td>
<td>2S</td>
</tr>
<tr>
<td>10</td>
<td>1</td>
<td>4S</td>
</tr>
<tr>
<td>11</td>
<td>x</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

Three registers, not all the same type

SMLSL{2} <Vd>, <Ta>, <Vn>, <Tb>, <Vm>,<Tb>

integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rm);

if size == '11' then UNDEFINED;
integer esize = 8 << if size == '11' then ReservedValue();
integer esize = 8 << UInt(size);
integer datasize = 64;
integer part = UInt(Q);
integer elements = datasize DIV esize;
boolean sub_op = (o1 == '1');
boolean unsigned = (U == '1');

Assembler Symbols

2

Is the second and upper half specifier. If present it causes the operation to be performed on the upper 64 bits of the registers holding the narrower elements, and is encoded in “Q”:

<table>
<thead>
<tr>
<th>Q</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>[absent]</td>
</tr>
<tr>
<td>1</td>
<td>[present]</td>
</tr>
</tbody>
</table>

<Vd> Is the name of the SIMD&FP destination register, encoded in the "Rd" field.

<Ta> Is an arrangement specifier, encoded in “size”:

<table>
<thead>
<tr>
<th>size</th>
<th>&lt;Ta&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>8H</td>
</tr>
<tr>
<td>01</td>
<td>4S</td>
</tr>
<tr>
<td>10</td>
<td>2D</td>
</tr>
<tr>
<td>11</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

<Vn> Is the name of the first SIMD&FP source register, encoded in the "Rn" field.

<Tb> Is an arrangement specifier, encoded in “size:Q”:

<table>
<thead>
<tr>
<th>size</th>
<th>Q</th>
<th>&lt;Tb&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>0</td>
<td>8B</td>
</tr>
<tr>
<td>00</td>
<td>1</td>
<td>16B</td>
</tr>
<tr>
<td>01</td>
<td>0</td>
<td>4H</td>
</tr>
<tr>
<td>01</td>
<td>1</td>
<td>8H</td>
</tr>
<tr>
<td>10</td>
<td>0</td>
<td>2S</td>
</tr>
<tr>
<td>10</td>
<td>1</td>
<td>4S</td>
</tr>
<tr>
<td>11</td>
<td>x</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

<Vm> Is the name of the second SIMD&FP source register, encoded in the "Rm" field.
Operation

```c
CheckFPAdvSIMEnabled64();
bits(datasize) operand1 = Vpart[n, part];
bits(datasize) operand2 = Vpart[m, part];
bits(2*datasize) operand3 = V[d];
bites(2*datasize) result;
integer element1;
integer element2;
bites(2*esize) product;
bites(2*esize) accum;

for e = 0 to elements-1
    element1 = Int(Elem[operand1, e, esize], unsigned);
    element2 = Int(Elem[operand2, e, esize], unsigned);
    product = (element1 * element2)<2*esize-1:0>;
    if sub_op then
        accum = Elem[operand3, e, 2*esize] - product;
    else
        accum = Elem[operand3, e, 2*esize] + product;
    Elem[result, e, 2*esize] = accum;
V[d] = result;
```

Operational information

If PSTATE.DIT is 1:

- The execution time of this instruction is independent of:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
- The response of this instruction to asynchronous exceptions does not vary based on:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.

Internal version only: isa v30.25, AdvSIMD v27.01, pseudocode v85-xml-00beta_rc3-005; Build timestamp: 2018-09-13T13:2018-06-16T09:45

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SMOV

Signed Move vector element to general-purpose register. This instruction reads the signed integer from the source SIMD&FP register, sign-extends it to form a 32-bit or 64-bit value, and writes the result to destination general-purpose register.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

\[
\begin{array}{cccccccccccccccc}
0 & 0 & 0 & 1 & 1 & 1 & 0 & 0 & 0 & 0 & imm5 & 0 & 0 & 1 & 0 & 1 & 1 & Rn & Rd \\
\end{array}
\]

32-bit (Q == 0)

\[
\text{SMOV} \ <Wd>, \ <Vn>.<Ts>[<index>] \\
\]

64-reg, SMOV-64-reg (Q == 1)

\[
\text{SMOV} \ <Xd>, \ <Vn>.<Ts>[<index>] \\
\]

integer d = UInt(Rd);
integer n = UInt(Rn);

integer size;
\begin{align*}
\text{case } & \text{imm5 of} \\
& \text{when 'xxxxx1' size } = 0; \quad \text{// SMOV } [WX]d, Vn.B \\
& \text{when 'xxxx10' size } = 1; \quad \text{// SMOV } [WX]d, Vn.H \\
& \text{when '1xx100' size } = 2; \quad \text{// SMOV } Xd, Vn.S \\
& \text{otherwise UNDEFINED}; \\
\end{align*}

integer idxdsize = if imm5<4> == '1' then 128 else 64;
integer index = if imm5<4:1> == '1' then 128 else 64;
integer size = 8 << size;
integer datasize = if Q == '1' then 64 else 32;

Assembler Symbols

\begin{itemize}
\item <Wd> Is the 32-bit name of the general-purpose destination register, encoded in the "Rd" field.
\item <Xd> Is the 64-bit name of the general-purpose destination register, encoded in the "Rd" field.
\item <Vn> Is the name of the SIMD&FP source register, encoded in the "Rn" field.
\item <Ts> For the 32-bit variant: is an element size specifier, encoded in “imm5”:
\[
\begin{array}{cc}
\text{imm5} & \langle Ts \rangle \\
xxxx00 & \text{RESERVED} \\
xxxx10 & H \\
\end{array}
\]
\item <Ts> For the 64-reg, SMOV-64-reg variant: is an element size specifier, encoded in “imm5”:
\[
\begin{array}{cc}
\text{imm5} & \langle Ts \rangle \\
xxU00 & \text{RESERVED} \\
xxxx10 & H \\
xx100 & S \\
\end{array}
\]
\item <index> For the 32-bit variant: is the element index encoded in “imm5”:
\[
\begin{array}{cc}
\text{imm5} & \langle index \rangle \\
xxxx00 & \text{RESERVED} \\
xxxx10 & \text{imm5<4:1>} \\
xxxx10 & \text{imm5<4:2>} \\
\end{array}
\]
\end{itemize}
For the 64-reg,SMOV-64-reg variant: is the element index encoded in “imm5”:

<table>
<thead>
<tr>
<th>imm5</th>
<th>&lt;index&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>xx000</td>
<td>RESERVED</td>
</tr>
<tr>
<td>xxxx1</td>
<td>imm5&lt;4:1&gt;</td>
</tr>
<tr>
<td>xxx10</td>
<td>imm5&lt;4:2&gt;</td>
</tr>
<tr>
<td>xx100</td>
<td>imm5&lt;4:3&gt;</td>
</tr>
</tbody>
</table>

**Operation**

```c
CheckFPAdvSIMDEnabled64();
bits(idxdsize) operand = V[n];
X[d] = SignExtend(Elem[operand, index, esize], datasize);
```

**Operational information**

If PSTATE.DIT is 1:
- The execution time of this instruction is independent of:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
- The response of this instruction to asynchronous exceptions does not vary based on:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.

Internal version only: isa v30.25 v29.05, AdvSIMD v27.01 v26.0, pseudocode v85-xml-00bet8_rc3a35a; Build timestamp: 2018-09-13T13:2018-06-16T09:04:45

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SMULL, SMULL2 (by element)

Signed Multiply Long (vector, by element). This instruction multiplies each vector element in the lower or upper half of the first source SIMD&FP register by the specified vector element of the second source SIMD&FP register, places the result in a vector, and writes the vector to the destination SIMD&FP register. The destination vector elements are twice as long as the elements that are multiplied. The SMULL instruction extracts vector elements from the lower half of the first source register, while the SMULL2 instruction extracts vector elements from the upper half of the first source register. Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

```
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 |  9 |  8 |  7 |  6 |  5 |  4 |  3 |  2 |  1 |  0 |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
|  0 |  Q |  0 |  1 |  1 |  1 |  1 |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| 0xQ| 0x0| 0x1| 0x1| 0x1| 0x1| 0x1|   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
```

Vector

```
integer idxdsz = if H == '1' then 128 else 64;
integer index;
bit Rmhi;

case size of
  when '01' index = UInt(H:L:M); Rmhi = '0';
  when '10' index = UInt(H:L);       Rmhi = M;
otherwise UNDEFINED;
integer d = otherwise UnallocatedEncoding();
integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rmhi:Rm);

integer esize = 8 << UInt(size);
integer datasize = 64;
integer part = UInt(Q);
integer elements = datasize DIV esize;
boolean unsigned = (U == '1');
```

Assembler Symbols

2 Is the second and upper half specifier. If present it causes the operation to be performed on the upper 64 bits of the registers holding the narrower elements, and is encoded in "Q":

```
<table>
<thead>
<tr>
<th>Q</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>[absent]</td>
</tr>
<tr>
<td>1</td>
<td>[present]</td>
</tr>
</tbody>
</table>
```

<Vd> Is the name of the SIMD&FP destination register, encoded in the "Rd" field.

<Ta> Is an arrangement specifier, encoded in “size”:

```
<table>
<thead>
<tr>
<th>size</th>
<th>&lt;Ta&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>RESERVED</td>
</tr>
<tr>
<td>01</td>
<td>4S</td>
</tr>
<tr>
<td>10</td>
<td>2D</td>
</tr>
<tr>
<td>11</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>
```

<Vn> Is the name of the first SIMD&FP source register, encoded in the "Rn" field.

<Tb> Is an arrangement specifier, encoded in “size:Q”:

```
<table>
<thead>
<tr>
<th>size</th>
<th>&lt;Ta&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>RESERVED</td>
</tr>
<tr>
<td>01</td>
<td>4S</td>
</tr>
<tr>
<td>10</td>
<td>2D</td>
</tr>
<tr>
<td>11</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>
```
<Vm> Is the name of the second SIMD&FP source register, encoded in “size:M:Rm”:

<table>
<thead>
<tr>
<th>size</th>
<th>&lt;Vm&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>RESERVED</td>
</tr>
<tr>
<td>01</td>
<td>0:Rm</td>
</tr>
<tr>
<td>10</td>
<td>M:Rm</td>
</tr>
<tr>
<td>11</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

Restricted to V0-V15 when element size <Ts> is H.

<Ts> Is an element size specifier, encoded in “size”:

<table>
<thead>
<tr>
<th>size</th>
<th>&lt;Ts&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>RESERVED</td>
</tr>
<tr>
<td>01</td>
<td>H</td>
</tr>
<tr>
<td>10</td>
<td>S</td>
</tr>
<tr>
<td>11</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

<index> Is the element index, encoded in “size:L:H:M”:

<table>
<thead>
<tr>
<th>size</th>
<th>&lt;index&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>RESERVED</td>
</tr>
<tr>
<td>01</td>
<td>H:L:M</td>
</tr>
<tr>
<td>10</td>
<td>H:L</td>
</tr>
<tr>
<td>11</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

Operation

```c
CheckFPAdvSIMDEnabled64();
bits(datasize) operand1 = Vpart[n, part];
bits(idxdsize) operand2 = V[m];
bits(2*datasize) result;
integer element1;
integer element2;
bits(2*esize) product;

element2 = Int(Elem[operand2, index, esize], unsigned);
for e = 0 to elements-1
    element1 = Int(Elem[operand1, e, esize], unsigned);
    product = (element1 * element2)<2*esize-1:0>;
    Elem[result, e, 2*esize] = product;
V[d] = result;
```

Operational information

If PSTATE.DIT is 1:
- The execution time of this instruction is independent of:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
- The response of this instruction to asynchronous exceptions does not vary based on:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
SMULL, SMULL2 (vector)

Signed Multiply Long (vector). This instruction multiplies corresponding signed integer values in the lower or upper half of the vectors of the two source SIMD&FP registers, places the results in a vector, and writes the vector to the destination SIMD&FP register.

The destination vector elements are twice as long as the elements that are multiplied.

The SMULL instruction extracts each source vector from the lower half of each source register, while the SMULL2 instruction extracts each source vector from the upper half of each source register.

Depending on the settings in the CP1CR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

Three registers, not all the same type

SMULL(2) \langle Vd\rangle, \langle Ta\rangle, \langle Vn\rangle, \langle Tb\rangle, \langle Vm\rangle, \langle Tb\rangle

integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rm);

if size == '11' then UNDEFINED;
integer esize = 8 <<if size == '11' then ReservedValue()::
integer esize = 8 <<UInt(size);
integer datasize = 64;
integer part = UInt(Q);
integer elements = datasize DIV esize;

boolean unsigned = (U == '1');

Assembler Symbols

2 Is the second and upper half specifier. If present it causes the operation to be performed on the upper 64 bits of the registers holding the narrower elements, and is encoded in “Q”:

<table>
<thead>
<tr>
<th>Q</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>[absent]</td>
</tr>
<tr>
<td>1</td>
<td>[present]</td>
</tr>
</tbody>
</table>

\langle Vd\rangle Is the name of the SIMD&FP destination register, encoded in the "Rd" field.

\langle Ta\rangle Is an arrangement specifier, encoded in “size”:

<table>
<thead>
<tr>
<th>size</th>
<th>\langle Ta\rangle</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>8H</td>
</tr>
<tr>
<td>01</td>
<td>4S</td>
</tr>
<tr>
<td>10</td>
<td>2D</td>
</tr>
<tr>
<td>11</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

\langle Vn\rangle Is the name of the first SIMD&FP source register, encoded in the "Rn" field.

\langle Tb\rangle Is an arrangement specifier, encoded in “size:Q”:

<table>
<thead>
<tr>
<th>size</th>
<th>Q</th>
<th>\langle Tb\rangle</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>0</td>
<td>8B</td>
</tr>
<tr>
<td>00</td>
<td>1</td>
<td>16B</td>
</tr>
<tr>
<td>01</td>
<td>0</td>
<td>4H</td>
</tr>
<tr>
<td>01</td>
<td>1</td>
<td>8H</td>
</tr>
<tr>
<td>10</td>
<td>0</td>
<td>2S</td>
</tr>
<tr>
<td>10</td>
<td>1</td>
<td>4S</td>
</tr>
<tr>
<td>11</td>
<td>x</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

\langle Vm\rangle Is the name of the second SIMD&FP source register, encoded in the "Rm" field.
Operation

```c
CheckFPAdvSIMDEnabled64();
bite{datasize} operand1 = Vpart[n, part];
bite{datasize} operand2 = Vpart[m, part];
bite{2*datasize} result;
integer element1;
integer element2;

for e = 0 to elements-1
    element1 = Int{Elem[operand1, e, esize], unsigned};
    element2 = Int{Elem[operand2, e, esize], unsigned};
    Elem[result, e, 2*esize] = (element1 * element2)<2*esize-1:0>;
V[d] = result;
```

Operational information

If PSTATE.DIT is 1:
- The execution time of this instruction is independent of:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
- The response of this instruction to asynchronous exceptions does not vary based on:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
**SQABS**

Signed saturating Absolute value. This instruction reads each vector element from the source SIMD&FP register, puts the absolute value of the result into a vector, and writes the vector to the destination SIMD&FP register. All the values in this instruction are signed integer values. If overflow occurs with any of the results, those results are saturated. If saturation occurs, the cumulative saturation bit \( FPSCR.QC \) is set. Depending on the settings in the \( CPACR_EL1, CPTR_EL2, \) and \( CPTR_EL3 \) registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

It has encodings from 2 classes: **Scalar** and **Vector**

### Scalar

#### 31 30 29 28 27 25 23 22 21 20 19 18 16 15 13 12 11 10 9 8 7 6 5 4 3 2 1 0

| 0 | 1 | 0 | 1 | 1 | 1 | 0 | size | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | Rn | Rd |
| U |

#### Assembly:

```
integer d = UInt(Rd);
integer n = UInt(Rn);
integer esize = 8 << UInt(size);
integer datasize = esize;
integer elements = 1;
boolean neg = (U == '1');
```

### Vector

#### 31 30 29 28 27 25 23 22 21 20 19 18 16 15 13 12 11 10 9 8 7 6 5 4 3 2 1 0

| 0 | Q | 0 | 0 | 1 | 1 | 1 | 0 | size | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | Rn | Rd |
| U |

#### Assembly:

```
integer d = UInt(Rd);
integer n = UInt(Rn);
if size:Q == '110' then UNDEFINED;
integer esize = 8 << if size:Q == '110' then ReservedValue() else UInt(size);
integer datasize = if Q == '1' then 128 else 64;
integer elements = datasize DIV esize;
boolean neg = (U == '1');
```

### Assembler Symbols

- **<V>** Is a width specifier, encoded in "size":
  
<table>
<thead>
<tr>
<th>size</th>
<th>&lt;V&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>B</td>
</tr>
<tr>
<td>01</td>
<td>H</td>
</tr>
<tr>
<td>10</td>
<td>S</td>
</tr>
<tr>
<td>11</td>
<td>D</td>
</tr>
</tbody>
</table>

- **<d>** Is the number of the SIMD&FP destination register, encoded in the "Rd" field.

- **<n>** Is the number of the SIMD&FP source register, encoded in the "Rn" field.
<Vd> Is the name of the SIMD&FP destination register, encoded in the "Rd" field.

<T> Is an arrangement specifier, encoded in “size-Q”:

<table>
<thead>
<tr>
<th>size</th>
<th>00</th>
<th>00</th>
<th>01</th>
<th>01</th>
<th>10</th>
<th>10</th>
<th>11</th>
<th>11</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q</td>
<td>0B</td>
<td>1B</td>
<td>4H</td>
<td>8H</td>
<td>2S</td>
<td>4S</td>
<td>RES</td>
<td>2D</td>
</tr>
</tbody>
</table>

<Vn> Is the name of the SIMD&FP source register, encoded in the "Rn" field.

Operation

```c
CheckFPAdvSIMDEnabled64();
bits(datasize) operand = V[n];
bits(datasize) result;
integer element;
boolean sat;
for e = 0 to elements-1
    element = SInt(Elem[operand, e, esize]);
    if neg then
        element = -element;
    else
        element = Abs(element);
    Elem[result, e, esize], sat) = SignedSatQ(element, esize);
if sat then FPSR.QC = '1';
V[d] = result;
```

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**SQADD**

Signed saturating Add. This instruction adds the values of corresponding elements of the two source SIMD&FP registers, places the results into a vector, and writes the vector to the destination SIMD&FP register.

If overflow occurs with any of the results, those results are saturated. If saturation occurs, the cumulative saturation bit $FPSCR.QC$ is set. Depending on the settings in the $CPACR_EL1$, $CPTR_EL2$, and $CPTR_EL3$ registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

It has encodings from 2 classes: Scalar and Vector

**Scalar**

```
31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
0 1 0 1 1 1 0 | size | 1 | Rm | 0 0 0 0 1 1 | Rn | Rd
```

**Vector**

```
31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
0 | Q | 0 0 0 1 1 1 0 | size | 1 | Rm | 0 0 0 0 1 1 | Rn | Rd
```

**Assembler Symbols**

- `<V>` is a width specifier, encoded in "size":
  
<table>
<thead>
<tr>
<th>size</th>
<th><code>&lt;V&gt;</code></th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>B</td>
</tr>
<tr>
<td>01</td>
<td>H</td>
</tr>
<tr>
<td>10</td>
<td>S</td>
</tr>
<tr>
<td>11</td>
<td>D</td>
</tr>
</tbody>
</table>

- `<d>` is the number of the SIMD&FP destination register, in the "Rd" field.
- `<n>` is the number of the first SIMD&FP source register, encoded in the "Rn" field.

```java
int d = Uint(Rd);
int n = Uint(Rn);
int m = Uint(Rm);
int esize = 8 << Uint(size);
int datasize = esize;
int elements = 1;
boolean unsigned = (U == '1');
```

```java
int d = Uint(Rd);
int n = Uint(Rn);
int m = Uint(Rm);
if size:Q == '110' then UNDEFINED;
int esize = 8 << Uint(size);
int datasize = if Q == '1' then 128 else 64;
int elements = datasize DIV esize;
boolean unsigned = (U == '1');
```
Is the number of the second SIMD&FP source register, encoded in the "Rm" field.

Is the name of the SIMD&FP destination register, encoded in the "Rd" field.

Is an arrangement specifier, encoded in "size:Q":

<table>
<thead>
<tr>
<th>size</th>
<th>Q</th>
<th>&lt;T&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>0</td>
<td>8B</td>
</tr>
<tr>
<td>00</td>
<td>1</td>
<td>16B</td>
</tr>
<tr>
<td>01</td>
<td>0</td>
<td>4H</td>
</tr>
<tr>
<td>01</td>
<td>1</td>
<td>8H</td>
</tr>
<tr>
<td>10</td>
<td>0</td>
<td>2S</td>
</tr>
<tr>
<td>10</td>
<td>1</td>
<td>4S</td>
</tr>
<tr>
<td>11</td>
<td>0</td>
<td>RESERVED</td>
</tr>
<tr>
<td>11</td>
<td>1</td>
<td>2D</td>
</tr>
</tbody>
</table>

Is the name of the first SIMD&FP source register, encoded in the "Rn" field.

Is the name of the second SIMD&FP source register, encoded in the "Rm" field.

**Operation**

```c
CheckFPAdvSIMDEnabled64();
bits(datasize) operand1 = V[n];
bits(datasize) operand2 = V[m];
bits(datasize) result;
integer element1;
integer element2;
integer sum;
boolean sat;
for e = 0 to elements-1
    element1 = Int(Elem[operand1, e, esize], unsigned);
    element2 = Int(Elem[operand2, e, esize], unsigned);
    sum = element1 + element2;
    (Elem[result, e, esize], sat) = SatQ(sum, esize, unsigned);
    if sat then FPSR.QC = '1';
V[d] = result;
```

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SQDMLAL, SQDMLAL2 (by element)

Signed saturating Doubling Multiply-Add Long (by element). This instruction multiplies each vector element in the lower or upper half of the first source SIMD&FP register by the specified vector element of the second source SIMD&FP register, doubles the results, and accumulates the final results with the vector elements of the destination SIMD&FP register. The destination vector elements are twice as long as the elements that are multiplied.

If overflow occurs with any of the results, those results are saturated. If saturation occurs, the cumulative saturation bit $FPSR.QC$ is set.

The SQDMLAL instruction extracts vector elements from the lower half of the first source register, while the SQDMLAL2 instruction extracts vector elements from the upper half of the first source register.

Depending on the settings in the $CPACR_EL1$, $CPTR_EL2$, and $CPTR_EL3$ registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

It has encodings from 2 classes: Scalar and Vector

### Scalar

```
| 31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0 |
|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| 0 1 0 1 1 1 1 1 | size | L | M | Rm | 0 0 1 1 | H | 0 | Rn | Rd |
| 02               |     |   |   |    |    |    |    |
```

### Vector

```
| 31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0 |
|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| 0 0 0 1 1 1 1 | size | L | M | Rm | 0 0 1 1 | H | 0 | Rn | Rd |
| 02               |     |   |   |    |    |    |    |
```

```plaintext
SQDMLAL <Va><d>, <Vb><n>, <Vm>.<Ts>[<index>]
```

integer idxdsize = if H == '1' then 128 else 64;
integer index;
bit Rmhi;
case size of
  when '01' index = UInt(H:L:M); Rmhi = '0';
  when '10' index = UInt(H:L); Rmhi = M;
otherwise UNDEFINED;
integer d = otherwise UnallocatedEncoding();
integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rmhi:Rm);
integer esize = 8 << UInt(size);
integer datasize = esize;
integer elements = 1;
integer part = 0;
boolean sub_op = (o2 == '1');
```
Vector

\[ \text{SQDMLAL} \] \( <Vd>, <Vn>, <Ta>, <Tb>, <Vm>, <Ts>[<index>] \)

\begin{verbatim}
integer idxxdsz = if H == '1' then 128 else 64;
integer index;
bit Rmhi;

case size of
    when '01' index = UInt(H:L:M); Rmhi = '0';
    when '10' index = UInt(H:L); Rmhi = M;
otherwise UNDEFINED;

integer d = otherwise UnallocatedEncoding();
integer n = UInt(Rn);
integer m = UInt(Rmhi:Rm);

integer esize = 8 << UInt(size);
integer datasize = 64;
integer part = UInt(Q);
integer elements = datasize DIV esize;

boolean sub_op = (o2 == '1');
\end{verbatim}

Assembler Symbols

2
Is the second and upper half specifier. If present it causes the operation to be performed on the upper 64 bits of the registers holding
the narrower elements, and is encoded in “Q”:

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Q</td>
<td>2</td>
</tr>
<tr>
<td>0</td>
<td>[absent]</td>
</tr>
<tr>
<td>1</td>
<td>[present]</td>
</tr>
</tbody>
</table>

\(<Vd>\)
Is the name of the SIMD&FP destination register, encoded in the “Rd” field.

\(<Ta>\)
Is an arrangement specifier, encoded in “size”:

\begin{verbatim}
<table>
<thead>
<tr>
<th>size</th>
<th>&lt;Ta&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>RESERVED</td>
</tr>
<tr>
<td>01</td>
<td>4S</td>
</tr>
<tr>
<td>10</td>
<td>2D</td>
</tr>
<tr>
<td>11</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>
\end{verbatim}

\(<Vn>\)
Is the name of the first SIMD&FP source register, encoded in the "Rn" field.

\(<Tb>\)
Is an arrangement specifier, encoded in “size:Q”:

\begin{verbatim}
<table>
<thead>
<tr>
<th>size</th>
<th>Q</th>
<th>&lt;Tb&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>x</td>
<td>RESERVED</td>
</tr>
<tr>
<td>01</td>
<td>0</td>
<td>4H</td>
</tr>
<tr>
<td>01</td>
<td>1</td>
<td>8H</td>
</tr>
<tr>
<td>10</td>
<td>0</td>
<td>2S</td>
</tr>
<tr>
<td>10</td>
<td>1</td>
<td>4S</td>
</tr>
<tr>
<td>11</td>
<td>x</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>
\end{verbatim}

\(<Va>\)
Is the destination width specifier, encoded in “size”:

\begin{verbatim}
<table>
<thead>
<tr>
<th>size</th>
<th>&lt;Va&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>RESERVED</td>
</tr>
<tr>
<td>01</td>
<td>S</td>
</tr>
<tr>
<td>10</td>
<td>D</td>
</tr>
<tr>
<td>11</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>
\end{verbatim}

\(<d>\)
Is the number of the SIMD&FP destination register, encoded in the "Rd" field.

\(<Vb>\)
Is the source width specifier, encoded in “size”:
Is the number of the first SIMD&FP source register, encoded in the "Rn" field.

Is the name of the second SIMD&FP source register, encoded in "size:M:Rm":

Restricted to V0-V15 when element size <Ts> is H.

Is an element size specifier, encoded in "size":

Is the element index, encoded in "size:L:H:M":

Operation

```
CheckFPAdvSIMDEnabled64();

bits(datasize) operand1 = Vpart[n, part];
bits(idxdsize) operand2 = V[m];
bits(2*datasize) operand3 = V[d];

integer element1;
integer element2;
bits(2*esize) product;
integer accum;
boolean sat1;
boolean sat2;

element2 = SInt(Elem[operand2, index, esize]);
for e = 0 to elements-1
  element1 = SInt(Elem[operand1, e, esize]);
  (product, sat1) = SignedSatQ(2 * element1 * element2, 2*esize);
  if sub_op then
    accum = SInt(Elem[operand3, e, 2*esize]) - SInt(product);
  else
    accum = SInt(Elem[operand3, e, 2*esize]) + SInt(product);
  (Elem[result, e, 2*esize], sat2) = SignedSatQ(accum, 2*esize);
  if sat1 || sat2 then FPSR.QC = '1';

V[d] = result;
```

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SQDMLAL, SQDMLAL2 (vector)

Signed saturating Doubling Multiply-Add Long. This instruction multiplies corresponding signed integer values in the lower or upper half of the vectors of the two source SIMD&FP registers, doubles the results, and accumulates the final results with the vector elements of the destination SIMD&FP register. The destination vector elements are twice as long as the elements that are multiplied.

If overflow occurs with any of the results, those results are saturated. If saturation occurs, the cumulative saturation bit $FPSR.QC$ is set.

The $SQDMLAL$ instruction extracts each source vector from the lower half of each source register, while the $SQDMLAL2$ instruction extracts each source vector from the upper half of each source register.

Depending on the settings in the $CPACR_EL1$, $CPTR_EL2$, and $CPTR_EL3$ registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

It has encodings from 2 classes: $Scalar$ and $Vector$

Scalar

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9  | 8  | 7  | 6  | 5  | 4  | 3  | 2  | 1  | 0  |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0  | 1  | 0  | 1  | 1  | 1  | 1  | 0  | 1  | 0  | 0  | 1  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  |

Rm Rn Rd o1

$SQDMLAL <Va>d, <Vb>n, <Vb>m$

```plaintext
integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rm);

if size == '00' || size == '11' then UNDEFINED;
integer esize = 8 << if size == '00' || size == '11' then ReservedValue();
integer esize = 8 << UInt(size);
integer datasize = esize;
integer elements = 1;
integer part = 0;

boolean sub_op = (o1 == '1');
```

Vector

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9  | 8  | 7  | 6  | 5  | 4  | 3  | 2  | 1  | 0  |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0  | Q  | 0  | 0  | 1  | 1  | 1  | 0  | 1  | 0  | 0  | 1  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  |

Rm Rn Rd o1

$SQDMLAL(2) <Vd>Ta>, <Vn>Tb>, <Vm>Tb$

```plaintext
integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rm);

if size == '00' || size == '11' then UNDEFINED;
integer esize = 8 << if size == '00' || size == '11' then ReservedValue();
integer esize = 8 << UInt(size);
integer datasize = 64;
integer part = UInt(Q);
integer elements = datasize DIV esize;

boolean sub_op = (o1 == '1');
```
Assembler Symbols

2. Is the second and upper half specifier. If present it causes the operation to be performed on the upper 64 bits of the registers holding
the narrower elements, and is encoded in “Q”:

<table>
<thead>
<tr>
<th>Q</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>[absent]</td>
</tr>
<tr>
<td>1</td>
<td>[present]</td>
</tr>
</tbody>
</table>

<Vd> Is the name of the SIMD&FP destination register, encoded in the “Rd” field.

<Ta> Is an arrangement specifier, encoded in “size”:

<table>
<thead>
<tr>
<th>size</th>
<th>&lt;Ta&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>RESERVED</td>
</tr>
<tr>
<td>01</td>
<td>4S</td>
</tr>
<tr>
<td>10</td>
<td>2D</td>
</tr>
<tr>
<td>11</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

<Vn> Is the name of the first SIMD&FP source register, encoded in the “Rn” field.

<Tb> Is an arrangement specifier, encoded in “size:Q”:

<table>
<thead>
<tr>
<th>size</th>
<th>Q</th>
<th>&lt;Tb&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>x</td>
<td>RESERVED</td>
</tr>
<tr>
<td>01</td>
<td>0</td>
<td>4H</td>
</tr>
<tr>
<td>01</td>
<td>1</td>
<td>8H</td>
</tr>
<tr>
<td>10</td>
<td>0</td>
<td>2S</td>
</tr>
<tr>
<td>10</td>
<td>1</td>
<td>4S</td>
</tr>
<tr>
<td>11</td>
<td>x</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

<Vm> Is the name of the second SIMD&FP source register, encoded in the “Rm” field.

<Va> Is the destination width specifier, encoded in “size”:

<table>
<thead>
<tr>
<th>size</th>
<th>&lt;Va&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>RESERVED</td>
</tr>
<tr>
<td>01</td>
<td>S</td>
</tr>
<tr>
<td>10</td>
<td>D</td>
</tr>
<tr>
<td>11</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

<d> Is the number of the SIMD&FP destination register, encoded in the “Rd” field.

<Vb> Is the source width specifier, encoded in “size”:

<table>
<thead>
<tr>
<th>size</th>
<th>&lt;Vb&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>RESERVED</td>
</tr>
<tr>
<td>01</td>
<td>H</td>
</tr>
<tr>
<td>10</td>
<td>S</td>
</tr>
<tr>
<td>11</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

<n> Is the number of the first SIMD&FP source register, encoded in the “Rn” field.

<m> Is the number of the second SIMD&FP source register, encoded in the “Rm” field.
Operation

```c
CheckFPAdvSIMEnabled64();
bits(datasize) operand1 = Vpart[n, part];
bits(datasize) operand2 = Vpart[m, part];
bits(2*datasize) operand3 = V[d];
bits(2*datasize) result;
integer element1;
integer element2;
bits(2*esize) product;
integer accum;
boolean sat1;
boolean sat2;
for e = 0 to elements-1
    element1 = SInt(Elem[operand1, e, esize]);
    element2 = SInt(Elem[operand2, e, esize]);
    (product, sat1) = SignedSatQ(2 * element1 * element2, 2*esize);
    if sub_op then
        accum = SInt(Elem[operand3, e, 2*esize]) - SInt(product);
    else
        accum = SInt(Elem[operand3, e, 2*esize]) + SInt(product);
    (Elem[result, e, 2*esize], sat2) = SignedSatQ(accum, 2*esize);
if sat1 || sat2 then FPSR.QC = '1';
V[d] = result;
```

Internal version only: isa v30.25, AdvSIMD v29.05, pseudocode v85-xml-00bet8_rc3-35v, Build timestamp: 2018-09-13T13:20:45-04:45

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SQDMLSL, SQDMLSL2 (by element)

Signed saturating Doubling Multiply-Subtract Long (by element). This instruction multiplies each vector element in the lower or upper half of the first source SIMD&FP register by the specified vector element of the second source SIMD&FP register, doubles the results, and subtracts the final results from the vector elements of the destination SIMD&FP register. The destination vector elements are twice as long as the elements that are multiplied. All the values in this instruction are signed integer values.

If overflow occurs with any of the results, those results are saturated. If saturation occurs, the cumulative saturation bit FPSR.QC is set.

The SQDMLSL instruction extracts vector elements from the lower half of the first source register, while the SQDMLSL2 instruction extracts vector elements from the upper half of the first source register.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

It has encodings from 2 classes: Scalar and Vector

Scalar

|       | 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 |  9 |  8 |  7 |  6 |  5 |  4 |  3 |  2 |  1 |  0 |
|-------|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0     | 1  | 0  | 1  | 1  | 1  | 1  | size | L | M | Rm | 0  | 1  | 1  | H  | 0  | Rn | Rd |
| o2    |    |    |    |    |    |    |      |   |   |    |    |    |    |      |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |

Scalar

```plaintext
SQDMLSL <Va<d>, <Vb<n>, <Vm>.<Ts>[<index>]
```

```plaintext
integer idxdsiz = if H == '1' then 128 else 64;
integer index;
bit Rmhi;
case size of
    when '01' index = UInt(H:L:M); Rmhi = '0';
    when '10' index = UInt(H:L); Rmhi = M;
    otherwise UNDEFINED;
integer d = otherwise UnallocatedEncoding();
integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rmhi:Rm);
integer esize = 8 << UInt(size);
integer datasize = esize;
integer elements = 1;
integer part = 0;
boolean sub_op = (o2 == '1');
```

Vector

```plaintext
SQDMLSL <Va<d>, <Vb<n>, <Vm>.<Ts>[<index>]
```

```plaintext
integer idxdsiz = if H == '1' then 128 else 64;
integer index;
bit Rmhi;
case size of
    when '01' index = UInt(H:L:M); Rmhi = '0';
    when '10' index = UInt(H:L); Rmhi = M;
    otherwise UNDEFINED;
integer d = otherwise UnallocatedEncoding();
integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rmhi:Rm);
integer esize = 8 << UInt(size);
integer datasize = esize;
integer elements = 1;
integer part = 0;
boolean sub_op = (o2 == '1');
```
Vector

`SQDMLSL[2] <Vd>,<Ta>, <Vn>,<Tb>, <Vm>,<Ts>[<index>]`

```plaintext
type integer idxdsiz = if H == '1' then 128 else 64;
type integer index;
type bit Rmhi;
case size of
  when '01' index = UInt(H:L:M); Rmhi = '0';
  when '10' index = UInt(H:L); Rmhi = M;
  otherwise UNDEFINED;

type integer d = otherwise UnallocatedEncoding();
type integer d = UInt(Rd);
type integer n = UInt(Rn);
type integer m = UInt(Rmhi:Rm);
type integer esize = 8 << UInt(size);
type integer datasize = 64;
type integer part = UInt(Q);
type integer elements = datasize DIV esize;

type boolean sub_op = (o2 == '1');
```

**Assembler Symbols**

2

Is the second and upper half specifier. If present it causes the operation to be performed on the upper 64 bits of the registers holding the narrower elements, and is encoded in “Q”:

<table>
<thead>
<tr>
<th>Q</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>[absent]</td>
</tr>
<tr>
<td>1</td>
<td>[present]</td>
</tr>
</tbody>
</table>

`<Vd>`

Is the name of the SIMD&FP destination register, encoded in the “Rd” field.

`<Ta>`

Is an arrangement specifier, encoded in “size”:

<table>
<thead>
<tr>
<th>size</th>
<th>&lt;Ta&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>RESERVED</td>
</tr>
<tr>
<td>01</td>
<td>4S</td>
</tr>
<tr>
<td>10</td>
<td>2D</td>
</tr>
<tr>
<td>11</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

`<Vn>`

Is the name of the first SIMD&FP source register, encoded in the “Rn” field.

`<Tb>`

Is an arrangement specifier, encoded in “size:Q”:

<table>
<thead>
<tr>
<th>size</th>
<th>Q</th>
<th>&lt;Tb&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>x</td>
<td>RESERVED</td>
</tr>
<tr>
<td>01</td>
<td>0</td>
<td>4H</td>
</tr>
<tr>
<td>01</td>
<td>1</td>
<td>8H</td>
</tr>
<tr>
<td>10</td>
<td>0</td>
<td>2S</td>
</tr>
<tr>
<td>10</td>
<td>1</td>
<td>4S</td>
</tr>
<tr>
<td>11</td>
<td>x</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

`<Va>`

Is the destination width specifier, encoded in “size”:

<table>
<thead>
<tr>
<th>size</th>
<th>&lt;Va&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>RESERVED</td>
</tr>
<tr>
<td>01</td>
<td>S</td>
</tr>
<tr>
<td>10</td>
<td>D</td>
</tr>
<tr>
<td>11</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

`<d>`

Is the number of the SIMD&FP destination register, encoded in the “Rd” field.

`<Vb>`

Is the source width specifier, encoded in “size”:
Is the number of the first SIMD&FP source register, encoded in the "Rn" field.

Is the name of the second SIMD&FP source register, encoded in “size:M:Rm”:

Restricted to V0-V15 when element size <Ts> is H.

Is an element size specifier, encoded in “size”: 

Is the element index, encoded in “size:L:H:M”:

Operation

```c
CheckFPAdvSIMDEnabled64();
bits(datasize) operand1 = Vpart[n, part];
bits(idxdsize) operand2 = V[m];
bits(2*datasize) operand3 = V[d];
bits(2*.datasize) result;
integer element1;
integer element2;
b bits(2*esize) product;
integer accum;
boolean sat1;
boolean sat2;

element2 = SInt(Elem[operand2, index, esize]);
for e = 0 to elements-1
    element1 = SInt(Elem[operand1, e, esize]);
    (product, sat1) = SignedSatQ(2 * element1 * element2, 2*esize);
    if sub_op then
        accum = SInt(Elem[operand3, e, 2*esize]) - SInt(product);
    else
        accum = SInt(Elem[operand3, e, 2*esize]) + SInt(product);
    (Elem[result, e, 2*esize], sat2) = SignedSatQ(accum, 2*esize);
    if sat1 || sat2 then FPSR.QC = '1';

V[d] = result;
```
SQDMLSL, SQDMLSL2 (vector)

Signed saturating Doubling Multiply-Subtract Long. This instruction multiplies corresponding signed integer values in the lower or upper half of the vectors of the two source SIMD&FP registers, doubles the results, and subtracts the final results from the vector elements of the destination SIMD&FP register. The destination vector elements are twice as long as the elements that are multiplied.

If overflow occurs with any of the results, those results are saturated. If saturation occurs, the cumulative saturation bit $FPSR.QC$ is set.

The SQDMLSL instruction extracts each source vector from the lower half of each source register, while the SQDMLSL2 instruction extracts each source vector from the upper half of each source register.

Depending on the settings in the $CPACR_EL1$, $CPTR_EL2$, and $CPTR_EL3$ registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

It has encodings from 2 classes: Scalar and Vector

Scalar

31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
0 1 0 1 1 1 0 size 1 1 0 1 1 0 0 0 1 1 1 0 0

Scalar

SQDMLSL $<Va><d>$, $<Vb><n>$, $<Vb><m>$

integer d = $UInt(Rd)$;
integer n = $UInt(Rn)$;
integer m = $UInt(Rm)$;

if size == '00' || size == '11' then UNDEFINED;
integer esize = 8 << if size == '00' || size == '11' then $ReservedValue()$;
integer esize = 8 << $UInt(size)$;
in integer datasize = esize;
integer elements = 1;
integer part = 0;
boolean sub_op = (o1 == '1');

Vector

31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
0 1 0 0 1 1 1 0 size 1 1 0 1 1 0 0 0

Vector

SQDMLSL2(2) $<Vd>.<Ta>$, $<Vn>.<Tb>$, $<Vm>.<Tb>$

integer d = $UInt(Rd)$;
integer n = $UInt(Rn)$;
integer m = $UInt(Rm)$;

if size == '00' || size == '11' then UNDEFINED;
integer esize = 8 << if size == '00' || size == '11' then $ReservedValue()$;
integer esize = 8 << $UInt(size)$;
in integer datasize = 64;
in integer part = $UInt(Q)$;
in integer elements = datasize DIV esize;
boolean sub_op = (o1 == '1');
Assembler Symbols

2  Is the second and upper half specifier. If present it causes the operation to be performed on the upper 64 bits of the registers holding the narrower elements, and is encoded in “Q”:

<table>
<thead>
<tr>
<th>Q</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>[absent]</td>
</tr>
<tr>
<td>1</td>
<td>[present]</td>
</tr>
</tbody>
</table>

<Vd>  Is the name of the SIMD&FP destination register, encoded in the "Rd" field.
<Ta>  Is an arrangement specifier, encoded in “size”:

<table>
<thead>
<tr>
<th>size &lt;Ta&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00   RESERVED</td>
</tr>
<tr>
<td>01   4S</td>
</tr>
<tr>
<td>10   2D</td>
</tr>
<tr>
<td>11   RESERVED</td>
</tr>
</tbody>
</table>

<Vn>  Is the name of the first SIMD&FP source register, encoded in the "Rn" field.
<Tb>  Is an arrangement specifier, encoded in “size:Q”:

<table>
<thead>
<tr>
<th>size Q &lt;Tb&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00   x RESERVED</td>
</tr>
<tr>
<td>01   0 4H</td>
</tr>
<tr>
<td>01   1 8H</td>
</tr>
<tr>
<td>10   0 2S</td>
</tr>
<tr>
<td>10   1 4S</td>
</tr>
<tr>
<td>11   x RESERVED</td>
</tr>
</tbody>
</table>

<Vm>  Is the name of the second SIMD&FP source register, encoded in the "Rm" field.
<Va>  Is the destination width specifier, encoded in “size”:

<table>
<thead>
<tr>
<th>size &lt;Va&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00   RESERVED</td>
</tr>
<tr>
<td>01   S</td>
</tr>
<tr>
<td>10   D</td>
</tr>
<tr>
<td>11   RESERVED</td>
</tr>
</tbody>
</table>

<d>  Is the number of the SIMD&FP destination register, encoded in the "Rd" field.
<Vb>  Is the source width specifier, encoded in “size”:

<table>
<thead>
<tr>
<th>size &lt;Vb&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00   RESERVED</td>
</tr>
<tr>
<td>01   H</td>
</tr>
<tr>
<td>10   S</td>
</tr>
<tr>
<td>11   RESERVED</td>
</tr>
</tbody>
</table>

<n>  Is the number of the first SIMD&FP source register, encoded in the "Rn" field.
<m>  Is the number of the second SIMD&FP source register, encoded in the "Rm" field.
Operation

```c
CheckFPAdvSIMEnabled64();
bits(datasize) operand1 = Vpart[n, part];
bits(datasize) operand2 = Vpart[m, part];
bits(2*datasize) operand3 = V[d];
bits(2*datasize) result;
integer element1;
integer element2;
bits(2*esize) product;
integer accum;
boolean sat1;
boolean sat2;

for e = 0 to elements-1
  element1 = SInt(Elem[operand1, e, esize]);
  element2 = SInt(Elem[operand2, e, esize]);
  (product, sat1) = SignedSatQ(2 * element1 * element2, 2*esize);
  if sub_op then
    accum = SInt(Elem[operand3, e, 2*esize]) - SInt(product);
  else
    accum = SInt(Elem[operand3, e, 2*esize]) + SInt(product);
  (Elem[result, e, 2*esize], sat2) = SignedSatQ(accum, 2*esize);
  if sat1 || sat2 then FPSR.QC = '1';
V[d] = result;
```

Internal version only: isa v30.25 v29.05, AdvSIMD v27.01 v26.0, pseudocode v85-xml-00bet8_rc3-355; Build timestamp: 2018-09-13T13:2018-06-16T09:04:45

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SQDMULH (by element)

Signed saturating Doubling Multiply returning High half (by element). This instruction multiplies each vector element in the first source SIMD&FP register by the specified vector element of the second source SIMD&FP register, doubles the results, places the most significant half of the final results into a vector, and writes the vector to the destination SIMD&FP register.

The results are truncated. For rounded results, see SQRDMULH.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

It has encodings from 2 classes: Scalar and Vector

Scalar

SQDMULH <V><d>, <V><n>, <Vm>.<Ts>[<index>]

```plaintext
integer idxdsz = if H == '1' then 128 else 64;
integer index;
bv Rmhi;
case size of
  when '01' index = UInt(H:L:M); Rmhi = '0';
  when '10' index = UInt(H:L); Rmhi = M;
otherwise UNDEFINED;

integer d = otherwise UnallocatedEncoding();
integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rmhi:Rm);

integer esize = 8 << UInt(size);
integer datasize = esize;
integer elements = 1;

boolean round = (op == '1');
```

Vector

```plaintext
```
Vector

\[ \text{SQDMULH} <V_d>, <V_n>, <T>, <V_m>[<index>] \]

```plaintext
integer idxdsize = if H == '1' then 128 else 64;
integer index;
bit Rmhi;

case size of
    when '01' index = UInt(H:L:M); Rmhi = '0';
    when '10' index = UInt(H:L); Rmhi = M;
    otherwise UNDEFINED;
integer d = otherwise UnallocatedEncoding();
integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rmhi:Rm);

integer esize = 8 << UInt(size);
integer datasize = if Q == '1' then 128 else 64;
integer elements = datasize DIV esize;
boolean round = (op == '1');
```

Assembler Symbols

- `<V>` is a width specifier, encoded in “size”:
  ```
  size   <V>
  ----   ----
  00     RESERVED
  01     H
  10     S
  11     RESERVED
  ```

- `<d>` is the number of the SIMD&FP destination register, encoded in the “Rd” field.

- `<n>` is the number of the first SIMD&FP source register, encoded in the "Rn" field.

- `<V_d>` is the name of the SIMD&FP destination register, encoded in the "Rd" field.

- `<T>` is an arrangement specifier, encoded in “size:Q”:
  ```
  size   Q   <T>
  ----   ---- ----
  00     x     RESERVED
  01     0     4H
  01     1     8H
  10     0     2S
  10     1     4S
  11     x     RESERVED
  ```

- `<V_n>` is the name of the first SIMD&FP source register, encoded in the "Rn" field.

- `<V_m>` is the name of the second SIMD&FP source register, encoded in “size:M:Rm”:
  ```
  size   <V_m>
  ----   ----
  00     RESERVED
  01     0:Rm
  10     M:Rm
  11     RESERVED
  ```

Restricted to V0-V15 when element size `<Ts>` is H.

- `<Ts>` is an element size specifier, encoded in “size”:
  ```
  size   <Ts>
  ----   ----
  00     RESERVED
  01     H
  10     S
  11     RESERVED
  ```

- `<index>` is the element index, encoded in “size:L:H:M”:

SQDMULH (by element) Page 1088
Operation

```c
CheckFPAdvSIMDEnabled64();
bits(datasize) operand1 = V[n];
bits(idxdsize) operand2 = V[m];
bits(datasize) result;
integer round_const = if round then 1 << (esize - 1) else 0;
integer element1;
integer element2;
integer product;
boolean sat;

element2 = SInt(Elem[operand2, index, esize]);
for e = 0 to elements-1
    element1 = SInt(Elem[operand1, e, esize]);
    product = (2 * element1 * element2) + round_const;
    // The following only saturates if element1 and element2 equal -(2^(esize-1))
    (Elem[result, e, esize], sat) = SignedSatQ(product >> esize, esize);
    if sat then FPSR.QC = '1';
V[d] = result;
```

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SQDMULH (vector)

Signed saturating Doubling Multiply returning High half. This instruction multiplies the values of corresponding elements of the two source SIMD&FP registers, doubles the results, places the most significant half of the final results into a vector, and writes the vector to the destination SIMD&FP register.

The results are truncated. For rounded results, see SQRDMAIL.

If overflow occurs with any of the results, those results are saturated. If saturation occurs, the cumulative saturation bit FPSR.QC is set.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

It has encodings from 2 classes: Scalar and Vector

Scalar

<table>
<thead>
<tr>
<th>31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 1 0 1 1 1 1 0</td>
</tr>
<tr>
<td>U</td>
</tr>
</tbody>
</table>

Scalar

```c
SQDMULH "<V><d>, <V><n>, <V><m>
```

integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rm);
if size == '11' || size == '00' then UNDEFINED;
integer esize = 8 <<if size == '11' || size == '00' then ReservedValue4;
integer esize = 8 <<UInt(size);
integer datasize = esize;
integer elements = 1;
boolean rounding = (U == '1');

Vector

<table>
<thead>
<tr>
<th>31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 Q 0 1 1 1 0</td>
</tr>
<tr>
<td>U</td>
</tr>
</tbody>
</table>

Vector

```c
SQDMULH "<Vd>.<T>, <Vn>.<T>, <Vm>.<T>
```

integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rm);
if size == '11' || size == '00' then UNDEFINED;
integer esize = 8 <<if size == '11' || size == '00' then ReservedValue4;
integer esize = 8 <<UInt(size);
integer datasize = if Q == '1' then 128 else 64;
integer elements = datasize DIV esize;
boolean rounding = (U == '1');

Assembler Symbols

```
<V> Is a width specifier, encoded in "size":
```
<table>
<thead>
<tr>
<th>size</th>
<th>&lt;V&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>RESERVED</td>
</tr>
<tr>
<td>01</td>
<td>H</td>
</tr>
<tr>
<td>10</td>
<td>S</td>
</tr>
<tr>
<td>11</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

<d> Is the number of the SIMD&FP destination register, in the "Rd" field.

<n> Is the number of the first SIMD&FP source register, encoded in the "Rn" field.

<m> Is the number of the second SIMD&FP source register, encoded in the "Rm" field.

<Vd> Is the name of the SIMD&FP destination register, encoded in the "Rd" field.

<T> Is an arrangement specifier, encoded in “size:Q”:

<table>
<thead>
<tr>
<th>size Q</th>
<th>&lt;T&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>x</td>
</tr>
<tr>
<td>01 0</td>
<td>4H</td>
</tr>
<tr>
<td>01 1</td>
<td>8H</td>
</tr>
<tr>
<td>10 0</td>
<td>2S</td>
</tr>
<tr>
<td>10 1</td>
<td>4S</td>
</tr>
<tr>
<td>11 x</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

<Vn> Is the name of the first SIMD&FP source register, encoded in the "Rn" field.

<Vm> Is the name of the second SIMD&FP source register, encoded in the "Rm" field.

**Operation**

```c
#include <lib/integer.h>
#include <lib/int64.h>
#include <lib/wm64.h>
#include <limit.h>

void CheckFPAdvSIMDEnabled64();

void SQDMULH(const uint64_t *operand1, const uint64_t *operand2, uint64_t *result, uint64_t esize);

void SQDMULH(const uint64_t *operand1, const uint64_t *operand2, uint64_t *result, uint64_t esize)
{
    int64_t bits[2];
    int16_t maxIn = (esize >> 1) + 1;
    int16_t maxOut = (esize >> 1) + 1;
    int16_t product = int32_t((operand1[0] * operand2[0]) >> esize);
    int16_t sat = (product >> esize) > maxOut;
    int16_t round_const = (sat ? 0 : product >> esize);
    int16_t result = int32_t((operand1[0] * operand2[0]) >> esize);
    int16_t satres = SInt2Q(result, esize, sat);
    if (satres != result)
    {
        FPSR.QC = 1;
        result = satres;
    }

    SQDMULH(operand1, operand2, result, esize);
}
```

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SQDMULL, SQDMULL2 (by element)

Signed saturating Doubling Multiply Long (by element). This instruction multiplies each vector element in the lower or upper half of the first source SIMD&FP register by the specified vector element of the second source SIMD&FP register, doubles the results, places the final results in a vector, and writes the vector to the destination SIMD&FP register. All the values in this instruction are signed integer values. If overflow occurs with any of the results, those results are saturated. If saturation occurs, the cumulative saturation bit \( \text{FPSR}.\text{QC} \) is set.

The SQDMULL instruction extracts the first source vector from the lower half of the first source register, while the SQDMULL2 instruction extracts the first source vector from the upper half of the first source register.

Depending on the settings in the \( \text{CPACR\_EL1, CPTR\_EL2, and CPTR\_EL3} \) registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

It has encodings from 2 classes: Scalar and Vector

**Scalar**

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0  | 1  | 0  | 1  | 1  | 1  | 1  | size | L | M | Rm | 1  | 0  | 1  | 1  | H | 0  | Rn | Rd |

**Scalar**

\[ \text{SQDMULL} \ang{Va}\ang{d}, \ang{Vb}\ang{n}, \ang{Vm}.\ang{Ts}[\langle index\rangle] \]

```plaintext
integer idxdsize = if H == '1' then 128 else 64;
integer index;
bit Rmhi;
case size of
    when '01' index = \text{UInt}(H:L:M); Rmhi = '0';
    when '10' index = \text{UInt}(H:L);   Rmhi = M;
otherwise UNDEFINED;

integer d = otherwise \text{UnallocatedEncoding}();
integer d = \text{UInt}(Rd);
integer n = \text{UInt}(Rn);
integer m = \text{UInt}(Rmhi:Rm);

integer esize = 8 << \text{UInt}(size);
integer datasize = esize;
integer elements = 1;
integer part = 0;
```

**Vector**

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0  | O | 0  | 1  | 1  | 1  | 1  | size | L | M | Rm | 1  | 0  | 1  | 1  | H | 0  | Rn | Rd |

SQDMULL, SQDMULL2 (by element)
Vector

\[
\text{SQDMULL}(2) \ <Vd>, <Ta>, <Vn>, <Tb>, <Vm>, <Ts>[<index>]\]

```plaintext
integer idxdsz = if H == '1' then 128 else 64;
integer index;
bit Rmhi;
case size of
  when '01' index = UInt(H:L:M); Rmhi = '0';
  when '10' index = UInt(H:L);   Rmhi = M;
  otherwise UNDEFINED;

integer d = otherwise UnallocatedEncoding();

integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rmhi:Rm);

integer esize = 8 << UInt(size);
integer datasize = 64;
integer part = UInt(Q);
integer elements = datasize DIV esize;
```

**Assembler Symbols**

2

Is the second and upper half specifier. If present it causes the operation to be performed on the upper 64 bits of the registers holding the narrower elements, and is encoded in “Q”:

<table>
<thead>
<tr>
<th>Q</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>[absent]</td>
</tr>
<tr>
<td>1</td>
<td>[present]</td>
</tr>
</tbody>
</table>

\(<Vd>\)

Is the name of the SIMD&FP destination register, encoded in the "Rd" field.

\(<Ta>\)

Is an arrangement specifier, encoded in “size”:

<table>
<thead>
<tr>
<th>size</th>
<th>&lt;Ta&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>RESERVED</td>
</tr>
<tr>
<td>01</td>
<td>4S</td>
</tr>
<tr>
<td>10</td>
<td>2D</td>
</tr>
<tr>
<td>11</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

\(<Vn>\)

Is the name of the first SIMD&FP source register, encoded in the "Rn" field.

\(<Tb>\)

Is an arrangement specifier, encoded in “size:Q”:

<table>
<thead>
<tr>
<th>size</th>
<th>Q</th>
<th>&lt;Tb&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>x</td>
<td>RESERVED</td>
</tr>
<tr>
<td>01</td>
<td>0</td>
<td>4H</td>
</tr>
<tr>
<td>01</td>
<td>1</td>
<td>8H</td>
</tr>
<tr>
<td>10</td>
<td>0</td>
<td>2S</td>
</tr>
<tr>
<td>10</td>
<td>1</td>
<td>4S</td>
</tr>
<tr>
<td>11</td>
<td>x</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

\(<Va>\)

Is the destination width specifier, encoded in “size”:

<table>
<thead>
<tr>
<th>size</th>
<th>&lt;Va&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>RESERVED</td>
</tr>
<tr>
<td>01</td>
<td>S</td>
</tr>
<tr>
<td>10</td>
<td>D</td>
</tr>
<tr>
<td>11</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

\(<d>\)

Is the number of the SIMD&FP destination register, encoded in the "Rd" field.

\(<Vb>\)

Is the source width specifier, encoded in “size”:

<table>
<thead>
<tr>
<th>size</th>
<th>&lt;Vb&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>RESERVED</td>
</tr>
<tr>
<td>01</td>
<td>H</td>
</tr>
<tr>
<td>10</td>
<td>S</td>
</tr>
<tr>
<td>11</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

\(<n>\)

Is the number of the first SIMD&FP source register, encoded in the "Rn" field.
Is the name of the second SIMD&FP source register, encoded in “size:M:Rm”:

<table>
<thead>
<tr>
<th>size</th>
<th>&lt;Vm&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>RESERVED</td>
</tr>
<tr>
<td>01</td>
<td>0:Rm</td>
</tr>
<tr>
<td>10</td>
<td>M:Rm</td>
</tr>
<tr>
<td>11</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

Restricted to V0-V15 when element size `<Ts>` is H.

Is an element size specifier, encoded in “size”:

<table>
<thead>
<tr>
<th>size</th>
<th>&lt;Ts&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>RESERVED</td>
</tr>
<tr>
<td>01</td>
<td>H</td>
</tr>
<tr>
<td>10</td>
<td>S</td>
</tr>
<tr>
<td>11</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

Is the element index, encoded in “size:L:H:M”:

<table>
<thead>
<tr>
<th>size</th>
<th>&lt;index&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>RESERVED</td>
</tr>
<tr>
<td>01</td>
<td>H:L:M</td>
</tr>
<tr>
<td>10</td>
<td>H:L</td>
</tr>
<tr>
<td>11</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

### Operation

```c
CheckFPAdvSIMDEnabled64();

bits(datasize) operand1 = Vpart[n, part];
bits(idxdsize) operand2 = V[m];
bits(2*datasize) result;
integer element1;
integer element2;
bits(2*esize) product;
boolean sat;

element2 = SInt(Elem[operand2, index, esize]);
for e = 0 to elements-1
    element1 = SInt(Elem[operand1, e, esize]);
    (product, sat) = SignedSatQ(2 * element1 * element2, 2*esize);
    Elem[result, e, 2*esize] = product;
    if sat then FPSR.QC = '1';

V[d] = result;
```

Internal version only: isa v90.25-20.05, AdvSIMD v27.0.1b264, pseudocode v85-xml-00bet8_rc3.353 ; Build timestamp: 2018-09-13T13:2018-06-16T09:04:45

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SQDMULL, SQDMULL2 (vector)

Signed saturating Doubling Multiply Long. This instruction multiplies corresponding vector elements in the lower or upper half of the two source SIMD&FP registers, doubles the results, places the final results in a vector, and writes the vector to the destination SIMD&FP register. If overflow occurs with any of the results, those results are saturated. If saturation occurs, the cumulative saturation bit 

FPSCR QC is set. The SQDMULL instruction extracts each source vector from the lower half of each source register, while the SQDMULL2 instruction extracts each source vector from the upper half of each source register.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

It has encodings from 2 classes: Scalar and Vector

Scalar

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9  | 8  | 7  | 6  | 5  | 4  | 3  | 2  | 1  | 0  |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0  | 1  | 0  | 1  | 1  | 1  | 0  | size | 1  | Rm  | 1  | 1  | 0  | 1  | 0  | 0  | Rn  | Rd |

Scalar

SQDMULL <Va><d>, <Vb><n>, <Vb><m>

```plaintext
to INTEGER(Rd);
to INTEGER(Rn);
to INTEGER(Rm);
    if size == '00' || size == '11' then UNDEFINED;
    INTEGER esize = 8 << if size == '00' || size == '11' then ReservedValue();
    INTEGER esize = 8 << INTEGER(size);
    INTEGER datasize = esize;
    INTEGER elements = 1;
    INTEGER part = 0;
```

Vector

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9  | 8  | 7  | 6  | 5  | 4  | 3  | 2  | 1  | 0  |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| Q  | 0  | 0  | 1  | 1  | 1  | 0  | size | 1  | Rm  | 1  | 1  | 0  | 1  | 0  | 0  | Rn  | Rd |

Vector

SQDMULL[2] <Vd>.<Ta>, <Vn>.<Tb>, <Vm>.<Tb>

```plaintext
to INTEGER(Rd);
to INTEGER(Rn);
to INTEGER(Rm);
    if size == '00' || size == '11' then UNDEFINED;
    INTEGER esize = 8 << if size == '00' || size == '11' then ReservedValue();
    INTEGER esize = 8 << INTEGER(size);
    INTEGER datasize = 64;
    INTEGER part = INTEGER(Q);
    INTEGER elements = datasize DIV esize;
```

Assembler Symbols

2

Is the second and upper half specifier. If present it causes the operation to be performed on the upper 64 bits of the registers holding the narrower elements, and is encoded in “Q”:

<table>
<thead>
<tr>
<th>Q</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>[absent]</td>
</tr>
<tr>
<td>1</td>
<td>[present]</td>
</tr>
</tbody>
</table>
<Vd> Is the name of the SIMD&FP destination register, encoded in the "Rd" field.

<Ta> Is an arrangement specifier, encoded in “size”:

<table>
<thead>
<tr>
<th>size</th>
<th>&lt;Ta&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>RESERVED</td>
</tr>
<tr>
<td>01</td>
<td>4S</td>
</tr>
<tr>
<td>10</td>
<td>2D</td>
</tr>
<tr>
<td>11</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

<Vn> Is the name of the first SIMD&FP source register, encoded in the "Rn" field.

<Tb> Is an arrangement specifier, encoded in “size:Q”:

<table>
<thead>
<tr>
<th>size</th>
<th>Q</th>
<th>&lt;Tb&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>x</td>
<td>RESERVED</td>
</tr>
<tr>
<td>01</td>
<td>0</td>
<td>4H</td>
</tr>
<tr>
<td>01</td>
<td>1</td>
<td>8H</td>
</tr>
<tr>
<td>10</td>
<td>0</td>
<td>2S</td>
</tr>
<tr>
<td>10</td>
<td>1</td>
<td>4S</td>
</tr>
<tr>
<td>11</td>
<td>x</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

<Vm> Is the name of the second SIMD&FP source register, encoded in the "Rm" field.

<Va> Is the destination width specifier, encoded in “size”:

<table>
<thead>
<tr>
<th>size</th>
<th>&lt;Va&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>RESERVED</td>
</tr>
<tr>
<td>01</td>
<td>S</td>
</tr>
<tr>
<td>10</td>
<td>D</td>
</tr>
<tr>
<td>11</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

<d> Is the number of the SIMD&FP destination register, encoded in the "Rd" field.

<Vb> Is the source width specifier, encoded in “size”:

<table>
<thead>
<tr>
<th>size</th>
<th>&lt;Vb&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>RESERVED</td>
</tr>
<tr>
<td>01</td>
<td>H</td>
</tr>
<tr>
<td>10</td>
<td>S</td>
</tr>
<tr>
<td>11</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

<n> Is the number of the first SIMD&FP source register, encoded in the "Rn" field.

<m> Is the number of the second SIMD&FP source register, encoded in the "Rm" field.

**Operation**

```c
CheckFPAdvSIMDEnabled64();
bits(datasize) operand1 = Vpart[n, part];
bits(datasize) operand2 = Vpart[m, part];
bits(2*datasize) result;
integer element1;
integer element2;
bits(2*esize) product;
boolean sat;
for e = 0 to elements-1
  element1 = SInt(Elem[operand1, e, esize]);
  element2 = SInt(Elem[operand2, e, esize]);
  (product, sat) = SignedSatQ(2 * element1 * element2, 2*esize);
  Elem[result, e, 2*esize] = product;
if sat then FPSR.QC = '1';
V[d] = result;
```

Internal version only: isa v30.25,v29.05, AdvSIMD v27.01,v26.0, pseudocode v85-xml-00bce8/rc32582; Build timestamp: 2018-09-13T13:45

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SQNEG

Signed saturating Negate. This instruction reads each vector element from the source SIMD&FP register, negates each value, places the result into a vector, and writes the vector to the destination SIMD&FP register. All the values in this instruction are signed integer values.

If overflow occurs with any of the results, those results are saturated. If saturation occurs, the cumulative saturation bit \textit{FPSR}.QC is set.

Depending on the settings in the \textit{CPACR_EL1}, \textit{CPTR_EL2}, and \textit{CPTR_EL3} registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

It has encodings from 2 classes: \textbf{Scalar} and \textbf{Vector}.

\textbf{Scalar}

\begin{verbatim}
<table>
<thead>
<tr>
<th>size</th>
<th>Rd</th>
<th>Rn</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 1 1 1 1 1 0</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
\end{verbatim}

\textbf{Scalar}

\begin{verbatim}
Integer d = \texttt{UInt}(Rd);
Integer n = \texttt{UInt}(Rn);
Integer esize = 8 << \texttt{UInt}(size);
Integer datasize = esize;
Integer elements = 1;
Boolean neg = (U == '1');
\end{verbatim}

\textbf{Vector}

\begin{verbatim}
<table>
<thead>
<tr>
<th>size</th>
<th>Rd</th>
<th>Rn</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 1 1 1 1 1 0</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
\end{verbatim}

\textbf{Vector}

\begin{verbatim}
Integer d = \texttt{UInt}(Rd);
Integer n = \texttt{UInt}(Rn);
If size:Q == '110' then UNDEFINED;
Integer esize = 8 << \texttt{UInt}(size);
Integer datasize = datasize DIV esize;
Boolean neg = (U == '1');
\end{verbatim}

\textbf{Assembler Symbols}

\begin{verbatim}

| <V> Is a width specifier, encoded in "size":

\begin{tabular}{c|c}
<table>
<thead>
<tr>
<th>size</th>
<th>&lt;V&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>B</td>
</tr>
<tr>
<td>01</td>
<td>H</td>
</tr>
<tr>
<td>10</td>
<td>S</td>
</tr>
<tr>
<td>11</td>
<td>D</td>
</tr>
</tbody>
</table>
\end{tabular}

| <d> Is the number of the SIMD&FP destination register, encoded in the "Rd" field.

| <n> Is the number of the SIMD&FP source register, encoded in the "Rn" field.

\end{verbatim}
<Vd>
Is the name of the SIMD&FP destination register, encoded in the "Rd" field.

<T>
Is an arrangement specifier, encoded in “size-Q”:

<table>
<thead>
<tr>
<th>size</th>
<th>Q</th>
<th>&lt;T&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>0</td>
<td>8B</td>
</tr>
<tr>
<td>00</td>
<td>1</td>
<td>16B</td>
</tr>
<tr>
<td>01</td>
<td>0</td>
<td>4H</td>
</tr>
<tr>
<td>01</td>
<td>1</td>
<td>8H</td>
</tr>
<tr>
<td>10</td>
<td>0</td>
<td>2S</td>
</tr>
<tr>
<td>10</td>
<td>1</td>
<td>4S</td>
</tr>
<tr>
<td>11</td>
<td>0</td>
<td>RESERVED</td>
</tr>
<tr>
<td>11</td>
<td>1</td>
<td>2D</td>
</tr>
</tbody>
</table>

<Vn>
Is the name of the SIMD&FP source register, encoded in the "Rn" field.

Operation

```c
CheckFPAdvSIMDEnabled64();
bits(datasize) operand = V[n];
bits(datasize) result;
integer element;
boolean sat;
for e = 0 to elements-1
    element = SInt(Elem[operand, e, esize]);
    if neg then
        element = -element;
    else
        element = Abs(element);
    (Elem[result, e, esize], sat) = SignedSatQ(element, esize);
    if sat then FPSR.QC = '1';
V[d] = result;
```

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SQRDMLAH (by element)

Signed Saturating Rounding Doubling Multiply Accumulate returning High Half (by element). This instruction multiplies the vector elements of the first source SIMD&FP register with the value of a vector element of the second source SIMD&FP register without saturating the multiply results, doubles the results, and accumulates the most significant half of the final results with the vector elements of the destination SIMD&FP register. The results are rounded.

If any of the results overflow, they are saturated. The cumulative saturation bit, FPSR.QC, is set if saturation occurs.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

It has encodings from 2 classes: Scalar and Vector

Scalar
(ARMv8.1)

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9  | 8  | 7  | 6  | 5  | 4  | 3  | 2  | 1  | 0  |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0  | 1  | 1  | 1  | 1  | 1  | L  | M  | Rm | 1  | 1  | 0  | 1  | H  | 0  | Rn | Rd |

Scalar

SQRDMLAH <V><d>, <V><n>, <Vm>.<Ts>[<index>]

```hl Lang=cpp
if !HaveQRDMLAHExt() then UNDEFINED;

integer idxdsize = if H == '1' then 128 else 64;
integer index;
bit Rmhi;
case size of
  when '01' index = (H:L:M); Rmhi = '0';
  when '10' index = UInt(H:L);   Rmhi = M;
  otherwise UnallocatedEncoding(H:L);   Rmhi = M;
  otherwise UNDEFINED;

integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rmhi:Rm);
integer esize = 8 << UInt(size);
integer datasize = esize;
integer elements = 1;

boolean rounding = TRUE;
boolean sub_op = (S == '1');
```

Vector
(ARMv8.1)

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9  | 8  | 7  | 6  | 5  | 4  | 3  | 2  | 1  | 0  |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0  | Q  | 1  | 0  | 1  | 1  | L  | M  | Rm | 1  | 1  | 0  | 1  | H  | 0  | Rn | Rd |

SQRDMLAH (by element)
Vector

SQRDM LAH <Vd>.<T>, <Vn>.<T>, <Vm>.<Ts>[<index>]

```c
if !HaveQRDMLAHExt() then UNDEFINED;

text integer idxsize = if H == '1' then 128 else 64;
text integer index;
text bit Rmhi;
text case size of
  when '01' index = () then UnallocatedEncoding();
text integer idxsize = if H == '1' then 128 else 64;
text integer index;
text bit Rmhi;
text case size of
  when '01' index = UInt(H:L:M); Rmhi = '0';
  when '10' index = UInt(H:L); Rmhi = M;
  otherwise UnallocatedEncoding(H:L); Rmhi = M;
  otherwise UNDEFINED;

integer d = UInt(Rd);
text integer n = UInt(Rn);
text integer m = UInt(Rmhi:Rm);
text integer esize = 8 << UInt(size);
text integer datasize = if Q == '1' then 128 else 64;
text integer elements = datasize DIV esize;

boolean rounding = TRUE;
text boolean sub_op = (S == '1');
```

Assembler Symbols

- `<V>`: Is a width specifier, encoded in “size”:
  - size | <V>
    - 00 | RESERVED
    - 01 | H
    - 10 | S
    - 11 | RESERVED

- `<d>`: Is the number of the SIMD&FP destination register, encoded in the "Rd" field.

- `<n>`: Is the number of the first SIMD&FP source register, encoded in the "Rn" field.

- `<Vd>`: Is the name of the SIMD&FP destination register, encoded in the "Rd" field.

- `<T>`: Is an arrangement specifier, encoded in “size:Q”:
  - size | Q | <T>
    - 00 | x | RESERVED
    - 01 | 0 | 4H
    - 01 | 1 | 8H
    - 10 | 0 | 2S
    - 10 | 1 | 4S
    - 11 | x | RESERVED

- `<Vn>`: Is the name of the first SIMD&FP source register, encoded in the "Rn" field.

- `<Vm>`: Is the name of the second SIMD&FP source register, encoded in “size:M:Rm”:
  - size | <Vm>
    - 00 | RESERVED
    - 01 | 0:Rm
    - 10 | M:Rm
    - 11 | RESERVED

Restricted to V0-V15 when element size `<Ts>` is H.

- `<Ts>`: Is an element size specifier, encoded in “size”:

SQRDM LAH (by element)
Operation

```c
CheckFPAdvSIMDEnabled64();
bits(datasize) operand1 = V[n];
bits(idxsize) operand2 = V[m];
bits(datasize) operand3 = V[d];
bits(datasize) result;
integer rounding_const = if rounding then 1 << (esize - 1) else 0;
integer element1;
integer element2;
integer element3;
integer product;
boolean sat;
element2 = SInt(Elem[operand2, index, esize]);
for e = 0 to elements-1
    element1 = SInt(Elem[operand1, e, esize]);
    element3 = SInt(Elem[operand3, e, esize]);
    if sub_op then
        accum = ((element3 << esize) - 2 * (element1 * element2) + rounding_const);
    else
        accum = ((element3 << esize) + 2 * (element1 * element2) + rounding_const);
    (Elem[result, e, esize], sat) = SignedSatQ(accum >> esize, esize);
    if sat then FPSR.QC = '1';
V[d] = result;
```


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SQRDMLAH (vector)

Signed Saturating Rounding Doubling Multiply Accumulate returning High Half (vector). This instruction multiplies the vector elements of the first source SIMD&FP register with the corresponding vector elements of the second source SIMD&FP register without saturating the multiply results, doubles the results, and accumulates the most significant half of the final results with the vector elements of the destination SIMD&FP register. The results are rounded.

If any of the results overflow, they are saturated. The cumulative saturation bit, FPSR.QC, is set if saturation occurs.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

It has encodings from 2 classes: Scalar and Vector

Scalar
(ARMv8.1)

<table>
<thead>
<tr>
<th>31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0</th>
<th>size</th>
<th>Rm</th>
<th>Rn</th>
<th>Rd</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 1 1 1 1 0</td>
<td>0</td>
<td></td>
<td>1</td>
<td>0 0 0 0 1</td>
</tr>
</tbody>
</table>

Scalar

SQRDMLAH <V><d>, <V><n>, <V><m>

```java
if !HaveQRDMLAHExt() then UNDEFINED;

integer d = Rn; 
integer n = UInt(Rn); 
integer m = UInt(Rm);
if size == '11' || size == '00' then ReservedValue(Rm);
if size == '11' || size == '00' then UNDEFINED;

integer esize = 8 << UInt(size); 
integer datasize = esize; 
integer elements = 1; 
boolean rounding = TRUE; 
boolean sub_op = (S == '1');
```

Vector
(ARMv8.1)

<table>
<thead>
<tr>
<th>31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0</th>
<th>size</th>
<th>Rm</th>
<th>Rn</th>
<th>Rd</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 0</td>
<td>1</td>
<td>0 1 1 1 0</td>
<td>0</td>
<td>1</td>
</tr>
</tbody>
</table>
SQRDMLAH \(<Vd>.<T>, <Vn>.<T>, <Vm>.<T>\)

\[
\text{if } \text{HasQRDMLAHExt()} \text{ then UNDEFINED;}
\]
\[
\begin{align*}
\text{integer } d &= \text{UInt}(Rd); \\
\text{integer } n &= \text{UInt}(Rn); \\
\text{integer } m &= \text{UInt}(Rm); \\
\text{if } \text{size} == '11' \text{ || } \text{size} == '00' \text{ then ReservedValue}(Rm); \\
\text{if } \text{size} == '11' \text{ || } \text{size} == '00' \text{ then UNDEFINED; }
\end{align*}
\]
\[
\begin{align*}
\text{integer } \text{esize} &= 8 << \text{UInt}(\text{size}); \\
\text{integer } \text{datasize} &= \text{if } Q == '1' \text{ then 128 else 64}; \\
\text{integer } \text{elements} &= \text{datasize} \text{ DIV esize}; \\
\text{boolean } \text{rounding} &= \text{TRUE}; \\
\text{boolean } \text{sub_op} &= (S == '1');
\end{align*}
\]

**Assembler Symbols**

\(<V>\)  
Is a width specifier, encoded in “size”:

<table>
<thead>
<tr>
<th>size</th>
<th>&lt;V&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>RESERVED</td>
</tr>
<tr>
<td>01</td>
<td>H</td>
</tr>
<tr>
<td>10</td>
<td>S</td>
</tr>
<tr>
<td>11</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

\(<d>\)  
Is the number of the SIMD&FP destination register, in the "Rd" field.

\(<n>\)  
Is the number of the first SIMD&FP source register, encoded in the "Rn" field.

\(<m>\)  
Is the number of the second SIMD&FP source register, encoded in the "Rm" field.

\(<Vd>\)  
Is the name of the SIMD&FP destination register, encoded in the "Rd" field.

\(<T>\)  
Is an arrangement specifier, encoded in “size:Q”:

<table>
<thead>
<tr>
<th>size</th>
<th>Q</th>
<th>&lt;T&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>x</td>
<td>RESERVED</td>
</tr>
<tr>
<td>01</td>
<td>0</td>
<td>4H</td>
</tr>
<tr>
<td>01</td>
<td>1</td>
<td>8H</td>
</tr>
<tr>
<td>10</td>
<td>0</td>
<td>2S</td>
</tr>
<tr>
<td>10</td>
<td>1</td>
<td>4S</td>
</tr>
<tr>
<td>11</td>
<td>x</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

\(<Vn>\)  
Is the name of the first SIMD&FP source register, encoded in the "Rn" field.

\(<Vm>\)  
Is the name of the second SIMD&FP source register, encoded in the "Rm" field.
Operation

CheckFPAdvSIMEnabled64();

bits(datasize) operand1 = \texttt{V}[n];
bits(datasize) operand2 = \texttt{V}[m];
bits(datasize) operand3 = \texttt{V}[d];

bits(datasize) result;

integer rounding_const = if rounding then 1 \ll (esize - 1) else 0;

integer element1;
integer element2;
integer element3;
integer product;
boolean sat;

for e = 0 to elements-1

\begin{align*}
\text{element1} &= \texttt{SInt}(\texttt{Elem}(operand1, e, esize)); \\
\text{element2} &= \texttt{SInt}(\texttt{Elem}(operand2, e, esize)); \\
\text{element3} &= \texttt{SInt}(\texttt{Elem}(operand3, e, esize)); \\
\end{align*}

if sub_op then

\begin{align*}
\text{accum} &= ((\text{element3} \ll esize) - 2 \times (\text{element1} \times \text{element2}) + \text{rounding}\_\text{const}); \\
\end{align*}

else

\begin{align*}
\text{accum} &= ((\text{element3} \ll esize) + 2 \times (\text{element1} \times \text{element2}) + \text{rounding}\_\text{const}); \\
\end{align*}

\begin{align*}
(\texttt{Elem}[\text{result}, e, esize], \text{sat}) &= \texttt{SignedSatQ}(\text{accum} >> \text{esize}, \text{esize}); \\
\end{align*}

if sat then FPSR.QC = '1';

V[d] = result;
SQRDMLSH (by element)

Signed Saturating Rounding Doubling Multiply Subtract returning High Half (by element). This instruction multiplies the vector elements of the first source SIMD&FP register with the value of a vector element of the second source SIMD&FP register without saturating the multiply results, doubles the results, and subtracts the most significant half of the final results from the vector elements of the destination SIMD&FP register. The results are rounded.

If any of the results overflow, they are saturated. The cumulative saturation bit, FPSR.QC, is set if saturation occurs.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

It has encodings from 2 classes: Scalar and Vector

Scalar

(ARMv8.1)

| 31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0 |
|-----------------|-----------------|--------------|-----------------|-----------------|
| 0 1 1 1 1 1 1 1 | size | L | M | Rm | 1 1 1 1 H 0 | Rn | Rd |
| S               |

Scalar

SQRDMLSH <V><d>, <V><n>, <Vm>.<Ts>[<index>]

if !HaveQRDMLAHExt() then UNDEFINED;

integer idxdszsize = if H == '1' then 128 else 64;
integer index;
bit Rmhi;
case size of
  when '01' index = 4 then UnallocatedEncoding();
  integer idxdszsize = if H == '1' then 128 else 64;
  integer index;
  bit Rmhi;
  case size of
    when '01' index = UInt(H:L:M); Rmhi = '0';
    when '10' index = UInt(H:L); Rmhi = M;
    otherwise UnallocatedEncoding(H:L); Rmhi = M;
    otherwise UNDEFINED;
  ()

integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rmhi:Rm);

integer esize = 8 << UInt(size);
integer datasize = esize;
integer elements = 1;

boolean rounding = TRUE;
boolean sub_op = (S == '1');

Vector

(ARMv8.1)

| 31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0 |
|-----------------|-----------------|--------------|-----------------|-----------------|
| 0 | Q | 1 0 1 1 1 1 | size | L | M | Rm | 1 1 1 1 H 0 | Rn | Rd |
| S |
Vector

SQRDMLSH <Vd>.<T>, <Vn>.<T>, <Vm>.<Ts>[<index>]

```c
if (!HaveQRDMLAHExt()) then UNDEFINED;

integer idxdsize = if H == '1' then 128 else 64;
integer index;
bit Rmhi;
case size of
  when '01' index = () then UnallocatedEncoding();
  integer idxdsize = if H == '1' then 128 else 64;
  integer index;
  bit Rmhi;
  case size of
    when '01' index = UInt(H:L:M); Rmhi = '0';
    when '10' index = UInt(H:L); Rmhi = M;
    otherwise UnallocatedEncoding(H:L); Rmhi = M;
    otherwise UNDEFINED;

d = UInt(Rd);
n = UInt(Rn);
m = UInt(Rmhi:Rm);

integer esize = 8 << UInt(size);
integer datasize = if Q == '1' then 128 else 64;
integer elements = datasize DIV esize;

boolean rounding = TRUE;
boolean sub_op = (S == '1');
```

Assembler Symbols

- `<V>`: Is a width specifier, encoded in “size”:
<table>
<thead>
<tr>
<th>size</th>
<th>&lt;V&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>RESERVED</td>
</tr>
<tr>
<td>01</td>
<td>H</td>
</tr>
<tr>
<td>10</td>
<td>S</td>
</tr>
<tr>
<td>11</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

- `<d>`: Is the number of the SIMD&FP destination register, encoded in the "Rd" field.

- `<n>`: Is the number of the first SIMD&FP source register, encoded in the "Rn" field.

- `<Vd>`: Is the name of the SIMD&FP destination register, encoded in the "Rd" field.

- `<T>`: Is an arrangement specifier, encoded in “size:Q”:
<table>
<thead>
<tr>
<th>size</th>
<th>Q</th>
<th>&lt;T&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>x</td>
<td>RESERVED</td>
</tr>
<tr>
<td>01</td>
<td>0</td>
<td>4H</td>
</tr>
<tr>
<td>01</td>
<td>1</td>
<td>8H</td>
</tr>
<tr>
<td>10</td>
<td>0</td>
<td>2S</td>
</tr>
<tr>
<td>10</td>
<td>1</td>
<td>4S</td>
</tr>
<tr>
<td>11</td>
<td>x</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

- `<Vn>`: Is the name of the first SIMD&FP source register, encoded in the "Rn" field.

- `<Vm>`: Is the name of the second SIMD&FP source register, encoded in “size:M:Rm”:
<table>
<thead>
<tr>
<th>size</th>
<th>&lt;Vm&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>RESERVED</td>
</tr>
<tr>
<td>01</td>
<td>0:Rm</td>
</tr>
<tr>
<td>10</td>
<td>M:Rm</td>
</tr>
<tr>
<td>11</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

Restricted to V0-V15 when element size `<Ts>` is H.

- `<Ts>`: Is an element size specifier, encoded in “size”:
Operation

```
CheckFPAdvSIMDEnabled64();

bits(datasize) operand1 = V[n];
bits(idxdsize) operand2 = V[m];
bits(datasize) operand3 = V[d];
bits(datasize) result;

integer rounding_const = if rounding then 1 << (esize - 1) else 0;
integer element1;
integer element2;
integer element3;
integer product;
boolean sat;

element2 = SInt(Elem[operand2, index, esize]);
for e = 0 to elements-1
    element1 = SInt(Elem[operand1, e, esize]);
    element3 = SInt(Elem[operand3, e, esize]);
    if sub_op then
        accum = ((element3 << esize) - 2 * (element1 * element2) + rounding_const);
    else
        accum = ((element3 << esize) + 2 * (element1 * element2) + rounding_const);
    (Elem[result, e, esize], sat) = SignedSatQ(accum >> esize, esize);
    if sat then FPSR.QC = '1';

V[d] = result;
```

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SQRDMLSH (vector)

Signed Saturating Rounding Doubling Multiply Subtract returning High Half (vector). This instruction multiplies the vector elements of the first source SIMD&FP register with the corresponding vector elements of the second source SIMD&FP register without saturating the multiply results, doubles the results, and subtracts the most significant half of the final results from the vector elements of the destination SIMD&FP register. The results are rounded.

If any of the results overflow, they are saturated. The cumulative saturation bit, FPSR.QC, is set if saturation occurs.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

It has encodings from 2 classes: Scalar and Vector

Scalar (ARMv8.1)

|   |   |   |   |   |   |   |   |   |   | size |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   | Rd |
| 0 | 1 | 1 | 1 | 1 | 1 | 0 |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |

Scalar

\[
\text{SQRDMLSH} (<V><d>), (<V><n>), (<V><m>)}
\]

\[
\text{if } !\text{HaveQRDMLAExt}() \text{ then UNDEFINED;}
\]

\[
\text{integer } d = 1 \text{ then unallocatedEncoding();}
\]

\[
\text{integer } d = \text{UInt}(Rd);
\]

\[
\text{integer } n = \text{UInt}(Rn);
\]

\[
\text{integer } m = \text{UInt}(Rm);
\]

\[
\text{if size == '11' } \text{or size == '00'} \text{ then ReservedValue}(Rm);
\]

\[
\text{if size == '11' } \text{or size == '00'} \text{ then UNDEFINED;}
\]

\[
\text{integer esize } = 8 \text{ << UInt(size);}
\]

\[
\text{integer datasize } = \text{esize;}
\]

\[
\text{integer elements } = 1;
\]

\[
\text{boolean rounding } = \text{TRUE;}
\]

\[
\text{boolean sub_op } = (S == '1');
\]

Vector (ARMv8.1)

|   |   |   |   |   |   |   |   |   |   | size |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   | Rd |
| 0 | Q | 1 | 0 | 1 | 1 | 1 | 0 |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |

SQRDMLSH (vector)
Vector

SQRDMLSH <Vd>.<T>, <Vn>.<T>, <Vm>.<T>

```plaintext
if !HaveQRDMLAHExt() then UNDEFINED;

integer d = UnallocatedEncoding();
integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rm);
if size == '11' || size == '00' then ReservedValue(Rm);
if size == '11' || size == '00' then UNDEFINED;

dsize = 8 << UInt(size);
datasize = if Q == '1' then 128 else 64;
elements = datasize DIV esize;

boolean rounding = TRUE;
boolean sub_op = (S == '1');
```

Assembler Symbols

<table>
<thead>
<tr>
<th>&lt;V&gt;</th>
<th>Is a width specifier, encoded in “size”:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>size</td>
</tr>
<tr>
<td></td>
<td>00</td>
</tr>
<tr>
<td></td>
<td>10</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>&lt;d&gt;</th>
<th>Is the number of the SIMD&amp;FP destination register, in the &quot;Rd&quot; field.</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;n&gt;</td>
<td>Is the number of the first SIMD&amp;FP source register, encoded in the &quot;Rn&quot; field.</td>
</tr>
<tr>
<td>&lt;m&gt;</td>
<td>Is the number of the second SIMD&amp;FP source register, encoded in the &quot;Rm&quot; field.</td>
</tr>
<tr>
<td>&lt;Vd&gt;</td>
<td>Is the name of the SIMD&amp;FP destination register, encoded in the &quot;Rd&quot; field.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>&lt;T&gt;</th>
<th>Is an arrangement specifier, encoded in “size:Q”:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>size</td>
</tr>
<tr>
<td></td>
<td>00</td>
</tr>
<tr>
<td></td>
<td>01</td>
</tr>
<tr>
<td></td>
<td>01</td>
</tr>
<tr>
<td></td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>11</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>&lt;Vn&gt;</th>
<th>Is the name of the first SIMD&amp;FP source register, encoded in the &quot;Rn&quot; field.</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;Vm&gt;</td>
<td>Is the name of the second SIMD&amp;FP source register, encoded in the &quot;Rm&quot; field.</td>
</tr>
</tbody>
</table>
Operation

```c
CheckFPAdvSIMEnabled64();
bits(datasize) operand1 = V[n];
bits(datasize) operand2 = V[m];
bits(datasize) operand3 = V[d];
bits(datasize) result;
integer rounding_const = if rounding then 1 << (esize - 1) else 0;
integer element1;
integer element2;
integer element3;
integer product;
boolean sat;

for e = 0 to elements-1
    element1 = SInt(Elem[operand1, e, esize]);
    element2 = SInt(Elem[operand2, e, esize]);
    element3 = SInt(Elem[operand3, e, esize]);
    if sub_op then
        accum = ((element3 << esize) - 2 * (element1 * element2) + rounding_const);
    else
        accum = ((element3 << esize) + 2 * (element1 * element2) + rounding_const);
    (Elem[result, e, esize], sat) = SignedSatQ(accum >> esize, esize);
    if sat then FPSR.QC = '1';

V[d] = result;
```

Internal version only: isa v30.25, AdvSIMD v27.01, pseudocode v85-xml-00bet8_rc3_35; Build timestamp: 2018-09-13T13:2018-06-16T04:45

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SQRDMULH (by element)

Signed saturating Rounding Doubling Multiply returning High half (by element). This instruction multiplies each vector element in the first source SIMD&FP register by the specified vector element of the second source SIMD&FP register, doubles the results, places the most significant half of the final results into a vector, and writes the vector to the destination SIMD&FP register.

The results are rounded. For truncated results, see SQDMULH.

If any of the results overflows, they are saturated. If saturation occurs, the cumulative saturation bit FPSR.QC is set.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

It has encodings from 2 classes: Scalar and Vector

Scalar

```
31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
0 1 0 1 1 1 1 1     size  L  M  Rm  1 1 0 1  H  0     Rn  Rd

op
```

Scalar

```
SQRDMULH <V><d>, <V><n>, <Vm>.<Ts>[<index>]

integer idxdsiz = if H == '1' then 128 else 64;
integer index;
bit Rmhi;

case size of
  when '01' index = UInt(H:L:M); Rmhi = '0';
  when '10' index = UInt(H:L);   Rmhi = M;
otherwise UNDEFINED;

integer d = otherwise UnallocatedEncoding();
integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rmhi:Rm);

integer esize = 8 << UInt(size);
integer datasize = esize;
integer elements = 1;

boolean round = (op == '1');
```

Vector

```
31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
0 1 0 1 1 1 1     size  L  M  Rm  1 1 0 1  H  0     Rn  Rd

op
```

SQRDMULH (by element)
Vector

SQRDMULH <Vd><T>, <Vn><T>, <Vm><Ts>[<index>]

integer idxdsiz = if H == '1' then 128 else 64;
integer index;
bit Rmhi;
case size of
  when '01' index = UInt(H:L:M); Rmhi = '0';
  when '10' index = UInt(H:L); Rmhi = M;
  otherwise UNDEFINED;
integer d = otherwise UnallocatedEncoding();
integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rmhi:Rm);
integer esize = 8 << UInt(size);
integer datasize = if Q == '1' then 128 else 64;
integer elements = datasize DIV esize;
boolean round = (op == '1');

Assembler Symbols

<V> Is a width specifier, encoded in "size":

<table>
<thead>
<tr>
<th>size</th>
<th>&lt;V&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>RESERVED</td>
</tr>
<tr>
<td>01</td>
<td>H</td>
</tr>
<tr>
<td>10</td>
<td>S</td>
</tr>
<tr>
<td>11</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

<d> Is the number of the SIMD&FP destination register, encoded in the "Rd" field.

<n> Is the number of the first SIMD&FP source register, encoded in the "Rn" field.

<Vd> Is the name of the SIMD&FP destination register, encoded in the "Rd" field.

<T> Is an arrangement specifier, encoded in “size:Q”:

<table>
<thead>
<tr>
<th>size</th>
<th>Q</th>
<th>&lt;T&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>x</td>
<td>RESERVED</td>
</tr>
<tr>
<td>01</td>
<td>0</td>
<td>4H</td>
</tr>
<tr>
<td>01</td>
<td>1</td>
<td>8H</td>
</tr>
<tr>
<td>10</td>
<td>0</td>
<td>2S</td>
</tr>
<tr>
<td>10</td>
<td>1</td>
<td>4S</td>
</tr>
<tr>
<td>11</td>
<td>x</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

<Vn> Is the name of the first SIMD&FP source register, encoded in the "Rn" field.

<Vm> Is the name of the second SIMD&FP source register, encoded in “size:M:Rm”:

<table>
<thead>
<tr>
<th>size</th>
<th>&lt;Vm&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>RESERVED</td>
</tr>
<tr>
<td>01</td>
<td>0:Rm</td>
</tr>
<tr>
<td>10</td>
<td>M:Rm</td>
</tr>
<tr>
<td>11</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

Restricted to V0-V15 when element size <Ts> is H.

<Ts> Is an element size specifier, encoded in “size”:

<table>
<thead>
<tr>
<th>size</th>
<th>&lt;Ts&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>RESERVED</td>
</tr>
<tr>
<td>01</td>
<td>H</td>
</tr>
<tr>
<td>10</td>
<td>S</td>
</tr>
<tr>
<td>11</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

<index> Is the element index, encoded in “size:L:H:M”: 
Operation

CheckFPAdvSIMEnabled64();
bits(datasize) operand1 = V[n];
bits(idxsdsiz) operand2 = V[m];
bits(datasize) result;
integer round_const = if round then 1 << (esize - 1) else 0;
integer element1;
integer element2;
integer product;
boolean sat;
element2 = SInt(Elem[operand2, index, esize]);
for e = 0 to elements-1
  element1 = SInt(Elem[operand1, e, esize]);
  product = (2 * element1 * element2) + round_const;
  // The following only saturates if element1 and element2 equal -(2^(esize-1))
  (Elem[result, e, esize], sat) = SignedSatQ(product >> esize, esize);
  if sat then FPSR.QC = '1';
V[d] = result;
SQRDMULH (vector)

Signed saturating Rounding Doubling Multiply returning High half. This instruction multiplies the values of corresponding elements of the two source SIMD&FP registers, doubles the results, places the most significant half of the final results into a vector, and writes the vector to the destination SIMD&FP register.

The results are rounded. For truncated results, see SQRDMULH.

If overflow occurs with any of the results, those results are saturated. If saturation occurs, the cumulative saturation bit FPSR.QC is set.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

It has encodings from 2 classes: Scalar and Vector

Scalar

```
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9  | 8  | 7  | 6  | 5  | 4  | 3  | 2  | 1  | 0  |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0  | 1  | 1  | 1  | 1  | 1  | 0  |    |    | size |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |

Rm  |    |    |    |    |    |    |    |    | 1   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |

Rn  |    |    |    |    |    |    |    |    |    |    | 1   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |

Rd  |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
```

Scalar

```
SQRDMULH <V><d>, <V><n>, <V><m>

integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rm);
if size == '11' || size == '00' then UNDEFINED;
integer esize = 8 <<if size == '11' || size == '00' then ReservedValue4;
integer esize = 8 <<UInt(size);
integer datasize = esize;
integer elements = 1;
boolean rounding = (U == '1');

Vector

```
```

Vector

```
SQRDMULH <Vd>.<T>, <Vn>.<T>, <Vm>.<T>

integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rm);
if size == '11' || size == '00' then UNDEFINED;
integer esize = 8 <<if size == '11' || size == '00' then ReservedValue4;
integer esize = 8 <<UInt(size);
integer datasize = if Q == '1' then 128 else 64;
integer elements = datasize DIV esize;
boolean rounding = (U == '1');

Assembler Symbols

<V> Is a width specifier, encoded in "size":
<table>
<thead>
<tr>
<th>size</th>
<th>&lt;V&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>RESERVED</td>
</tr>
<tr>
<td>01</td>
<td>H</td>
</tr>
<tr>
<td>10</td>
<td>S</td>
</tr>
<tr>
<td>11</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

<d>
Is the number of the SIMD&FP destination register, in the "Rd" field.

<n>
Is the number of the first SIMD&FP source register, encoded in the "Rn" field.

<m>
Is the number of the second SIMD&FP source register, encoded in the "Rm" field.

<Vd>
Is the name of the SIMD&FP destination register, encoded in the "Rd" field.

<T>
Is an arrangement specifier, encoded in “size:Q”:

<table>
<thead>
<tr>
<th>size</th>
<th>Q</th>
<th>&lt;T&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>x</td>
<td>RESERVED</td>
</tr>
<tr>
<td>01</td>
<td>0</td>
<td>4H</td>
</tr>
<tr>
<td>1</td>
<td>8H</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>0</td>
<td>2S</td>
</tr>
<tr>
<td>10</td>
<td>1</td>
<td>4S</td>
</tr>
<tr>
<td>11</td>
<td>x</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

<Vn>
Is the name of the first SIMD&FP source register, encoded in the "Rn" field.

<Vm>
Is the name of the second SIMD&FP source register, encoded in the "Rm" field.

### Operation

```c
void CheckFPAdvSIMDEnabled64();
bits(datasize) operand1 = V[n];
bits(datasize) operand2 = V[m];
bits(datasize) result;
integer round_const = if rounding then 1 << (esize - 1) else 0;
integer element1;
integer element2;
integer product;
boolean sat;
for e = 0 to elements-1
    element1 = SInt(Elem[operand1, e, esize]);
    element2 = SInt(Elem[operand2, e, esize]);
    product = (2 * element1 * element2) + round_const;
    (Elem[result, e, esize], sat) = SignedSatQ(product >> esize, esize);
    if sat then FPSR.QC = '1';
V[d] = result;
```

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SQRSHL

Signed saturating Rounding Shift Left (register). This instruction takes each vector element in the first source SIMD&FP register, shifts it by a value from the least significant byte of the corresponding vector element of the second source SIMD&FP register, places the results into a vector, and writes the vector to the destination SIMD&FP register.

If the shift value is positive, the operation is a left shift. Otherwise, it is a right shift. The results are rounded. For truncated results, see `SQRSHL`. If overflow occurs with any of the results, those results are saturated. If saturation occurs, the cumulative saturation bit `FPSR.QC` is set.

Depending on the settings in the `CPACR_EL1`, `CPTR_EL2`, and `CPTR_EL3` registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

It has encodings from 2 classes: Scalar and Vector

**Scalar**

```
|   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   | 1  | 0 |
| 0 | 1 | 0 | 1 | 1 | 1 | 0 |   |   |   |   |   |   |   |   |   |   |   |   | U |
|   |   |   |   |   |   |   | Rm | 0 | 1 | 0 | 1 | 1 |   |   |   |   |   |   |   |   |
|   |   |   |   |   |   |   |   |   |   |   |   |   |   |   | Rn |   |   |   |   |   |   |   |   |
|   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   | Rd |
```

**Vector**

```
|   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   | 1  | 0 |
| 0 | Q | 0 | 0 | 1 | 1 | 1 | 0 |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   | U |
|   |   |   |   |   |   |   | Rm | 0 | 1 | 0 | 1 | 1 |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |  R |
|   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   | S |
|   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
```

**Assembler Symbols**

`<V>` is a width specifier, encoded in “size”:

```
integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rm);
integer esize = 8 << UInt(size);
integer datasize = esize;
integer elements = 1;
boolean unsigned = (U == '1');
boolean rounding = (R == '1');
boolean saturating = (S == '1');
if S == '0' && size != '11' then UNDEFINED;
```
Is the number of the SIMD&FP destination register, in the "Rd" field.

<n>
Is the number of the first SIMD&FP source register, encoded in the "Rn" field.

<m>
Is the number of the second SIMD&FP source register, encoded in the "Rm" field.

<Vd>
Is the name of the SIMD&FP destination register, encoded in the "Rd" field.

<T>
Is an arrangement specifier, encoded in “size:Q”:

<table>
<thead>
<tr>
<th>size</th>
<th>Q</th>
<th>T</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>0</td>
<td>8B</td>
</tr>
<tr>
<td>00</td>
<td>1</td>
<td>16B</td>
</tr>
<tr>
<td>01</td>
<td>0</td>
<td>4H</td>
</tr>
<tr>
<td>01</td>
<td>1</td>
<td>8H</td>
</tr>
<tr>
<td>10</td>
<td>0</td>
<td>2S</td>
</tr>
<tr>
<td>10</td>
<td>1</td>
<td>4S</td>
</tr>
<tr>
<td>11</td>
<td>0</td>
<td>RESERVED</td>
</tr>
<tr>
<td>11</td>
<td>1</td>
<td>2D</td>
</tr>
</tbody>
</table>

<Vn>
Is the name of the first SIMD&FP source register, encoded in the "Rn" field.

<Vm>
Is the name of the second SIMD&FP source register, encoded in the "Rm" field.

**Operation**

```c
CheckFPAdvSIMDEnabled64();
bits(datasize) operand1 = V[n];
bits(datasize) operand2 = V[m];
bits(datasize) result;

integer round_const = 0;
integer shift;
integer element;
boolean sat;

for e = 0 to elements-1
    shift = SInt(Elem[operand2, e, esize]<7:0>);
    if rounding then
        round_const = 1 << (-shift - 1); // 0 for left shift, 2^(n-1) for right shift
        element = (Int(Elem[operand1, e, esize], unsigned) + round_const) << shift;
    if saturating then
        (Elem[result, e, esize], sat) = SatQ(element, esize, unsigned);
        if sat then FPSR.QC = '1';
    else
        Elem[result, e, esize] = element<esize-1:0>;

V[d] = result;
```

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SQRSHRN, SQRSHRN2

Signed saturating Rounded Shift Right Narrow (immediate). This instruction reads each vector element in the source SIMD&FP register, right shifts each result by an immediate value, saturates each shifted result to a value that is half the original width, puts the final result into a vector, and writes the vector to the lower or upper half of the destination SIMD&FP register. All the values in this instruction are signed integer values. The destination vector elements are half as long as the source vector elements. The results are rounded. For truncated results, see SQRSHRN.

The SQRSHRN instruction writes the vector to the lower half of the destination register and clears the upper half, while the SQRSHRN2 instruction writes the vector to the upper half of the destination register without affecting the other bits of the register.

If saturation occurs, the cumulative saturation bit FPSR.QC is set.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

It has encodings from 2 classes: Scalar and Vector

Scalar

<table>
<thead>
<tr>
<th>31</th>
<th>30</th>
<th>29</th>
<th>28</th>
<th>27</th>
<th>26</th>
<th>25</th>
<th>24</th>
<th>23</th>
<th>22</th>
<th>21</th>
<th>20</th>
<th>19</th>
<th>18</th>
<th>17</th>
<th>16</th>
<th>15</th>
<th>14</th>
<th>13</th>
<th>12</th>
<th>11</th>
<th>10</th>
<th>9</th>
<th>8</th>
<th>7</th>
<th>6</th>
<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>!= 0000</td>
<td>immb</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>Rn</td>
<td>Rd</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>U</td>
<td>immh</td>
<td>op</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Scalar

SQRSHRN <Vb><d>, <Va><n>, #<shift>

```plaintext
integer d = UInt(Rd);
integer n = UInt(Rn);

if immh == '0000' then UNDEFINED;
if immh<3> == '1' then UNDEFINED;
integer esize = 8 << if immh == '0000' then ReservedValue();
               if immh<3> == '1' then ReservedValue();
integer esize = 8 << HighestSetBit(immh);
integer datasize = esize;
integer elements = 1;
integer part = 0;

integer shift = (2 * esize) - UInt(immh:immb);
boolean round = (op == '1');
boolean unsigned = (U == '1');
```

Vector

<table>
<thead>
<tr>
<th>31</th>
<th>30</th>
<th>29</th>
<th>28</th>
<th>27</th>
<th>26</th>
<th>25</th>
<th>24</th>
<th>23</th>
<th>22</th>
<th>21</th>
<th>20</th>
<th>19</th>
<th>18</th>
<th>17</th>
<th>16</th>
<th>15</th>
<th>14</th>
<th>13</th>
<th>12</th>
<th>11</th>
<th>10</th>
<th>9</th>
<th>8</th>
<th>7</th>
<th>6</th>
<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Q</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>!= 0000</td>
<td>immb</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>Rn</td>
<td>Rd</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>U</td>
<td>immh</td>
<td>op</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
integer $d = \text{UInt}(Rd)$;
integer $n = \text{UInt}(Rn)$;

if $\text{immh} == '0000'$ then \text{SEE(asimdimm)};
if $\text{immh<3>} == '1'$ then \text{UNDEFINED};
integer $\text{esize} = 8 << \text{HighestSetBit}(\text{immh})$;
integer $\text{datasize} = 64$;
integer $\text{part} = \text{UInt}(Q)$;
integer $\text{elements} = \text{datasize DIV esize}$;

integer $\text{shift} = (2 \ast \text{esize}) - \text{UInt}(\text{immh:immb})$;
boolean $\text{round} = (\text{op} == '1')$;
boolean $\text{unsigned} = (\text{U} == '1')$;

**Assembler Symbols**

2

Is the second and upper half specifier. If present it causes the operation to be performed on the upper 64 bits of the registers holding the narrower elements, and is encoded in “Q”:

<table>
<thead>
<tr>
<th>Q</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>[absent]</td>
</tr>
<tr>
<td>1</td>
<td>[present]</td>
</tr>
</tbody>
</table>

$<Vd>$

Is the name of the SIMD&FP destination register, encoded in the "Rd" field.

$<Tb>$

Is an arrangement specifier, encoded in “immh:Q”:

<table>
<thead>
<tr>
<th>immh</th>
<th>Q</th>
<th>\text{SEE Advanced SIMD modified immediate}</th>
</tr>
</thead>
<tbody>
<tr>
<td>0000</td>
<td>x</td>
<td>SEE Advanced SIMD modified immediate</td>
</tr>
<tr>
<td>0001</td>
<td>0</td>
<td>8B</td>
</tr>
<tr>
<td>0001</td>
<td>1</td>
<td>16B</td>
</tr>
<tr>
<td>001x</td>
<td>0</td>
<td>4H</td>
</tr>
<tr>
<td>001x</td>
<td>1</td>
<td>8H</td>
</tr>
<tr>
<td>01xx</td>
<td>0</td>
<td>2S</td>
</tr>
<tr>
<td>01xx</td>
<td>1</td>
<td>4S</td>
</tr>
<tr>
<td>1xxx</td>
<td>x</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

$<Vn>$

Is the name of the SIMD&FP source register, encoded in the "Rn" field.

$<Ta>$

Is an arrangement specifier, encoded in “immh”:

<table>
<thead>
<tr>
<th>immh</th>
<th>\text{SEE Advanced SIMD modified immediate}</th>
</tr>
</thead>
<tbody>
<tr>
<td>0000</td>
<td>SEE Advanced SIMD modified immediate</td>
</tr>
<tr>
<td>0001</td>
<td>8H</td>
</tr>
<tr>
<td>001x</td>
<td>4S</td>
</tr>
<tr>
<td>01xx</td>
<td>2D</td>
</tr>
<tr>
<td>1xxx</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

$<Vb>$

Is the destination width specifier, encoded in “immh”:

<table>
<thead>
<tr>
<th>immh</th>
<th>\text{SEE Advanced SIMD modified immediate}</th>
</tr>
</thead>
<tbody>
<tr>
<td>0000</td>
<td>RESERVED</td>
</tr>
<tr>
<td>0001</td>
<td>B</td>
</tr>
<tr>
<td>001x</td>
<td>H</td>
</tr>
<tr>
<td>01xx</td>
<td>S</td>
</tr>
<tr>
<td>1xxx</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

$<d>$

Is the number of the SIMD&FP destination register, in the "Rd" field.

$<Va>$

Is the source width specifier, encoded in “immh”:

<table>
<thead>
<tr>
<th>immh</th>
<th>\text{SEE Advanced SIMD modified immediate}</th>
</tr>
</thead>
<tbody>
<tr>
<td>0000</td>
<td>RESERVED</td>
</tr>
<tr>
<td>0001</td>
<td>H</td>
</tr>
<tr>
<td>001x</td>
<td>S</td>
</tr>
<tr>
<td>01xx</td>
<td>D</td>
</tr>
<tr>
<td>1xxx</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>
Is the number of the first SIMD&FP source register, encoded in the “Rn” field.

For the scalar variant: is the right shift amount, in the range 1 to the destination operand width in bits, encoded in “immh:immb”:

<table>
<thead>
<tr>
<th>immh</th>
<th>&lt;shift&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0000</td>
<td>RESERVED</td>
</tr>
<tr>
<td>0001</td>
<td>(16-UInt(immh:immb))</td>
</tr>
<tr>
<td>001x</td>
<td>(32-UInt(immh:immb))</td>
</tr>
<tr>
<td>01xx</td>
<td>(64-UInt(immh:immb))</td>
</tr>
<tr>
<td>1xxx</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

For the vector variant: is the right shift amount, in the range 1 to the destination element width in bits, encoded in “immh:immb”:

<table>
<thead>
<tr>
<th>immh</th>
<th>&lt;shift&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0000</td>
<td>SEE Advanced SIMD modified immediate</td>
</tr>
<tr>
<td>0001</td>
<td>(16-UInt(immh:immb))</td>
</tr>
<tr>
<td>001x</td>
<td>(32-UInt(immh:immb))</td>
</tr>
<tr>
<td>01xx</td>
<td>(64-UInt(immh:immb))</td>
</tr>
<tr>
<td>1xxx</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

Operation

```c
CheckFPAdvSIMDEnabled64();
bits(datasize*2) operand = V[n];
bits(datasize) result;
integer round_const = if round then (1 << (shift - 1)) else 0;
integer element;
boolean sat;
for e = 0 to elements-1
  element = (Int(Elem[operand, e, 2*esize], unsigned) + round_const) >> shift;
  (Elem[result, e, esize], sat) = SatQ(element, esize, unsigned);
  if sat then FPSR.QC = '1';
Vpart[d, part] = result;
```

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SQRSHRUN, SQRSHRUN2

Signed saturating Rounded Shift Right Unsigned Narrow (immediate). This instruction reads each signed integer value in the vector of the source SIMD&FP register, right shifts each value by an immediate value, saturates the result to an unsigned integer value that is half the original width, places the final result into a vector, and writes the vector to the destination SIMD&FP register. The results are rounded. For truncated results, see SQRSHRUN.

The SQRSHRUN instruction writes the vector to the lower half of the destination register and clears the upper half, while the SQRSHRUN2 instruction writes the vector to the upper half of the destination register without affecting the other bits of the register.

If saturation occurs, the cumulative saturation bit FPSR.QC is set.

Depending on the settings in the CPICR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

It has encodings from 2 classes: Scalar and Vector

Scalar

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0  | 1  | 1  | 1  | 1  | 1  | 1  | 0  | !=0000 | immh | 1  | 0  | 0  | 0  | 1  | 1  | Rn  | Rd  |

Scalar

SQRSHRUN <Vb><d>, <Va><n>, #<shift>

integer d = UInt(Rd);
integer n = UInt(Rn);
if immh == '0000' then UNDEFINED;
if immh<3> == '1' then UNDEFINED;
integer esize = 8 <<= if immh == '0000' then ReservedValue();
if immh<3> == '1' then ReservedValue();
integer esize = 8 <<= HighestSetBit(immh);
integer datasize = esize;
integer elements = 1;
integer part = 0;
integer shift = (2 * esize) - UInt(immh:immb);
boolean round = (op == '1');

Vector

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0  | Q  | 1  | 0  | 1  | 1  | 1  | 1  | 0  | !=0000 | immh | 1  | 0  | 0  | 0  | 1  | 1  | Rn  | Rd  |

immh   | 1  | 0  | 0  | 0  | 1  | 1  | Rn  | Rd  |

op
Vector

SQRSHRUN(2) <Vd>,<Tb>, <Vn>,<Ta>, #<shift>

integer d = UInt(Rd);
integer n = UInt(Rn);

if immh == '0000' then SEE(asimdimm);
if immh[3] == '1' then UNDEFINED;
integer esize = 8 << if immh[3] == '1' then ReservedValue();
integer esize = 8 << HighestSetBit(immh);
integer datasize = 64;
integer part = UInt(Q);
integer elements = datasize DIV esize;

integer shift = (2 * esize) - UInt(immh:immb);
boolean round = (op == '1');

Assembler Symbols

2 Is the second and upper half specifier. If present it causes the operation to be performed on the upper 64 bits of the registers holding the narrower elements, and is encoded in "Q":

<table>
<thead>
<tr>
<th>Q</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>[absent]</td>
</tr>
<tr>
<td>1</td>
<td>[present]</td>
</tr>
</tbody>
</table>

<Vd> Is the name of the SIMD&FP destination register, encoded in the "Rd" field.
<Tb> Is an arrangement specifier, encoded in “immh:Q”:

```
<table>
<thead>
<tr>
<th>immh</th>
<th>Q</th>
<th>Assembler Symbols</th>
</tr>
</thead>
<tbody>
<tr>
<td>0000</td>
<td>x</td>
<td>SEE Advanced SIMD modified immediate</td>
</tr>
<tr>
<td>0001</td>
<td>0</td>
<td>8B</td>
</tr>
<tr>
<td>0001</td>
<td>1</td>
<td>16B</td>
</tr>
<tr>
<td>001x</td>
<td>0</td>
<td>4H</td>
</tr>
<tr>
<td>001x</td>
<td>1</td>
<td>8H</td>
</tr>
<tr>
<td>01xx</td>
<td>0</td>
<td>2S</td>
</tr>
<tr>
<td>01xx</td>
<td>1</td>
<td>4S</td>
</tr>
<tr>
<td>1xxx</td>
<td>x</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>
```

<Vn> Is the name of the SIMD&FP source register, encoded in the "Rn" field.
<Ta> Is an arrangement specifier, encoded in “immh”:

```
<table>
<thead>
<tr>
<th>immh</th>
<th>Ta</th>
</tr>
</thead>
<tbody>
<tr>
<td>0000</td>
<td>SEE Advanced SIMD modified immediate</td>
</tr>
<tr>
<td>0001</td>
<td>8H</td>
</tr>
<tr>
<td>001x</td>
<td>4S</td>
</tr>
<tr>
<td>01xx</td>
<td>2D</td>
</tr>
<tr>
<td>1xxx</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>
```

<Vb> Is the destination width specifier, encoded in “immh”:

```
<table>
<thead>
<tr>
<th>immh</th>
<th>Vb</th>
</tr>
</thead>
<tbody>
<tr>
<td>0000</td>
<td>RESERVED</td>
</tr>
<tr>
<td>0001</td>
<td>B</td>
</tr>
<tr>
<td>001x</td>
<td>H</td>
</tr>
<tr>
<td>01xx</td>
<td>S</td>
</tr>
<tr>
<td>1xxx</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>
```

<d> Is the number of the SIMD&FP destination register, in the "Rd" field.
<Va> Is the source width specifier, encoded in “immh”:

```
<table>
<thead>
<tr>
<th>immh</th>
<th>Va</th>
</tr>
</thead>
<tbody>
<tr>
<td>0000</td>
<td>RESERVED</td>
</tr>
<tr>
<td>0001</td>
<td>H</td>
</tr>
<tr>
<td>001x</td>
<td>S</td>
</tr>
<tr>
<td>01xx</td>
<td>D</td>
</tr>
<tr>
<td>1xxx</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>
```

<n> Is the number of the first SIMD&FP source register, encoded in the "Rn" field.
For the scalar variant: is the right shift amount, in the range 1 to the destination operand width in bits, encoded in “immh:immb”:

<table>
<thead>
<tr>
<th>immh</th>
<th>&lt;shift&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0000</td>
<td>RESERVED</td>
</tr>
<tr>
<td>0001</td>
<td>(16-UInt(immh:immb))</td>
</tr>
<tr>
<td>001x</td>
<td>(32-UInt(immh:immb))</td>
</tr>
<tr>
<td>01xx</td>
<td>(64-UInt(immh:immb))</td>
</tr>
<tr>
<td>1xxx</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

For the vector variant: is the right shift amount, in the range 1 to the destination element width in bits, encoded in “immh:immb”:

<table>
<thead>
<tr>
<th>immh</th>
<th>&lt;shift&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0000</td>
<td>SEE Advanced SIMD modified immediate</td>
</tr>
<tr>
<td>0001</td>
<td>(16-UInt(immh:immb))</td>
</tr>
<tr>
<td>001x</td>
<td>(32-UInt(immh:immb))</td>
</tr>
<tr>
<td>01xx</td>
<td>(64-UInt(immh:immb))</td>
</tr>
<tr>
<td>1xxx</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

Operation

```c
CheckFPAdvSIMDEnabled64();
bits(datasize*2) operand = V[n];
bits(datasize) result;
integer round_const = if round then (1 << (shift - 1)) else 0;
integer element;
boolean sat;
for e = 0 to elements-1
  element = (SInt(Elem[operand, e, 2*esize]) + round_const) >> shift;
  (Elem[result, e, esize], sat) = UnsignedSatQ(element, esize);
  if sat then FPSR.QC = '1';
Vpart[d, part] = result;
```

(Old) htmldiff from- (new)
**SQSHL (immediate)**

Signed saturating Shift Left (immediate). This instruction reads each vector element in the source SIMD&FP register, shifts each result by an immediate value, places the final result in a vector, and writes the vector to the destination SIMD&FP register. The results are truncated. For rounded results, see \textit{UQRSHL}.

If overflow occurs with any of the results, those results are saturated. If saturation occurs, the cumulative saturation bit \textit{FPSR}.QC is set. Depending on the settings in the \textit{CPACR_EL1}, \textit{CPTR_EL2}, and \textit{CPTR_EL3} registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

It has encodings from 2 classes: \textit{Scalar} and \textit{Vector}.

**Scalar**

```
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 |  9 |  8 |  7 |  6 |  5 |  4 |  3 |  2 |  1 |  0 |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0  | 1  | 0  | 1  | 1  | 1  | 1  | 1  | 1  | 0  | ! = 0000 | immh | 0  | 1  | 1  | 0  | 1  | Rn |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| U  | immh | op |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
```

**Vector**

```
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 |  9 |  8 |  7 |  6 |  5 |  4 |  3 |  2 |  1 |  0 |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0  | 1  | 0  | 1  | 1  | 1  | 1  | 1  | 0  | ! = 0000 | immh | 0  | 1  | 1  | 0  | 1  | Rn |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| U  | immh | op |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
```

SQSHL (immediate)
Vector

SQSHL <Vd>.<T>, <Vn>.<T>, #<shift>

integer d = UInt(Rd);
integer n = UInt(Rn);

if immh == '0000' then SEE(asimdimm);
if immh[3]:Q == '10' then UNDEFINED;
integer esize = 8 << if immh[3]:Q == '10' then ReservedValue();
integer esize = 8 << HighestSetBit(immh);
integer datasize = if Q == '1' then 128 else 64;
integer elements = datasize DIV esize;

integer shift = UInt(immh:immb) - esize;

boolean src_unsigned;
boolean dst_unsigned;

case op:U of
  when '00' UnallocatedEncoding(immh:immb) = esize;
  when '01' src_unsigned = FALSE; dst_unsigned = TRUE;
  when '10' src_unsigned = FALSE; dst_unsigned = FALSE;
  when '11' src_unsigned = TRUE;  dst_unsigned = TRUE;

Assembler Symbols

<V> Is a width specifier, encoded in “immh”:

<table>
<thead>
<tr>
<th>immh</th>
<th>&lt;V&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0000</td>
<td>RESERVED</td>
</tr>
<tr>
<td>0001</td>
<td>B</td>
</tr>
<tr>
<td>01x</td>
<td>H</td>
</tr>
<tr>
<td>01xx</td>
<td>S</td>
</tr>
<tr>
<td>1xx</td>
<td>D</td>
</tr>
</tbody>
</table>

<d> Is the number of the SIMD&FP destination register, in the "Rd" field.

<n> Is the number of the first SIMD&FP source register, encoded in the "Rn" field.

<Vd> Is the name of the SIMD&FP destination register, encoded in the "Rd" field.

<T> Is an arrangement specifier, encoded in “immh:Q”:

<table>
<thead>
<tr>
<th>immh</th>
<th>Q</th>
<th>&lt;T&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0000</td>
<td>x</td>
<td>SEE Advanced SIMD modified immediate</td>
</tr>
<tr>
<td>0001</td>
<td>0</td>
<td>8B</td>
</tr>
<tr>
<td>0001</td>
<td>1</td>
<td>16B</td>
</tr>
<tr>
<td>01x</td>
<td>0</td>
<td>4H</td>
</tr>
<tr>
<td>01x</td>
<td>1</td>
<td>8H</td>
</tr>
<tr>
<td>01xx</td>
<td>0</td>
<td>2S</td>
</tr>
<tr>
<td>01xx</td>
<td>1</td>
<td>4S</td>
</tr>
<tr>
<td>1xx</td>
<td>0</td>
<td>RESERVED</td>
</tr>
<tr>
<td>1xx</td>
<td>1</td>
<td>2D</td>
</tr>
</tbody>
</table>

<Vn> Is the name of the SIMD&FP source register, encoded in the "Rn" field.

<shift> For the scalar variant: is the left shift amount, in the range 0 to the operand width in bits minus 1, encoded in “immh:immb”:

<table>
<thead>
<tr>
<th>immh</th>
<th>&lt;shift&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0000</td>
<td>RESERVED</td>
</tr>
<tr>
<td>0001</td>
<td>(UInt(immh:immb)-8)</td>
</tr>
<tr>
<td>001x</td>
<td>(UInt(immh:immb)-16)</td>
</tr>
<tr>
<td>01xx</td>
<td>(UInt(immh:immb)-32)</td>
</tr>
<tr>
<td>1xx</td>
<td>(UInt(immh:immb)-64)</td>
</tr>
</tbody>
</table>

For the vector variant: is the left shift amount, in the range 0 to the element width in bits minus 1, encoded in “immh:immb”:
<table>
<thead>
<tr>
<th>immh</th>
<th>&lt;shift&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0000</td>
<td>SEE Advanced SIMD modified immediate</td>
</tr>
<tr>
<td>0001</td>
<td>(UInt(immh:immb)-8)</td>
</tr>
<tr>
<td>001x</td>
<td>(UInt(immh:immb)-16)</td>
</tr>
<tr>
<td>01xx</td>
<td>(UInt(immh:immb)-32)</td>
</tr>
<tr>
<td>lxxx</td>
<td>(UInt(immh:immb)-64)</td>
</tr>
</tbody>
</table>

The operation is defined as:

```c
CheckFPAdvSIMDEnabled64();
bis(datasize) operand = V[n];
bis(datasize) result;
integer element;
boolean sat;
for e = 0 to elements-1
    element = Int(Elem[operand, e, esize], src_unsigned) << shift;
    (Elem[result, e, esize], sat) = SatQ(element, esize, dst_unsigned);
    if sat then FPSR.QC = '1';
V[d] = result;
```

Internal version only: isa v30.25 v29.05, AdvSIMD v27.01 v26.0, pseudocode v85-xml-00bet8_rc3557; Build timestamp: 2018-09-13T13:2018-06-16T09:0445

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SQSHL (register)

Signed saturating Shift Left (register). This instruction takes each element in the vector of the first source SIMD&FP register, shifts each element by a value from the least significant byte of the corresponding element of the second source SIMD&FP register, places the results in a vector, and writes the vector to the destination SIMD&FP register.

If the shift value is positive, the operation is a left shift. Otherwise, it is a right shift. The results are truncated. For rounded results, see \textit{SQRSHL}.

If overflow occurs with any of the results, those results are saturated. If saturation occurs, the cumulative saturation bit \texttt{FPSR.QC} is set.

Depending on the settings in the \texttt{CPACR_EL1}, \texttt{CPTR_EL2}, and \texttt{CPTR_EL3} registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

It has encodings from 2 classes: \texttt{Scalar} and \texttt{Vector}.

\textbf{Scalar}

\begin{verbatim}
31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
0 1 0 1 1 1 1 0 size 1 Rm 0 1 0 0 1 1 Rn Rd

U R S
\end{verbatim}

\textbf{Scalar}

\texttt{SQSHL <V><d>, <V><n>, <V><m>}

\begin{verbatim}
integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rm);
integer esize = 8 << UInt(size);
integer datasize = esize;
integer elements = 1;
boolean unsigned = (U != '1');
boolean rounding = (R != '1');
boolean saturating = (S != '1');
if S == '0' && size != '11' then UNDEFINED;
integer esize = 8 << UInt(size);
integer datasize = if Q == '1' then 128 else 64;
integer elements = datasize DIV esize;
boolean unsigned = (U == '1');
boolean rounding = (R == '1');
boolean saturating = (S == '1');
\end{verbatim}

\textbf{Vector}

\begin{verbatim}
31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
0 Q 0 1 1 1 1 0 size 1 Rm 0 1 0 0 1 1 Rn Rd

U R S
\end{verbatim}

\textbf{Vector}

\texttt{SQSHL <Vd>.<T>, <Vn>.<T>, <Vm>.<T>}

\begin{verbatim}
integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rm);
if size:Q == '110' then UNDEFINED;
integer esize = 8 << if size:Q == '110' then ReservedValue() else UInt(size);
integer datasize = if Q == '1' then 128 else 64;
integer elements = datasize DIV esize;
boolean unsigned = (U == '1');
boolean rounding = (R == '1');
boolean saturating = (S == '1');
\end{verbatim}

\textbf{Assembler Symbols}

\texttt{<V>}

Is a width specifier, encoded in "size":
Is the number of the SIMD&FP destination register, in the "Rd" field.

<n>
Is the number of the first SIMD&FP source register, encoded in the "Rn" field.

<m>
Is the number of the second SIMD&FP source register, encoded in the "Rm" field.

<Vd>
Is the name of the SIMD&FP destination register, encoded in the "Rd" field.

<T>
Is an arrangement specifier, encoded in “size:Q”:

<table>
<thead>
<tr>
<th>size</th>
<th>&lt;Q&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>B</td>
</tr>
<tr>
<td>01</td>
<td>H</td>
</tr>
<tr>
<td>10</td>
<td>S</td>
</tr>
<tr>
<td>11</td>
<td>D</td>
</tr>
</tbody>
</table>

<Vn>
Is the name of the first SIMD&FP source register, encoded in the "Rn" field.

<Vm>
Is the name of the second SIMD&FP source register, encoded in the "Rm" field.

Operation

```c
CheckFPAdvSIMDEnabled64();

bits(datasize) operand1 = V[n];
bits(datasize) operand2 = V[m];
bits(datasize) result;

integer round_const = 0;
integer shift;
integer element;
boolean sat;

for e = 0 to elements-1
    shift = SInt(Elem[operand2, e, esize]<7:0>);
    if rounding then
        round_const = 1 << (-shift - 1); // 0 for left shift, 2^(n-1) for right shift
        element = (Int(Elem[operand1, e, esize], unsigned) + round_const) << shift;
    else
        element = Int(Elem[operand1, e, esize], unsigned);
    if saturating then
        (Elem[result, e, esize], sat) = SatQ(element, esize, unsigned);
    else
        element = element<esize-1:0>;

V[d] = result;
```


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**SQSHLU**

Signed saturating Shift Left Unsigned (immediate). This instruction reads each signed integer value in the vector of the source SIMD&FP register, shifts each value by an immediate value, saturates the shifted result to an unsigned integer value, places the result in a vector, and writes the vector to the destination SIMD&FP register. The results are truncated. For rounded results, see **UQRSHL**.

If saturation occurs, the cumulative saturation bit FPSR.QC is set.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

It has encodings from 2 classes: **Scalar** and **Vector**

**Scalar**

| 31  | 30  | 29  | 28  | 27  | 26  | 25  | 24  | 23  | 22  | 21  | 20  | 19  | 18  | 17  | 16  | 15  | 14  | 13  | 12  | 11  | 10  | 9   | 8   | 7   | 6   | 5   | 4   | 3   | 2   | 1   | 0   |
|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| U   | immh| op  | Rn  | Rd  |

**SQSHLU** `<V><d>, <V><n>`, #<shift>

```plaintext
integer d = UInt(Rd);
integer n = UInt(Rn);

if immh == '0000' then UNDEFINED;
integer esize = 8 << if immh == '0000' then ReservedValue();
integer esize = 8 << HighestSetBit(immh);
integer datasize = esize;
integer elements = 1;

integer shift = UInt(immh:immb) - esize;

boolean src_unsigned;
boolean dst_unsigned;
case op:U of
  when '00' UnallocatedEncoding(immh:immb) - esize;

boolean src_unsigned;
boolean dst_unsigned;
case op:U of
  when '00' UNDEFINED;
  when '01' src_unsigned = FALSE; dst_unsigned = TRUE;
  when '10' src_unsigned = FALSE; dst_unsigned = FALSE;
  when '11' src_unsigned = TRUE; dst_unsigned = TRUE;
```

**Vector**

| 31  | 30  | 29  | 28  | 27  | 26  | 25  | 24  | 23  | 22  | 21  | 20  | 19  | 18  | 17  | 16  | 15  | 14  | 13  | 12  | 11  | 10  | 9   | 8   | 7   | 6   | 5   | 4   | 3   | 2   | 1   | 0   |
|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| Q   | U   | immh| op  | Rn  | Rd  |

SQSHLU
Vector

SQSHLU \(<V_d>.<T>, <V_n>.<T>, \#<\text{shift}>\)

```cpp
integer d = UInt(Rd);
integer n = UInt(Rn);

if immh == '0000' then SEE(asimdimm);
if immh<3>:q == '10' then UNDEFINED;
integer esize = 8 << HighestSetBit(immh);
integer datasize = if Q == '1' then 128 else 64;
integer elements = datasize DIV esize;

integer shift = UInt(immh:immb) - esize;
```

```cpp
boolean src_unsigned;
boolean dst_unsigned;
case op:U of
  when '00' UnallocatedEncoding(immh:immb) - esize;
  when '01' src_unsigned = FALSE; dst_unsigned = TRUE;
  when '10' src_unsigned = FALSE; dst_unsigned = FALSE;
  when '11' src_unsigned = TRUE;  dst_unsigned = TRUE;
```

Assembler Symbols

\(<V>\) Is a width specifier, encoded in \(\text{"immh"}\):

<table>
<thead>
<tr>
<th>immh</th>
<th>(&lt;V&gt;)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0000</td>
<td>RESERVED</td>
</tr>
<tr>
<td>0001</td>
<td>B</td>
</tr>
<tr>
<td>001x</td>
<td>H</td>
</tr>
<tr>
<td>01xx</td>
<td>S</td>
</tr>
<tr>
<td>1xxx</td>
<td>D</td>
</tr>
</tbody>
</table>

\(<d>\) Is the number of the SIMD&FP destination register, in the "Rd" field.

\(<n>\) Is the number of the first SIMD&FP source register, encoded in the "Rn" field.

\(<V_d>\) Is the name of the SIMD&FP destination register, encoded in the "Rd" field.

\(<T>\) Is an arrangement specifier, encoded in \(\text{"immh}:Q\)"

<table>
<thead>
<tr>
<th>immh</th>
<th>Q</th>
<th>(&lt;T&gt;)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0000</td>
<td>x</td>
<td>SEE Advanced SIMD modified immediate</td>
</tr>
<tr>
<td>0001</td>
<td>0</td>
<td>8B</td>
</tr>
<tr>
<td>0001</td>
<td>1</td>
<td>16B</td>
</tr>
<tr>
<td>001x</td>
<td>0</td>
<td>4H</td>
</tr>
<tr>
<td>001x</td>
<td>1</td>
<td>8H</td>
</tr>
<tr>
<td>01xx</td>
<td>0</td>
<td>2S</td>
</tr>
<tr>
<td>01xx</td>
<td>1</td>
<td>4S</td>
</tr>
<tr>
<td>1xxx</td>
<td>0</td>
<td>RESERVED</td>
</tr>
<tr>
<td>1xxx</td>
<td>1</td>
<td>2D</td>
</tr>
</tbody>
</table>

\(<V_n>\) Is the name of the SIMD&FP source register, encoded in the "Rn" field.

\(<\text{shift}>\) For the scalar variant: is the left shift amount, in the range 0 to the operand width in bits minus 1, encoded in \(\text{"immh}:\text{immb}\):

<table>
<thead>
<tr>
<th>immh</th>
<th>(&lt;\text{shift}&gt;)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0000</td>
<td>RESERVED</td>
</tr>
<tr>
<td>0001</td>
<td>(UInt(immh:immb)-8)</td>
</tr>
<tr>
<td>001x</td>
<td>(UInt(immh:immb)-16)</td>
</tr>
<tr>
<td>01xx</td>
<td>(UInt(immh:immb)-32)</td>
</tr>
<tr>
<td>1xxx</td>
<td>(UInt(immh:immb)-64)</td>
</tr>
</tbody>
</table>

For the vector variant: is the left shift amount, in the range 0 to the element width in bits minus 1, encoded in \(\text{"immh}:\text{immb}\):"
### Operation

```c
CheckFPAdvSIMDEnabled64();

bits(datasize) operand = V[n];
bits(datasize) result;
integer element;
boolean sat;

for e = 0 to elements-1
    element = Int(Elem[operand, e, esize], src_unsigned) << shift;
    (Elem[result, e, esize], sat) = SatQ(element, esize, dst_unsigned);
    if sat then FPSR.QC = '1';

V[d] = result;
```

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SQSHRN, SQSHRN2

Signed saturating Shift Right Narrow (immediate). This instruction reads each vector element in the source SIMD&FP register, right shifts and truncates each result by an immediate value, saturates each shifted result to a value that is half the original width, puts the final result into a vector, and writes the vector to the lower or upper half of the destination SIMD&FP register. All the values in this instruction are signed integer values. The destination vector elements are half as long as the source vector elements. For rounded results, see SQRSHRN.

The SQSHRN instruction writes the vector to the lower half of the destination register and clears the upper half, while the SQSHRN2 instruction writes the vector to the upper half of the destination register without affecting the other bits of the register.

If saturation occurs, the cumulative saturation bit FPSR.QC is set.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

It has encodings from 2 classes: Scalar and Vector

Scalar

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0  | 1  | 0  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 0  | 0  | 0  | 0  | 1  | 0  | 0  | 1  | 0  | 1  | Rn | Rd |
| U  | immh | op |

Scalar

SQSHRN <Vb><d>, <Va><n>, #<shift>

```plaintext
integer d = UInt(Rd);
integer n = UInt(Rn);

if immh == '0000' then UNDEFINED;
if immh<3> == '1' then UNDEFINED;
integer esize = 8 <<if immh == '0000' then ReservedValue();
if immh<3> == '1' then ReservedValue();
integer esize = 8 <<HighestSetBit(immh);
integer datasize = esize;
integer elements = 1;
integer part = 0;

integer shift = (2 * esize) - UInt(immh:immb);
boolean round = (op == '1');
boolean unsigned = (U == '1');
```

Vector

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0  | Q  | 0  | 1  | 1  | 1  | 1  | 0  | 0  | 0  | 0  | 1  | 0  | 1  | 0  | 1  | Rn | Rd |
| U  | immh | op |

SQSHRN, SQSHRN2
Vector

SQSHRN{2} <Vd>, <Tb>, <Vn>, <Ta>, #<shift>

integer d = UInt(Rd);
integer n = UInt(Rn);

if immh == '0000' then SEE(asimdimm);
if immh[3] == '1' then UNDEFINED;
integer esize = 8 << if immh[2] == '1' then ReservedValue();
integer esize = 8 << HighestSetBit(immh);
integer datasize = 64;
integer part = UInt(Q);
integer elements = datasize DIV esize;

integer shift = (2 * esize) - UInt(immh:immb);
boolean round = (op == '1');
boolean unsigned = (U == '1');

Assembler Symbols

2

Is the second and upper half specifier. If present it causes the operation to be performed on the upper 64 bits of the registers holding the narrower elements, and is encoded in “Q”:

<table>
<thead>
<tr>
<th>0</th>
<th>(absent)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>(present)</td>
</tr>
</tbody>
</table>

<Vd>

Is the name of the SIMD&FP destination register, encoded in the "Rd" field.

<Tb>

Is an arrangement specifier, encoded in “immh:Q”:

<table>
<thead>
<tr>
<th>immh</th>
<th>Q</th>
<th>&lt;Tb&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0000</td>
<td>x</td>
<td>SEE Advanced SIMD modified immediate</td>
</tr>
<tr>
<td>0001</td>
<td>0</td>
<td>8B</td>
</tr>
<tr>
<td>0001</td>
<td>1</td>
<td>16B</td>
</tr>
<tr>
<td>001x</td>
<td>0</td>
<td>4H</td>
</tr>
<tr>
<td>001x</td>
<td>1</td>
<td>8H</td>
</tr>
<tr>
<td>01xx</td>
<td>0</td>
<td>2S</td>
</tr>
<tr>
<td>01xx</td>
<td>1</td>
<td>4S</td>
</tr>
<tr>
<td>1xxx</td>
<td>x</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

<Vn>

Is the name of the SIMD&FP source register, encoded in the "Rn" field.

<Ta>

Is an arrangement specifier, encoded in “immh”:

<table>
<thead>
<tr>
<th>immh</th>
<th>&lt;Ta&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0000</td>
<td>SEE Advanced SIMD modified immediate</td>
</tr>
<tr>
<td>0001</td>
<td>8H</td>
</tr>
<tr>
<td>001x</td>
<td>4S</td>
</tr>
<tr>
<td>01xx</td>
<td>2D</td>
</tr>
<tr>
<td>1xxx</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

<Vb>

Is the destination width specifier, encoded in “immh”:

<table>
<thead>
<tr>
<th>immh</th>
<th>&lt;Vb&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0000</td>
<td>RESERVED</td>
</tr>
<tr>
<td>001</td>
<td>B</td>
</tr>
<tr>
<td>001x</td>
<td>H</td>
</tr>
<tr>
<td>01xx</td>
<td>S</td>
</tr>
<tr>
<td>1xxx</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

<d>

Is the number of the SIMD&FP destination register, in the "Rd" field.

<Va>

Is the source width specifier, encoded in “immh”:

<table>
<thead>
<tr>
<th>immh</th>
<th>&lt;Va&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0000</td>
<td>RESERVED</td>
</tr>
<tr>
<td>0001</td>
<td>H</td>
</tr>
<tr>
<td>001x</td>
<td>S</td>
</tr>
<tr>
<td>01xx</td>
<td>D</td>
</tr>
<tr>
<td>1xxx</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>
Is the number of the first SIMD&FP source register, encoded in the "Rn" field.

For the scalar variant: is the right shift amount, in the range 1 to the destination operand width in bits, encoded in “immh:immh”:

<table>
<thead>
<tr>
<th>immh</th>
<th>&lt;shift&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0000</td>
<td>RESERVED</td>
</tr>
<tr>
<td>0001</td>
<td>(16-UInt(immh:immb))</td>
</tr>
<tr>
<td>001x</td>
<td>(32-UInt(immh:immb))</td>
</tr>
<tr>
<td>01xx</td>
<td>(64-UInt(immh:immb))</td>
</tr>
<tr>
<td>lxxx</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

For the vector variant: is the right shift amount, in the range 1 to the destination element width in bits, encoded in “immh:immb”:

<table>
<thead>
<tr>
<th>immh</th>
<th>&lt;shift&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0000</td>
<td>SEE Advanced SIMD modified immediate</td>
</tr>
<tr>
<td>0001</td>
<td>(16-UInt(immh:immb))</td>
</tr>
<tr>
<td>001x</td>
<td>(32-UInt(immh:immb))</td>
</tr>
<tr>
<td>01xx</td>
<td>(64-UInt(immh:immb))</td>
</tr>
<tr>
<td>lxxx</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

**Operation**

```c
CheckFPAdvSIMDEnabled64();
bits(datasize*2) operand = V[n];
bits(datasize) result;
integer round_const = if round then (1 << (shift - 1)) else 0;
integer element;
boolean sat;
for e = 0 to elements-1
    element = (Int(Elem[operand, e, 2*esize], unsigned) + round_const) >> shift;
    (Elem[result, e, esize], sat) = SatQ(element, esize, unsigned);
    if sat then FPSR.QC = '1';
Vpart[d, part] = result;
```

Internal version only: isa v30.25, AdvSIMD v27.01, pseudocode v85-xml-00beta8_rc3357; Build timestamp: 2018-09-13T13:2018-06-16T02:04:45

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Signed saturating Shift Right Unsigned Narrow (immediate). This instruction reads each signed integer value in the vector of the source SIMD&FP register, right shifts each value by an immediate value, saturates the result to an unsigned integer value that is half the original width, places the final result into a vector, and writes the vector to the destination SIMD&FP register. The results are truncated. For rounded results, see SQRSHRUN.

The SQSHRUN instruction writes the vector to the lower half of the destination register and clears the upper half, while the SQSHRUN2 instruction writes the vector to the upper half of the destination register without affecting the other bits of the register. If saturation occurs, the cumulative saturation bit FPSR.QC is set. Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

It has encodings from 2 classes: Scalar and Vector

**Scalar**

```
31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
```

<table>
<thead>
<tr>
<th>0</th>
<th>1</th>
<th>1</th>
<th>1</th>
<th>1</th>
<th>1</th>
<th>1</th>
<th>1</th>
<th>0</th>
<th>!= 0000</th>
<th>immh</th>
<th>1</th>
<th>0</th>
<th>0</th>
<th>0</th>
<th>0</th>
<th>1</th>
<th>Rd</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Scalar**

```
SQSHRUN <Vb><d>, <Va><n>, #<shift>
```

```
integer d = UInt(Rd);
integer n = UInt(Rn);
if immh == '0000' then UNDEFINED;
if immh<3> == '1' then UNDEFINED;
integer esize = 8 << if immh == '0000' then ReservedValue();
if immh<3> == '1' then ReservedValue();
integer esize = 8 << HighestSetBit(immh);
integer datasize = esize;
integer elements = 1;
integer part = 0;
integer shift = (2 * esize) - UInt(immh:immb);
boolean round = (op == '1');
```

**Vector**

```
31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
```

<table>
<thead>
<tr>
<th>0</th>
<th>Q</th>
<th>1</th>
<th>0</th>
<th>1</th>
<th>1</th>
<th>1</th>
<th>1</th>
<th>0</th>
<th>!= 0000</th>
<th>immh</th>
<th>1</th>
<th>0</th>
<th>0</th>
<th>0</th>
<th>0</th>
<th>1</th>
<th>Rd</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

SQSHRUN, SQSHRUN2
Vector

SQSHRUN(2) <Vd>.<Tb>, <Vn>.<Ta>, #<shift>

integer d = UInt(Rd);
integer n = UInt(Rn);

if immh == '0000' then SEE(asimdimm);
if immh<3> == '1' then UNDEFINED;
integer esize = 8 << if immh<3> == '1' then ReservedValue();
integer esize = 8 << HighestSetBit(immh);
integer datasize = 64;
integer part = UInt(Q);
integer elements = datasize DIV esize;
integer shift = (2 * esize) - UInt(immh:immb);
boolean round = (op == '1');

Assembler Symbols

2

Is the second and upper half specifier. If present it causes the operation to be performed on the upper 64 bits of the registers holding the narrower elements, and is encoded in "Q":

<table>
<thead>
<tr>
<th>immh</th>
<th>Q 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>0000</td>
<td>x</td>
</tr>
<tr>
<td>0001</td>
<td>0</td>
</tr>
<tr>
<td>0001</td>
<td>1</td>
</tr>
<tr>
<td>001x</td>
<td>0</td>
</tr>
<tr>
<td>001x</td>
<td>1</td>
</tr>
<tr>
<td>01xx</td>
<td>0</td>
</tr>
<tr>
<td>01xx</td>
<td>1</td>
</tr>
<tr>
<td>1xxx</td>
<td>x</td>
</tr>
</tbody>
</table>

<Vd> Is the name of the SIMD&FP destination register, encoded in the "Rd" field.

<Tb> Is an arrangement specifier, encoded in “immh:Q”:

<table>
<thead>
<tr>
<th>immh</th>
<th>Q 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>0000</td>
<td>x</td>
</tr>
<tr>
<td>0001</td>
<td>0</td>
</tr>
<tr>
<td>0001</td>
<td>1</td>
</tr>
<tr>
<td>001x</td>
<td>0</td>
</tr>
<tr>
<td>001x</td>
<td>1</td>
</tr>
<tr>
<td>01xx</td>
<td>0</td>
</tr>
<tr>
<td>01xx</td>
<td>1</td>
</tr>
<tr>
<td>1xxx</td>
<td>x</td>
</tr>
</tbody>
</table>

<Vn> Is the name of the SIMD&FP source register, encoded in the "Rn" field.

<Ta> Is an arrangement specifier, encoded in “immh”:

<table>
<thead>
<tr>
<th>immh</th>
<th>&lt;Ta&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0000</td>
<td>SEE Advanced SIMD modified immediate</td>
</tr>
<tr>
<td>0001</td>
<td>8H</td>
</tr>
<tr>
<td>001x</td>
<td>4S</td>
</tr>
<tr>
<td>01xx</td>
<td>2D</td>
</tr>
<tr>
<td>1xxx</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

<Vb> Is the destination width specifier, encoded in “immh”:

<table>
<thead>
<tr>
<th>immh</th>
<th>&lt;Vb&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0000</td>
<td>RESERVED</td>
</tr>
<tr>
<td>0001</td>
<td>B</td>
</tr>
<tr>
<td>001x</td>
<td>H</td>
</tr>
<tr>
<td>01xx</td>
<td>S</td>
</tr>
<tr>
<td>1xxx</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

<d> Is the number of the SIMD&FP destination register, in the "Rd" field.

<Va> Is the source width specifier, encoded in “immh”:

<table>
<thead>
<tr>
<th>immh</th>
<th>&lt;Va&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0000</td>
<td>RESERVED</td>
</tr>
<tr>
<td>0001</td>
<td>H</td>
</tr>
<tr>
<td>001x</td>
<td>S</td>
</tr>
<tr>
<td>01xx</td>
<td>D</td>
</tr>
<tr>
<td>1xxx</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

<n> Is the number of the first SIMD&FP source register, encoded in the "Rn" field.
For the scalar variant: is the right shift amount, in the range 1 to the destination operand width in bits, encoded in “im mh:im mb”:

<table>
<thead>
<tr>
<th>immh</th>
<th>&lt;shift&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0000</td>
<td>RESERVED</td>
</tr>
<tr>
<td>0001</td>
<td>(16-UInt(im mh:im mb))</td>
</tr>
<tr>
<td>001x</td>
<td>(32-UInt(im mh:im mb))</td>
</tr>
<tr>
<td>01xx</td>
<td>(64-UInt(im mh:im mb))</td>
</tr>
<tr>
<td>1xxx</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

For the vector variant: is the right shift amount, in the range 1 to the destination element width in bits, encoded in “im mh:im mb”:

<table>
<thead>
<tr>
<th>immh</th>
<th>&lt;shift&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0000</td>
<td>SEE Advanced SIMD modified immediate</td>
</tr>
<tr>
<td>0001</td>
<td>(16-UInt(im mh:im mb))</td>
</tr>
<tr>
<td>001x</td>
<td>(32-UInt(im mh:im mb))</td>
</tr>
<tr>
<td>01xx</td>
<td>(64-UInt(im mh:im mb))</td>
</tr>
<tr>
<td>1xxx</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

**Operation**

```c
CheckFPAdvSIMDEnabled64();
bits(datasize*2) operand = V[n];
bits(datasize) result;
integer round_const = if round then (1 << (shift - 1)) else 0;
integer element;
boolean sat;
for e = 0 to elements-1
   element = (SInt(Elem[operand, e, 2*esize]) + round_const) >> shift;
   (Elem[result, e, esize], sat) = UnsignedSatQ(element, esize);
   if sat then FPSR.QC = '1';
Vpart[d, part] = result;
```

Internal version only: isa v30.25 v29.05, AdvSIMD v27.01 v26.01, pseudocode v85-xml-00bex8 rc3e53e; Build timestamp: 2018-09-13T13:2018-06-16T04:45

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SQSUB

Signed saturating Subtract. This instruction subtracts the element values of the second source SIMD&FP register from the corresponding element values of the first source SIMD&FP register, places the results into a vector, and writes the vector to the destination SIMD&FP register. If overflow occurs with any of the results, those results are saturated. If saturation occurs, the cumulative saturation bit \( FP_{SR} \).QC is set. Depending on the settings in the \( CPACR\_EL1 \), \( CPTR\_EL2 \), and \( CPTR\_EL3 \) registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

It has encodings from 2 classes: Scalar and Vector

**Scalar**

```
<table>
<thead>
<tr>
<th>0</th>
<th>1</th>
<th>0</th>
<th>1</th>
<th>1</th>
<th>1</th>
<th>0</th>
<th>size</th>
<th>1</th>
<th>Rm</th>
<th>0</th>
<th>0</th>
<th>1</th>
<th>0</th>
<th>1</th>
<th>1</th>
<th>Rn</th>
<th>Rd</th>
</tr>
</thead>
<tbody>
<tr>
<td>U</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
```

```
integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rm);
integer esize = 8 << UInt(size);
integer datasize = esize;
integer elements = 1;
boolean unsigned = (U == '1');
```

**Vector**

```
| 0 | Q | 0 | 0 | 1 | 1 | 1 | 0 | size | 1 | Rm | 0 | 0 | 1 | 0 | 1 | 1 | Rn | Rd |
|---|---|---|---|---|---|---|-----|---|---|---|---|---|---|---|---|---|---|
| U |
```

```
integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rm);
if size:Q == '110' then UNDEFINED;
integer esize = 8 << if size:Q == '110' then ReservedValue(1);
integer esize = 8 << UInt(size);
integer datasize = if Q == '1' then 128 else 64;
integer elements = datasize DIV esize;
boolean unsigned = (U == '1');
```

**Assembler Symbols**

\(<V>\) Is a width specifier, encoded in "size":

<table>
<thead>
<tr>
<th>size</th>
<th>&lt;V&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>B</td>
</tr>
<tr>
<td>01</td>
<td>H</td>
</tr>
<tr>
<td>10</td>
<td>S</td>
</tr>
<tr>
<td>11</td>
<td>D</td>
</tr>
</tbody>
</table>

\(<d>\) Is the number of the SIMD&FP destination register, in the "Rd" field.

\(<n>\) Is the number of the first SIMD&FP source register, encoded in the "Rn" field.
Is the number of the second SIMD&FP source register, encoded in the "Rm" field.

Is the name of the SIMD&FP destination register, encoded in the "Rd" field.

Is an arrangement specifier, encoded in "size:Q":

<table>
<thead>
<tr>
<th>size</th>
<th>Q</th>
<th>&lt;T&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>0</td>
<td>8B</td>
</tr>
<tr>
<td>00</td>
<td>1</td>
<td>16B</td>
</tr>
<tr>
<td>01</td>
<td>0</td>
<td>4H</td>
</tr>
<tr>
<td>01</td>
<td>1</td>
<td>8H</td>
</tr>
<tr>
<td>10</td>
<td>0</td>
<td>2S</td>
</tr>
<tr>
<td>10</td>
<td>1</td>
<td>4S</td>
</tr>
<tr>
<td>11</td>
<td>0</td>
<td>RESERVED</td>
</tr>
<tr>
<td>11</td>
<td>1</td>
<td>2D</td>
</tr>
</tbody>
</table>

Is the name of the first SIMD&FP source register, encoded in the "Rn" field.

Is the name of the second SIMD&FP source register, encoded in the "Rm" field.

**Operation**

```c
CheckFPAdvSIMDEnabled64();
bits(datasize) operand1 = V[n];
bits(datasize) operand2 = V[m];
bits(datasize) result;
integer element1;
integer element2;
integer diff;
boolean sat;
for e = 0 to elements-1
    element1 = Int(Elem[operand1, e, esize], unsigned);
    element2 = Int(Elem[operand2, e, esize], unsigned);
    diff = element1 - element2;
    (Elem[result, e, esize], sat) = SatQ(diff, esize, unsigned);
    if sat then FPSR.QC = '1';
V[d] = result;
```

Internal version only: isa v30.25 v29.05, AdvSIMD v27.01 v26.0, pseudocode v85-xml-00bet8_rc354.; Build timestamp: 2018-09-13T1345 2018-06-16T0945

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SQXTN, SQXTN2

Signed saturating extract Narrow. This instruction reads each vector element from the source SIMD&FP register, saturates the value to half the original width, places the result into a vector, and writes the vector to the lower or upper half of the destination SIMD&FP register. The destination vector elements are half as long as the source vector elements. All the values in this instruction are signed integer values. If overflow occurs with any of the results, those results are saturated. If saturation occurs, the cumulative saturation bit FPSR.QC is set.

The SQXTN instruction writes the vector to the lower half of the destination register and clears the upper half, while the SQXTN2 instruction writes the vector to the upper half of the destination register without affecting the other bits of the register.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

It has encodings from 2 classes: Scalar and Vector

Scalar

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9  | 8  | 7  | 6  | 5  | 4  | 3  | 2  | 1  | 0  |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0  | 1  | 0  | 1  | 1  | 1  | 0  | size| 1  | 0  | 0  | 0  | 0  | 1  | 0  | 1  | 0  | 0  | 1  | 0  | 0  | 0  | 1  | 0  | 0  | 0  | 1  | 0  | Rn | Rd |

Scalar

SQXTN <Vb><d>, <Va><n>

integer d = UInt(Rd);
integer n = UInt(Rn);

if size == '11' then UNDEFINED;
integer esize = 8 << if size == '11' then ReservedValue() else UInt(size);
integer datasize = esize;
integer part = 0;
integer elements = 1;

boolean unsigned = (U == '1');

Vector

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9  | 8  | 7  | 6  | 5  | 4  | 3  | 2  | 1  | 0  |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0  | Q  | 0  | 0  | 1  | 1  | 1  | 0  | size| 1  | 0  | 0  | 0  | 0  | 1  | 0  | 1  | 0  | 0  | 1  | 0  | 0  | 0  | 1  | 0  | 0  | 0  | 1  | 0  | Rn | Rd |

Vector

SQXTN(2) <Vd>.<Tb>, <Vn>.<Ta>

integer d = UInt(Rd);
integer n = UInt(Rn);

if size == '11' then UNDEFINED;
integer esize = 8 << if size == '11' then ReservedValue() else UInt(size);
integer datasize = 64;
integer part = UInt(Q);
integer elements = datasize DIV esize;

boolean unsigned = (U == '1');
Assembler Symbols

2
Is the second and upper half specifier. If present it causes the operation to be performed on the upper 64 bits of the registers holding the narrower elements, and is encoded in "Q":

<table>
<thead>
<tr>
<th>Q</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>[absent]</td>
</tr>
<tr>
<td>1</td>
<td>[present]</td>
</tr>
</tbody>
</table>

<Vd>
Is the name of the SIMD&FP destination register, encoded in the "Rd" field.

<Tb>
Is an arrangement specifier, encoded in “size:Q”:

<table>
<thead>
<tr>
<th>size</th>
<th>Q</th>
<th>&lt;Tb&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>0</td>
<td>8B</td>
</tr>
<tr>
<td>00</td>
<td>1</td>
<td>16B</td>
</tr>
<tr>
<td>01</td>
<td>0</td>
<td>4H</td>
</tr>
<tr>
<td>01</td>
<td>1</td>
<td>8H</td>
</tr>
<tr>
<td>10</td>
<td>0</td>
<td>2S</td>
</tr>
<tr>
<td>10</td>
<td>1</td>
<td>4S</td>
</tr>
<tr>
<td>11</td>
<td>x</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

<Vn>
Is the name of the SIMD&FP source register, encoded in the "Rn" field.

<Ta>
Is an arrangement specifier, encoded in “size”:

<table>
<thead>
<tr>
<th>size</th>
<th>&lt;Ta&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>8H</td>
</tr>
<tr>
<td>01</td>
<td>4S</td>
</tr>
<tr>
<td>10</td>
<td>2D</td>
</tr>
<tr>
<td>11</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

<Vb>
Is the destination width specifier, encoded in “size”:

<table>
<thead>
<tr>
<th>size</th>
<th>&lt;Vb&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>B</td>
</tr>
<tr>
<td>01</td>
<td>H</td>
</tr>
<tr>
<td>10</td>
<td>S</td>
</tr>
<tr>
<td>11</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

<d>
Is the number of the SIMD&FP destination register, encoded in the "Rd" field.

<Va>
Is the source width specifier, encoded in “size”:

<table>
<thead>
<tr>
<th>size</th>
<th>&lt;Va&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>H</td>
</tr>
<tr>
<td>01</td>
<td>S</td>
</tr>
<tr>
<td>10</td>
<td>D</td>
</tr>
<tr>
<td>11</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

<n>
Is the number of the SIMD&FP source register, encoded in the "Rn" field.

Operation

```c
CheckFPAdvSIMDEnabled64();
bits(2*datasize) operand = V[n];
bits(datasize) result;
bits(2*esize) element;
boolean sat;
for e = 0 to elements-1
    element = Elem[operand, e, 2*esize];
    (Elem[result, e, esize], sat) = SatQ(Int(element, unsigned), esize, unsigned);
    if sat then FPSR.QC = '1';
Vpart[d, part] = result;
```

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SQXTUN, SQXTUN2

Signed saturating extract Unsigned Narrow. This instruction reads each signed integer value in the vector of the source SIMD&FP register, saturates the value to an unsigned integer value that is half the original width, places the result into a vector, and writes the vector to the lower or upper half of the destination SIMD&FP register. The destination vector elements are half as long as the source vector elements.

If saturation occurs, the cumulative saturation bit FPSR.QC is set.

The SQXTUN instruction writes the vector to the lower half of the destination register and clears the upper half, while the SQXTUN2 instruction writes the vector to the upper half of the destination register without affecting the other bits of the register.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

It has encodings from 2 classes: Scalar and Vector

Scalar

```
<table>
<thead>
<tr>
<th>31</th>
<th>30</th>
<th>29</th>
<th>28</th>
<th>27</th>
<th>26</th>
<th>25</th>
<th>24</th>
<th>23</th>
<th>22</th>
<th>21</th>
<th>20</th>
<th>19</th>
<th>18</th>
<th>17</th>
<th>16</th>
<th>15</th>
<th>14</th>
<th>13</th>
<th>12</th>
<th>11</th>
<th>10</th>
<th>9</th>
<th>8</th>
<th>7</th>
<th>6</th>
<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>size</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>Rd</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rn</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
```

Scalar

```
integer d = UInt(Rd);
integer n = UInt(Rn);

if size == '11' then UNDEFINED;
integer esize = 8 << if size == '11' then ReservedValue() else UInt(size);
integer datasize = esize;
integer part = 0;
integer elements = 1;
```---

Vector

```
<table>
<thead>
<tr>
<th>31</th>
<th>30</th>
<th>29</th>
<th>28</th>
<th>27</th>
<th>26</th>
<th>25</th>
<th>24</th>
<th>23</th>
<th>22</th>
<th>21</th>
<th>20</th>
<th>19</th>
<th>18</th>
<th>17</th>
<th>16</th>
<th>15</th>
<th>14</th>
<th>13</th>
<th>12</th>
<th>11</th>
<th>10</th>
<th>9</th>
<th>8</th>
<th>7</th>
<th>6</th>
<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Q</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>size</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>Rd</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rn</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
```

Vector

```
integer d = UInt(Rd);
integer n = UInt(Rn);

if size == '11' then UNDEFINED;
integer esize = 8 << if size == '11' then ReservedValue() else UInt(size);
integer datasize = 64;
integer part = UInt(Q);
integer elements = datasize DIV esize;
```---

Assembler Symbols

```
Q 2
0  [absent]
1  [present]
```
Is the name of the SIMD&FP destination register, encoded in the "Rd" field.

Is an arrangement specifier, encoded in “size-Q”:

<table>
<thead>
<tr>
<th>size</th>
<th>Q</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>08H</td>
</tr>
<tr>
<td>00</td>
<td>116B</td>
</tr>
<tr>
<td>01</td>
<td>04H</td>
</tr>
<tr>
<td>01</td>
<td>18H</td>
</tr>
<tr>
<td>10</td>
<td>02S</td>
</tr>
<tr>
<td>10</td>
<td>14S</td>
</tr>
<tr>
<td>11</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

Is the name of the SIMD&FP source register, encoded in the "Rn" field.

Is an arrangement specifier, encoded in “size”:

<table>
<thead>
<tr>
<th>size</th>
<th>&lt;Ta&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>8H</td>
</tr>
<tr>
<td>01</td>
<td>4S</td>
</tr>
<tr>
<td>10</td>
<td>2D</td>
</tr>
<tr>
<td>11</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

Is the destination width specifier, encoded in “size”:

<table>
<thead>
<tr>
<th>size</th>
<th>&lt;Vb&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>B</td>
</tr>
<tr>
<td>01</td>
<td>H</td>
</tr>
<tr>
<td>10</td>
<td>S</td>
</tr>
<tr>
<td>11</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

Is the number of the SIMD&FP destination register, encoded in the "Rd" field.

Is the source width specifier, encoded in “size”:

<table>
<thead>
<tr>
<th>size</th>
<th>&lt;Va&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>H</td>
</tr>
<tr>
<td>01</td>
<td>S</td>
</tr>
<tr>
<td>10</td>
<td>D</td>
</tr>
<tr>
<td>11</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

Is the number of the SIMD&FP source register, encoded in the "Rn" field.

**Operation**

```c
CheckFPAdvSIMDEnabled64();
bits(2*datasize) operand = V[n];
bits(datasize) result;
bits(2*esize) element;
boolean sat;
for e = 0 to elements-1
    element = Elem[operand, e, 2*esize];
    (Elem[result, e, esize], sat) = UnsignedSatQ(SInt(element), esize);
    if sat then FPSR.QC = '1';
Vpart[d, part] = result;
```

Internal version only: isa v30.25+ v29.05+, AdvSIMD v27.01+ v26.0+, pseudocode v85-xml-00bet8_rc35553; Build timestamp: 2018-09-13T13:2018-06-16T09:04:45

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SRHADD

Signed Rounding Halving Add. This instruction adds corresponding signed integer values from the two source SIMD&FP registers, shifts each result right one bit, places the results into a vector, and writes the vector to the destination SIMD&FP register.

The results are rounded. For truncated results, see **SHADD**.

Depending on the settings in the `CPACR_EL1`, `CPTR_EL2`, and `CPTR_EL3` registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

![Register Table](new)

### Three registers of the same type

SRHADD `<Vd>`. `<T>`, `<Vn>`. `<T>`, `<Vm>`. `<T>`

```plaintext
integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rm);
if size == '11' then UNDEFINED;
integer esize = 8 << if size == '11' then ReservedValue();
integer esize = 8 << UInt(size);
integer datasize = if Q == '1' then 128 else 64;
integer elements = datasize DIV esize;
boolean unsigned = (U == '1');
```

### Assembler Symbols

**<Vd>**  
Is the name of the SIMD&FP destination register, encoded in the "Rd" field.

**<T>**  
Is an arrangement specifier, encoded in “size:Q”:

<table>
<thead>
<tr>
<th>size</th>
<th>Q</th>
<th>&lt;T&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>0</td>
<td>8B</td>
</tr>
<tr>
<td>00</td>
<td>1</td>
<td>16B</td>
</tr>
<tr>
<td>01</td>
<td>0</td>
<td>4H</td>
</tr>
<tr>
<td>01</td>
<td>1</td>
<td>8H</td>
</tr>
<tr>
<td>10</td>
<td>0</td>
<td>2S</td>
</tr>
<tr>
<td>10</td>
<td>1</td>
<td>4S</td>
</tr>
<tr>
<td>11</td>
<td>x</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

**<Vn>**  
Is the name of the first SIMD&FP source register, encoded in the "Rn" field.

**<Vm>**  
Is the name of the second SIMD&FP source register, encoded in the "Rm" field.

### Operation

```plaintext
CheckFPAdvSIMDEnabled64();
bits(datasize) operand1 = V[n];
bits(datasize) operand2 = V[m];
bits(datasize) result;
integer element1;
integer element2;
for e = 0 to elements-1
    element1 = Int(Elem[operand1, e, esize], unsigned);
    element2 = Int(Elem[operand2, e, esize], unsigned);
    Elem[result, e, esize] = (element1 + element2 + 1)<esize:1>;
V[d] = result;
```
SRI

Shift Right and Insert (immediate). This instruction reads each vector element in the source SIMD&FP register, right shifts each vector element by an immediate value, and inserts the result into the corresponding vector element in the destination SIMD&FP register such that the new zero bits created by the shift are not inserted but retain their existing value. Bits shifted out of the right of each vector element of the source register are lost.

The following figure shows an example of the operation of shift right by 3 for an 8-bit vector element.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

It has encodings from 2 classes: Scalar and Vector

Scalar

```
integer d = UInt(Rd);
integer n = UInt(Rn);
if immh<3> != '1' then UNDEFINED;
integer esize = 8 << 3;
integer datasize = esize;
integer elements = 1;
integer shift = (esize * 2) - if immh<3> != '1' then ReservedValue();
integer esize = 8 << 3;
integer datasize = esize;
integer elements = 1;
integer shift = (esize * 2) - if immh<3> != '1' then ReservedValue();
```

Vector

```
integer d = UInt(Rd);
integer n = UInt(Rn);
if immh<3> != '1' then UNDEFINED;
integer esize = 8 << 3;
integer datasize = esize;
integer elements = 1;
integer shift = (esize * 2) - if immh<3> != '1' then ReservedValue();
integer esize = 8 << 3;
integer datasize = esize;
integer elements = 1;
integer shift = (esize * 2) - if immh<3> != '1' then ReservedValue();
```
Vector

SRI <Vd>,<T>,<Vn>,<T>, #<shift>

```plaintext
ingTEGER d = UInt(Rd);
ingTEGER n = UInt(Rn);
if immh == '0000' then SEE(asimdimm);
if immh<3>:Q == '10' then UNDEFINED;
ingTEGER esize = 8 <<if immh<3>:Q == '10' then ReservedValue();
ingTEGER esize = 8 <<HighestSetBit(immh);
ingTEGER datasize = if Q == '1' then 128 else 64;
ingTEGER elements = datasize DIV esize;
integer shift = (esize * 2) - UInt(immh:immb);
```

Assembler Symbols

| `<V>` | Is a width specifier, encoded in “immh”:
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>immh</td>
<td><code>&lt;V&gt;</code></td>
</tr>
<tr>
<td>0xxx</td>
<td>RESERVED</td>
</tr>
<tr>
<td>1xxx</td>
<td>D</td>
</tr>
</tbody>
</table>

| `<d>` | Is the number of the SIMD&FP destination register, in the "Rd" field. |
| `<n>` | Is the number of the first SIMD&FP source register, encoded in the "Rn" field. |
| `<Vd>` | Is the name of the SIMD&FP destination register, encoded in the "Rd" field. |
| `<T>` | Is an arrangement specifier, encoded in “immh:Q”:
| immh | Q | `<T>` |
| 0000 | x | SEE Advanced SIMD modified immediate |
| 0001 | 0 | 8B |
| 0001 | 1 | 16B |
| 001x | 0 | 4H |
| 001x | 1 | 8H |
| 01xx | 0 | 2S |
| 01xx | 1 | 4S |
| 1xxx | 0 | RESERVED |
| 1xxx | 1 | 2D |

| `<Vn>` | Is the name of the SIMD&FP source register, encoded in the "Rn" field. |
| `<shift>` | For the scalar variant: is the right shift amount, in the range 1 to 64, encoded in “immh:immb”:
| immh | `<shift>` |
| 0xxx | RESERVED |
| 1xxx | (128-UInt(immh:immb)) |

| `<Vn>` | Is the name of the SIMD&FP source register, encoded in the "Rn" field. |
| `<shift>` | For the vector variant: is the right shift amount, in the range 1 to the element width in bits, encoded in “immh:immb”:
| immh | `<shift>` |
| 0000 | SEE Advanced SIMD modified immediate |
| 0001 | (16-UInt(immh:immb)) |
| 001x | (32-UInt(immh:immb)) |
| 01xx | (64-UInt(immh:immb)) |
| 1xxx | (128-UInt(immh:immb)) |
Operation

```c
CheckFPAdvSIMEnabled64();
bits(datasize) operand = V[n];
bits(datasize) operand2 = V[d];
bits(datasize) result;
bits(esize) mask = LSR(Ones(esize), shift);
bits(esize) shifted;

for e = 0 to elements-1
    shifted = LSR(Elem[operand, e, esize], shift);
    Elem[result, e, esize] = (Elem[operand2, e, esize] AND NOT(mask)) OR shifted;
V[d] = result;
```

Operational information

If PSTATE.DIT is 1:

- The execution time of this instruction is independent of:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
- The response of this instruction to asynchronous exceptions does not vary based on:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.

Internal version only: isa v30.25 v29.05, AdvSIMD v27.01 v26.0, pseudocode v85-xml-00bet8_rc3v85; Build timestamp: 2018-09-13T13:50 2018-06-16T09:04:45

Copyright © 2010-2018 ARM Limited or its affiliates. All rights reserved. This document is Non-Confidential.
Signed Rounding Shift Left (register). This instruction takes each signed integer value in the vector of the first source SIMD&FP register, shifts it by a value from the least significant byte of the corresponding element of the second source SIMD&FP register, places the results in a vector, and writes the vector to the destination SIMD&FP register.

If the shift value is positive, the operation is a left shift. If the shift value is negative, it is a rounding right shift. For a truncating shift, see SSHL.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

It has encodings from 2 classes: Scalar and Vector

**Scalar**

<table>
<thead>
<tr>
<th>31</th>
<th>30</th>
<th>29</th>
<th>28</th>
<th>27</th>
<th>26</th>
<th>25</th>
<th>24</th>
<th>23</th>
<th>22</th>
<th>21</th>
<th>20</th>
<th>19</th>
<th>18</th>
<th>17</th>
<th>16</th>
<th>15</th>
<th>14</th>
<th>13</th>
<th>12</th>
<th>11</th>
<th>10</th>
<th>9</th>
<th>8</th>
<th>7</th>
<th>6</th>
<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
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<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>Rm</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>Rn</td>
<td>Rd</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Vector**

<table>
<thead>
<tr>
<th>31</th>
<th>30</th>
<th>29</th>
<th>28</th>
<th>27</th>
<th>26</th>
<th>25</th>
<th>24</th>
<th>23</th>
<th>22</th>
<th>21</th>
<th>20</th>
<th>19</th>
<th>18</th>
<th>17</th>
<th>16</th>
<th>15</th>
<th>14</th>
<th>13</th>
<th>12</th>
<th>11</th>
<th>10</th>
<th>9</th>
<th>8</th>
<th>7</th>
<th>6</th>
<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>Rm</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>Rn</td>
<td>Rd</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Assembler Symbols**

< V > Is a width specifier, encoded in “size”:

integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rm);
integer esize = 8 << UInt(size);
integer datasize = esize;
integer elements = 1;
boolean unsigned = (U == '1');
boolean rounding = (R == '1');
boolean saturating = (S == '1');
<table>
<thead>
<tr>
<th>size</th>
<th>&lt;V&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0x</td>
<td>RESERVED</td>
</tr>
<tr>
<td>10</td>
<td>RESERVED</td>
</tr>
<tr>
<td>11</td>
<td>D</td>
</tr>
</tbody>
</table>

- `<d>` Is the number of the SIMD&FP destination register, in the "Rd" field.
- `<n>` Is the number of the first SIMD&FP source register, encoded in the "Rn" field.
- `<m>` Is the number of the second SIMD&FP source register, encoded in the "Rm" field.
- `<Vd>` Is the name of the SIMD&FP destination register, encoded in the "Rd" field.
- `<T>` Is an arrangement specifier, encoded in "size:Q":

<table>
<thead>
<tr>
<th>size</th>
<th>Q</th>
<th>&lt;T&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>8B</td>
<td></td>
</tr>
<tr>
<td>00</td>
<td>16B</td>
<td></td>
</tr>
<tr>
<td>01</td>
<td>4H</td>
<td></td>
</tr>
<tr>
<td>01</td>
<td>8H</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>2S</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>4S</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>RESERVED</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>2D</td>
<td></td>
</tr>
</tbody>
</table>

- `<Vn>` Is the name of the first SIMD&FP source register, encoded in the "Rn" field.
- `<Vm>` Is the name of the second SIMD&FP source register, encoded in the "Rm" field.

**Operation**

```c
CheckFPAdvSIMDEnabled64();
bits(datasize) operand1 = V[n];
bits(datasize) operand2 = V[m];
bits(datasize) result;

integer round_const = 0;
integer shift;
integer element;
boolean sat;

for e = 0 to elements-1
    shift = SInt(Elem[operand2, e, esize]<7:0>);
    if rounding then
        round_const = 1 << (-shift - 1); // 0 for left shift, 2^(n-1) for right shift
        element = (Int(Elem[operand1, e, esize], unsigned) + round_const) << shift;
    if saturating then
        (Elem[result, e, esize], sat) = SatQ(element, esize, unsigned);
        if sat then FPSR.QC = '1';
        else
            Elem[result, e, esize] = element<esize-1:0>;
    V[d] = result;
```


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SRSHR

Signed Rounding Shift Right (immediate). This instruction reads each vector element in the source SIMD&FP register, right shifts each result by an immediate value, places the final result into a vector, and writes the vector to the destination SIMD&FP register. All the values in this instruction are signed integer values. The results are rounded. For truncated results, see SSSH.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

It has encodings from 2 classes: Scalar and Vector

Scalar

SRSHR <V><d>, <V><n>, #<shift>

integer d = UInt(Rd);
integer n = UInt(Rn);

if immh<3> != '1' then UNDEFINED;
integer esize = 8 << 3;
integer datasize = esize;
integer elements = 1;

integer shift = (esize * 2) - if immh<3> != '1' then ReservedValue();
integer esize = 8 << 3;
integer datasize = esize;
integer elements = 1;

integer shift = (esize * 2) - UInt(immh:immb);
boolean unsigned = (U == '1');
boolean round = (o1 == '1');
boolean accumulate = (o0 == '1');

Vector

SRSHR
Vector

**SRSHR** <Vd>, <T>, <Vn>, <T>, #<shift>

```plaintext
integer d = UInt(Rd);
integer n = UInt(Rn);

if immh == '0000' then SEE(asimdimm);
if immh<3>:Q == '10' then UNDEFINED;
integer esize = 8 << if immh<3>:Q == '10' then ReservedValue();
integer esize = 8 << HighestSetBit(immh);
integer datasize = if Q == '1' then 128 else 64;
integer elements = datasize DIV esize;
integer shift = (esize * 2) - UInt(immh:immb);
boolean unsigned = (U == '1');
boolean round = (o1 == '1');
boolean accumulate = (o0 == '1');
```

**Assembler Symbols**

- `<V>` Is a width specifier, encoded in “immh”:
  ```plaintext
  immh  <V>
  0xxx  RESERVED
  1xx   D
  ```

- `<d>` Is the number of the SIMD&FP destination register, in the “Rd” field.
- `<n>` Is the number of the first SIMD&FP source register, encoded in the “Rn” field.
- `<Vd>` Is the name of the SIMD&FP destination register, encoded in the “Rd” field.
- `<T>` Is an arrangement specifier, encoded in “immh:Q”:
  ```plaintext
  immh    Q  <T>
  0000  x  SEE Advanced SIMD modified immediate
  0001  0  8B
  0001  1  16B
  001x  0  4H
  001x  1  8H
  01xx  0  2S
  01xx  1  4S
  1xx   0  RESERVED
  1xx   1  2D
  ```

- `<Vn>` Is the name of the SIMD&FP source register, encoded in the “Rn” field.
- `<shift>` For the scalar variant: is the right shift amount, in the range 1 to 64, encoded in “immh:immb”:
  ```plaintext
  immh  <shift>
  0xxx  RESERVED
  1xx   (128-UInt(immh:immb))
  ```

  For the vector variant: is the right shift amount, in the range 1 to the element width in bits, encoded in “immh:immb”:
  ```plaintext
  immh  <shift>
  0000  SEE Advanced SIMD modified immediate
  0001  (16-UInt(immh:immb))
  001x  (32-UInt(immh:immb))
  01xx  (64-UInt(immh:immb))
  1xxx  (128-UInt(immh:immb))
  ```
Operation

CheckFPAdvSIMDEnabled64();
bits(datasize) operand = V[n];
bits(datasize) operand2;
bits(datasize) result;
integer round_const = if round then (1 << (shift - 1)) else 0;
integer element;
operand2 = if accumulate then V[d] else Zeros();
for e = 0 to elements - 1
    element = (Int(Elem(operand, e, esize), unsigned) + round_const) >> shift;
    Elem[result, e, esize] = Elem[operand2, e, esize] + element<esize-1:0>;
V[d] = result;
SRSRA

Signed Rounding Shift Right and Accumulate (immediate). This instruction reads each vector element in the source SIMD&FP register, right
shifts each result by an immediate value, and accumulates the final results with the vector elements of the destination SIMD&FP register. All the
values in this instruction are signed integer values. The results are rounded. For truncated results, see SSRA.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an
attempt to execute the instruction might be trapped.

It has encodings from 2 classes: Scalar and Vector

Scalar

```
| 31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10  9  8  7  6  5  4  3  2  1  0 |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
|  0 |  1 | 1  | 1  | 1  | 1  | 1  | 0  | != | 0000 | immb | 0  | 0  | 1  | 1  | 0  | 1  | Rn | Rd |
| U  | immh| o1 | o0 |
```

**Scalar**

SRSRA `<V>`<d>, `<V>`<n>, #<shift>

```plaintext
integer d = UInt(Rd);
integer n = UInt(Rn);

if immh<3> != '1' then UNDEFINED;
integer esize = 8 << 3;
integer datasize = esize;
integer elements = 1;

integer shift = (esize * 2) - if immh<3> != '1' then ReservedValue();
integer esize = 8 << 3;
integer datasize = esize;
integer elements = 1;

integer shift = (esize * 2) - UInt(immh:immb);
boolean unsigned = (U == '1');
boolean round = (o1 == '1');
boolean accumulate = (o0 == '1');
```

Vector

```
| 31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10  9  8  7  6  5  4  3  2  1  0 |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
|  0 | Q  | 0  | 0  | 1  | 1  | 1  | 1  | != | 0000 | immb | 0  | 0  | 1  | 1  | 0  | 1  | Rn | Rd |
| U  | immh| o1 | o0 |
```

SRSRA
Vector

SRSRA <Vd>, <T>, <Vn>, <T>, #<shift>

integer d = UInt(Rd);
integer n = UInt(Rn);

if immh == '0000' then SEE(asimdimm);
if immh<3>:Q == '10' then UNDEFINED;
inumber esize = 8 << if immh<3>:Q == '10' then ReservedValue();
inumber esize = 8 << HighestSetBit(immh);
inumber datasize = if Q == '1' then 128 else 64;
inumber elements = datasize DIV esize;

integer shift = (esize * 2) - UInt(immh:immb);

boolean unsigned = (U == '1');
boolean round = (o1 == '1');
boolean accumulate = (o0 == '1');

Assembler Symbols

<V> Is a width specifier, encoded in “immh”:

<table>
<thead>
<tr>
<th>immh</th>
<th>&lt;V&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0xxx</td>
<td>RESERVED</td>
</tr>
<tr>
<td>1xxx</td>
<td>D</td>
</tr>
</tbody>
</table>

<d> Is the number of the SIMD&FP destination register, in the “Rd” field.

<n> Is the number of the first SIMD&FP source register, encoded in the “Rn” field.

<Vd> Is the name of the SIMD&FP destination register, encoded in the “Rd” field.

<T> Is an arrangement specifier, encoded in “immh:Q”:

<table>
<thead>
<tr>
<th>immh</th>
<th>Q</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>0000</td>
<td>x</td>
<td>SEE Advanced SIMD modified immediate</td>
</tr>
<tr>
<td>0001</td>
<td>0</td>
<td>8B</td>
</tr>
<tr>
<td>0001</td>
<td>1</td>
<td>16B</td>
</tr>
<tr>
<td>001x</td>
<td>0</td>
<td>4H</td>
</tr>
<tr>
<td>001x</td>
<td>1</td>
<td>8H</td>
</tr>
<tr>
<td>01xx</td>
<td>0</td>
<td>2S</td>
</tr>
<tr>
<td>01xx</td>
<td>1</td>
<td>4S</td>
</tr>
<tr>
<td>1xxx</td>
<td>0</td>
<td>RESERVED</td>
</tr>
<tr>
<td>1xxx</td>
<td>1</td>
<td>2D</td>
</tr>
</tbody>
</table>

<Vn> Is the name of the SIMD&FP source register, encoded in the "Rn" field.

<shift> For the scalar variant: is the right shift amount, in the range 1 to 64, encoded in “immh:immb”:

<table>
<thead>
<tr>
<th>immh</th>
<th>&lt;shift&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0xxx</td>
<td>RESERVED</td>
</tr>
<tr>
<td>1xxx</td>
<td>128-UInt(immh:immb)</td>
</tr>
</tbody>
</table>

For the vector variant: is the right shift amount, in the range 1 to the element width in bits, encoded in “immh:immb”:

<table>
<thead>
<tr>
<th>immh</th>
<th>&lt;shift&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0000</td>
<td>SEE Advanced SIMD modified immediate</td>
</tr>
<tr>
<td>0001</td>
<td>(16-UInt(immh:immb))</td>
</tr>
<tr>
<td>001x</td>
<td>(32-UInt(immh:immb))</td>
</tr>
<tr>
<td>01xx</td>
<td>(64-UInt(immh:immb))</td>
</tr>
<tr>
<td>1xxx</td>
<td>(128-UInt(immh:immb))</td>
</tr>
</tbody>
</table>
Operation

```c
CheckFPAdvSIMDEnabled64();
bits(datasize) operand = V[n];
bits(datasize) operand2;
bits(datasize) result;
integer round_const = if round then (1 << (shift - 1)) else 0;
integer element;

operand2 = if accumulate then V[d] else Zeros();
for e = 0 to elements-1
    element = (Int(Elem(operand, e, esize), unsigned) + round_const) >> shift;
    Elem[result, e, esize] = Elem[operand2, e, esize] + element<esize-1:0>;
V[d] = result;
```

Internal version only: isa v30.25 v29.05, AdvSIMD v27.01 v26.0, pseudocode v85-xml-00bet8_rc3a55; Build timestamp: 2018-09-13T13:20:09-04:00

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SSBB

Speculative Store Bypass Barrier is a memory barrier which prevents speculative loads from bypassing earlier stores to the same virtual address under certain conditions.

The semantics of the Speculative Store Bypass Barrier are:

- When a load to a location appears in program order after the SSBB, then the load does not speculatively read an entry earlier in the coherence order for that location than the entry generated by the latest store satisfying all of the following conditions:
  - The store is to the same location as the load.
  - The store uses the same virtual address as the load.
  - The store appears in program order before the SSBB.

- When a load to a location appears in program order before the SSBB, then the load does not speculatively read data from any store satisfying all of the following conditions:
  - The store is to the same location as the load.
  - The store uses the same virtual address as the load.
  - The store appears in program order after the SSBB.

```
31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
1 1 0 1 0 1 0 0 0 0 0 1 1 0 0 0 0 0 1 0 0 1 1 1 1 1
```

CRm opc

System

SSBB

```
case op of
  when MemBarrierOp_DSBDataSynchronizationBarrier(domain, types);
  when MemBarrierOp_DMBDataMemoryBarrier(domain, types);
  when MemBarrierOp_ISBInstructionSynchronizationBarrier();
  when MemBarrierOp_SSBBSpeculativeSynchronizationBarrierToVA();
  when MemBarrierOp_PSSBBSpeculativeSynchronizationBarrierToPA();
  when MemBarrierOp_SBSpeculationBarrier();
SSHL

Signed Shift Left (register). This instruction takes each signed integer value in the vector of the first source SIMD&FP register, shifts each value by a value from the least significant byte of the corresponding element of the second source SIMD&FP register, places the results in a vector, and writes the vector to the destination SIMD&FP register.

If the shift value is positive, the operation is a left shift. If the shift value is negative, it is a truncating right shift. For a rounding shift, see SRSRL.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

It has encodings from 2 classes: Scalar and Vector

Scalar

```
SSHL <V<d>, <V<n>, <V<m>
```

```
integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rm);
integer esize = 8 << UInt(size);
integer datasize = esize;
integer elements = 1;
boolean unsigned = (U == '1');
boolean rounding = (R == '1');
boolean saturating = (S == '1');
if S == '0' && size != '11' then UNDEFINED;
integer esize = 8 << UInt(size);
integer datasize = if Q == '1' then 128 else 64;
integer elements = datasize DIV esize;
boolean unsigned = (U == '1');
boolean rounding = (R == '1');
boolean saturating = (S == '1');
```

Vector

```
SSHL <Vd>, <T>, <Vn>, <T>, <Vm>.<T>
```

```
integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rm);
if size:Q == '110' then UNDEFINED;
integer esize = 8 << if size:Q == '110' then ReservedValue(1):
integer esize = 8 << UInt(size);
integer datasize = if Q == '1' then 128 else 64;
integer elements = datasize DIV esize;
boolean unsigned = (U == '1');
boolean rounding = (R == '1');
boolean saturating = (S == '1');
```

Assembler Symbols

```
<V> Is a width specifier, encoded in “size”:
```
Is the number of the SIMD&FP destination register, in the "Rd" field.

<n>
Is the number of the first SIMD&FP source register, encoded in the "Rn" field.

<m>
Is the number of the second SIMD&FP source register, encoded in the "Rm" field.

<Vd>
Is the name of the SIMD&FP destination register, encoded in the "Rd" field.

<T>
Is an arrangement specifier, encoded in “size:Q”:

<table>
<thead>
<tr>
<th>size</th>
<th>Q</th>
<th>T</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>0</td>
<td>8B</td>
</tr>
<tr>
<td>00</td>
<td>1</td>
<td>16B</td>
</tr>
<tr>
<td>01</td>
<td>0</td>
<td>4H</td>
</tr>
<tr>
<td>01</td>
<td>1</td>
<td>8H</td>
</tr>
<tr>
<td>10</td>
<td>0</td>
<td>2S</td>
</tr>
<tr>
<td>10</td>
<td>1</td>
<td>4S</td>
</tr>
<tr>
<td>11</td>
<td>0</td>
<td>RESERVED</td>
</tr>
<tr>
<td>11</td>
<td>1</td>
<td>2D</td>
</tr>
</tbody>
</table>

<Vn>
Is the name of the first SIMD&FP source register, encoded in the "Rn" field.

<Vm>
Is the name of the second SIMD&FP source register, encoded in the "Rm" field.

Operation

```c
CheckFPAdvSIMDEnabled64();
bits(datasize) operand1 = V[n];
bits(datasize) operand2 = V[m];
bits(datasize) result;
integer round_const = 0;
integer shift;
integer element;
boolean sat;
for e = 0 to elements-1
    shift = SInt(Elem[operand2, e, esize]<7:0>);
    if rounding then
        round_const = 1 << (-shift - 1); // 0 for left shift, 2^(n-1) for right shift
        element = (Int(Elem[operand1, e, esize], unsigned) + round_const) << shift;
    if saturating then
        (Elem[result, e, esize], sat) = SatQ(element, esize, unsigned);
        if sat then FPSR.QC = '1';
    else
        Elem[result, e, esize] = element<esize-1:0>;
V[d] = result;
```

Operational information

If PSTATE.DIT is 1:

- The execution time of this instruction is independent of:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
- The response of this instruction to asynchronous exceptions does not vary based on:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
SSHLL, SSHLL2

Signed Shift Left Long (immediate). This instruction reads each vector element from the source SIMD&FP register, left shifts each vector element by the specified shift amount, places the result into a vector, and writes the vector to the destination SIMD&FP register. The destination vector elements are twice as long as the source vector elements. All the values in this instruction are signed integer values.

The SSHLL instruction extracts vector elements from the lower half of the source register, while the SSHLL2 instruction extracts vector elements from the upper half of the source register.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

This instruction is used by the alias SXTL, SXTL2.

### Assembler Symbols

#### 2

Is the second and upper half specifier. If present it causes the operation to be performed on the upper 64 bits of the registers holding the narrower elements, and is encoded in “Q”:

<table>
<thead>
<tr>
<th>Q</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>[absent]</td>
</tr>
<tr>
<td>1</td>
<td>[present]</td>
</tr>
</tbody>
</table>

#### <Vd>

Is the name of the SIMD&FP destination register, encoded in the "Rd" field.

#### <Ta>

Is an arrangement specifier, encoded in “immh”:

<table>
<thead>
<tr>
<th>immh</th>
<th>&lt;Ta&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0000</td>
<td>SEE Advanced SIMD modified immediate</td>
</tr>
<tr>
<td>0001</td>
<td>8H</td>
</tr>
<tr>
<td>001x</td>
<td>4S</td>
</tr>
<tr>
<td>01xx</td>
<td>2D</td>
</tr>
<tr>
<td>lxxx</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

#### <Vn>

Is the name of the SIMD&FP source register, encoded in the "Rn" field.

#### <Tb>

Is an arrangement specifier, encoded in “immh:Q”:

### Vector

SSHLL{2} <Vd>.<Ta>, <Vn>.<Tb>, #<shift>

```plaintext
d = Un integer(Rd);
n = Un integer(Rn);
if immh == '0000' then SEE(asimdimm);
if immh<3> == '1' then UNDEFINED;
integer esize = 8 << (if immh<3> == '1' then ReservedValue();)
integer esize = 8 << HighestSetBit(immh);
integer datasize = 64;
integer part = Un integer(Q);
integer elements = datasize DIV esize;
integer shift = Un integer(immh:immb) - esize;
boolean unsigned = (U == '1');
```
Îmmh  Q  \(\text{<Th>}\)
\[\begin{array}{c|c}
0000 & x \\
0001 & 0 \\
0001 & 1 \\
001x & 0 \\
001x & 1 \\
01xx & 0 \\
01xx & 1 \\
1xxx & x \\
\end{array}\]

**<shift>** Is the left shift amount, in the range 0 to the source element width in bits minus 1, encoded in “immh:immb”:

<table>
<thead>
<tr>
<th>immh</th>
<th>&lt;shift&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0000</td>
<td>SEE Advanced SIMD modified immediate</td>
</tr>
<tr>
<td>0001</td>
<td>(UInt(immh:immb)-8)</td>
</tr>
<tr>
<td>001x</td>
<td>(UInt(immh:immb)-16)</td>
</tr>
<tr>
<td>01xx</td>
<td>(UInt(immh:immb)-32)</td>
</tr>
<tr>
<td>1xxx</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

**Alias Conditions**

<table>
<thead>
<tr>
<th>Alias</th>
<th>Is preferred when</th>
</tr>
</thead>
<tbody>
<tr>
<td>SXTL, SXTL2</td>
<td>immh == '000' &amp;&amp; BitCount(immh) == 1</td>
</tr>
</tbody>
</table>

**Operation**

```c
CheckFPAdvSIMDEnabled64();
bids(datasize) operand = Vpart[n, part];
bits(datasize*2) result;
integer element;
for e = 0 to elements-1
  element = Int(Elem[operand, e, esize], unsigned) << shift;
  Elem[result, e, 2*esize] = element<2*esize-1:0>;
V[d] = result;
```

**Operational information**

If PSTATE.DIT is 1:

- The execution time of this instruction is independent of:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
- The response of this instruction to asynchronous exceptions does not vary based on:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
SSHR

Signed Shift Right (immediate). This instruction reads each vector element in the source SIMD&FP register, right shifts each result by an immediate value, places the final result into a vector, and writes the vector to the destination SIMD&FP register. All the values in this instruction are signed integer values. The results are truncated. For rounded results, see SRSHR.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

It has encodings from 2 classes: Scalar and Vector

Scalar

<table>
<thead>
<tr>
<th>31</th>
<th>30</th>
<th>29</th>
<th>28</th>
<th>27</th>
<th>26</th>
<th>25</th>
<th>24</th>
<th>23</th>
<th>22</th>
<th>21</th>
<th>20</th>
<th>19</th>
<th>18</th>
<th>17</th>
<th>16</th>
<th>15</th>
<th>14</th>
<th>13</th>
<th>12</th>
<th>11</th>
<th>10</th>
<th>9</th>
<th>8</th>
<th>7</th>
<th>6</th>
<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>!=0000</td>
<td>immh</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>Rd</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>U</td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td>o1</td>
<td>o0</td>
<td></td>
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<td></td>
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<td></td>
</tr>
</tbody>
</table>

Scalar

SSHR \(<V><d>, <V><n>, \#<shift>\)

integer d = UInt(Rd);
integer n = UInt(Rn);

if immh<3> != '1' then UNDEFINED;
integer esize = 8 << 3;
integer datasize = esize;
integer elements = 1;

integer shift = (esize * 2) - if immh<2> != '1' then ReservedValue();
integer esize = 8 << 3;
integer datasize = esize;
integer elements = 1;

integer shift = (esize * 2) - UInt(immh:immb);
boolean unsigned = (U == '1');
boolean round = (o1 == '1');
boolean accumulate = (o0 == '1');

Vector

<table>
<thead>
<tr>
<th>31</th>
<th>30</th>
<th>29</th>
<th>28</th>
<th>27</th>
<th>26</th>
<th>25</th>
<th>24</th>
<th>23</th>
<th>22</th>
<th>21</th>
<th>20</th>
<th>19</th>
<th>18</th>
<th>17</th>
<th>16</th>
<th>15</th>
<th>14</th>
<th>13</th>
<th>12</th>
<th>11</th>
<th>10</th>
<th>9</th>
<th>8</th>
<th>7</th>
<th>6</th>
<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Q</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>!=0000</td>
<td>immh</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>Rd</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>U</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>o1</td>
<td>o0</td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

SSHR
### Assembler Symbols

<table>
<thead>
<tr>
<th><code>&lt;V&gt;</code></th>
<th>Is a width specifier, encoded in “immh”:</th>
</tr>
</thead>
<tbody>
<tr>
<td>immh</td>
<td><code>&lt;V&gt;</code></td>
</tr>
<tr>
<td>0xxx</td>
<td>RESERVED</td>
</tr>
<tr>
<td>1xxx</td>
<td>D</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><code>&lt;d&gt;</code></th>
<th>Is the number of the SIMD&amp;FP destination register, in the &quot;Rd&quot; field.</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>&lt;n&gt;</code></td>
<td>Is the number of the first SIMD&amp;FP source register, encoded in the &quot;Rn&quot; field.</td>
</tr>
<tr>
<td><code>&lt;Vd&gt;</code></td>
<td>Is the name of the SIMD&amp;FP destination register, encoded in the &quot;Rd&quot; field.</td>
</tr>
<tr>
<td><code>&lt;T&gt;</code></td>
<td>Is an arrangement specifier, encoded in “immh:Q”:</td>
</tr>
<tr>
<td>immh</td>
<td>Q</td>
</tr>
<tr>
<td>0000</td>
<td>x</td>
</tr>
<tr>
<td>0001</td>
<td>0</td>
</tr>
<tr>
<td>0001</td>
<td>1</td>
</tr>
<tr>
<td>001x</td>
<td>0</td>
</tr>
<tr>
<td>001x</td>
<td>1</td>
</tr>
<tr>
<td>01xx</td>
<td>0</td>
</tr>
<tr>
<td>01xx</td>
<td>1</td>
</tr>
<tr>
<td>1xxx</td>
<td>0</td>
</tr>
<tr>
<td>1xxx</td>
<td>1</td>
</tr>
</tbody>
</table>

| `<Vn>` | Is the name of the SIMD&FP source register, encoded in the "Rn" field. |
| `<shift>` | For the scalar variant: is the right shift amount, in the range 1 to 64, encoded in “immh:immb”: |
| immh  | `<shift>` |
| 0xxx  | RESERVED |
| 1xxx  | (128-UInt(immh:immb)) |

For the vector variant: is the right shift amount, in the range 1 to the element width in bits, encoded in “immh:immb”:

| immh  | `<shift>` |
| 0000  | SEE Advanced SIMD modified immediate |
| 0001  | (16-UInt(immh:immb)) |
| 001x  | (32-UInt(immh:immb)) |
| 01xx  | (64-UInt(immh:immb)) |
| 1xxx  | (128-UInt(immh:immb)) |
Operation

```c
CheckFPAdvSIMEnabled64();
bits(datasize) operand = V[n];
bits(datasize) operand2;
bits(datasize) result;
integer round_const = if round then (1 << (shift - 1)) else 0;
integer element;
operand2 = if accumulate then V[d] else Zeros();
for e = 0 to elements-1
  element = (Int(Elem[operand, e, esize], unsigned) + round_const) >> shift;
  Elem[result, e, esize] = Elem[operand2, e, esize] + element<esize-1:0>;
V[d] = result;
```

Operational information

If PSTATE.DIT is 1:

- The execution time of this instruction is independent of:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.

- The response of this instruction to asynchronous exceptions does not vary based on:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.

Internal version only: isa v30.25 v29.05, AdvSIMD v27.01 v26.0, pseudocode v85-xml-00bet8_rc3a52 ; Build timestamp: 2018-09-13T13:2018-06-16T09:45:45

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SSRA

Signed Shift Right and Accumulate (immediate). This instruction reads each vector element in the source SIMD&FP register, right shifts each result by an immediate value, and accumulates the final results with the vector elements of the destination SIMD&FP register. All the values in this instruction are signed integer values. The results are truncated. For rounded results, see SSRA.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

It has encodings from 2 classes: Scalar and Vector

Scalar

<table>
<thead>
<tr>
<th>31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 1 0 1 1 1 1 1 0 != 0000 immb 0 0 0 1 0 1 Rn Rd</td>
</tr>
<tr>
<td>U immh o1 o0</td>
</tr>
</tbody>
</table>

Scalar

SSRA <V><d>, <V><n>, #<shift>

```plaintext
integer d = UInt(Rd);
integer n = UInt(Rn);

if immh<3> != '1' then UNDEFINED;
integer esize = 8 << 3;
integer datasize = esize;
integer elements = 1;

integer shift = esize * 2 -
if immh<3> != '1' then ReservedValue();
integer esize = 8 << 3;
integer datasize = esize;
integer elements = 1;

integer shift = (esize * 2) -
if immh<3> != '1' then ReservedValue();
integer esize = 8 << 3;
integer datasize = esize;
integer elements = 1;

integer shift = (esize * 2) -
if immh<3> != '1' then ReservedValue();
integer esize = 8 << 3;
integer datasize = esize;
integer elements = 1;

boolean unsigned = (U == '1');
boolean round = (o1 == '1');
boolean accumulate = (o0 == '1');
```

Vector

<table>
<thead>
<tr>
<th>31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 Q 0 1 1 1 1 0 != 0000 immb 0 0 0 1 0 1 Rn Rd</td>
</tr>
<tr>
<td>U immh o1 o0</td>
</tr>
</tbody>
</table>
Vector

SSRA \( \langle V_d \rangle, \langle T \rangle, \langle V_n \rangle, \langle T \rangle, \# \langle shift \rangle \)

```plaintext
integer d = UInt(Rd);
integer n = UInt(Rn);

if immh == '0000' then SEE(asimdimm);
if immh<3>:Q == '10' then UNDEFINED;
integer esize = 8 << (if immh<3>:Q == '10' then ReservedValue();
integer esize = 8 << HighestSetBit(immh);
integer datasize = if Q == '1' then 128 else 64;
integer elements = datasize DIV esize;
integer shift = (esize * 2) - UInt(immh:immb);
boolean unsigned = (U == '1');
boolean round = (o1 == '1');
boolean accumulate = (o0 == '1');
```

Assemble Symbols

\(<V>\) Is a width specifier, encoded in “immh”:

<table>
<thead>
<tr>
<th>immh</th>
<th>&lt;V&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0xxx</td>
<td>RESERVED</td>
</tr>
<tr>
<td>1xx</td>
<td>D</td>
</tr>
</tbody>
</table>

\(<d>\) Is the number of the SIMD&FP destination register, in the "Rd" field.

\(<n>\) Is the number of the first SIMD&FP source register, encoded in the "Rn" field.

\(<V_d>\) Is the name of the SIMD&FP destination register, encoded in the "Rd" field.

\(<T>\) Is an arrangement specifier, encoded in “immh:Q”:

<table>
<thead>
<tr>
<th>immh</th>
<th>Q</th>
</tr>
</thead>
<tbody>
<tr>
<td>0000</td>
<td>x</td>
</tr>
<tr>
<td>0001</td>
<td>0</td>
</tr>
<tr>
<td>0001</td>
<td>1</td>
</tr>
<tr>
<td>001x</td>
<td>0</td>
</tr>
<tr>
<td>001x</td>
<td>1</td>
</tr>
<tr>
<td>01xx</td>
<td>0</td>
</tr>
<tr>
<td>01xx</td>
<td>1</td>
</tr>
<tr>
<td>1xx</td>
<td>0</td>
</tr>
<tr>
<td>1xx</td>
<td>1</td>
</tr>
</tbody>
</table>

\(<V_n>\) Is the name of the SIMD&FP source register, encoded in the "Rn" field.

\(<\text{shift}>\) For the scalar variant: is the right shift amount, in the range 1 to 64, encoded in “immh:immb”:

<table>
<thead>
<tr>
<th>immh</th>
<th>&lt;\text{shift}&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0xxx</td>
<td>RESERVED</td>
</tr>
<tr>
<td>1xx</td>
<td>(128-UInt(immh:immb))</td>
</tr>
</tbody>
</table>

For the vector variant: is the right shift amount, in the range 1 to the element width in bits, encoded in “immh:immb”:

<table>
<thead>
<tr>
<th>immh</th>
<th>&lt;\text{shift}&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0000</td>
<td>SEE Advanced SIMD modified immediate</td>
</tr>
<tr>
<td>0001</td>
<td>(16-UInt(immh:immb))</td>
</tr>
<tr>
<td>001x</td>
<td>(32-UInt(immh:immb))</td>
</tr>
<tr>
<td>01xx</td>
<td>(64-UInt(immh:immb))</td>
</tr>
<tr>
<td>1xx</td>
<td>(128-UInt(immh:immb))</td>
</tr>
</tbody>
</table>
Operation

```c
CheckFPAdvSIMEnabled64();
bits(datasize) operand = V[n];
bits(datasize) operand2;
bits(datasize) result;
integer round_const = if round then (1 << (shift - 1)) else 0;
integer element;
operand2 = if accumulate then V[d] else Zeros();
for e = 0 to elements-1
    element = (Int(Elem[operand, e, esize], unsigned) + round_const) >> shift;
    Elem[result, e, esize] = Elem[operand2, e, esize] + element<esize-1:0>;
V[d] = result;
```

Operational information

If PSTATE.DIT is 1:

- The execution time of this instruction is independent of:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
- The response of this instruction to asynchronous exceptions does not vary based on:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
SSUBL, SSUBL2

Signed Subtract Long. This instruction subtracts each vector element in the lower or upper half of the second source SIMD&FP register from the corresponding vector element of the first source SIMD&FP register, places the results into a vector, and writes the vector to the destination SIMD&FP register. All the values in this instruction are signed integer values. The destination vector elements are twice as long as the source vector elements.

The SSUBL instruction extracts each source vector from the lower half of each source register, while the SSUBL2 instruction extracts each source vector from the upper half of each source register.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

Three registers, not all the same type

SSUBL[2] <Vd>,<Ta>, <Vn>,<Tb>, <Vm>,<Tb>

integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rm);
if size == '11' then UNDEFINED;
integer esize = 8 << if size == '11' then ReservedValue();
integer datasize = 64;
integer part = UInt(Q);
integer elements = datasize DIV esize;
boolean sub_op = (o1 == '1');
boolean unsigned = (U == '1');

Assembler Symbols

2 Is the second and upper half specifier. If present it causes the operation to be performed on the upper 64 bits of the registers holding the narrower elements, and is encoded in “Q”:

<table>
<thead>
<tr>
<th>Q</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>[absent]</td>
</tr>
<tr>
<td>1</td>
<td>[present]</td>
</tr>
</tbody>
</table>

<Vd> Is the name of the SIMD&FP destination register, encoded in the "Rd" field.

<Ta> Is an arrangement specifier, encoded in “size”:

<table>
<thead>
<tr>
<th>size</th>
<th>&lt;Ta&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>8H</td>
</tr>
<tr>
<td>01</td>
<td>4S</td>
</tr>
<tr>
<td>10</td>
<td>2D</td>
</tr>
<tr>
<td>11</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

<Vn> Is the name of the first SIMD&FP source register, encoded in the "Rn" field.

<Tb> Is an arrangement specifier, encoded in “size-Q”:

<table>
<thead>
<tr>
<th>size</th>
<th>Q</th>
<th>&lt;Tb&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>0</td>
<td>8B</td>
</tr>
<tr>
<td>00</td>
<td>1</td>
<td>16B</td>
</tr>
<tr>
<td>01</td>
<td>0</td>
<td>4H</td>
</tr>
<tr>
<td>01</td>
<td>1</td>
<td>8H</td>
</tr>
<tr>
<td>10</td>
<td>0</td>
<td>2S</td>
</tr>
<tr>
<td>10</td>
<td>1</td>
<td>4S</td>
</tr>
<tr>
<td>11</td>
<td>x</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>
Is the name of the second SIMD&FP source register, encoded in the "Rm" field.

**Operation**

```c
CheckFPAdvSIMDEnabled64();
bits(datasize) operand1 = Vpart[n, part];
bits(datasize) operand2 = Vpart[m, part];
bits(2*datasize) result;
integer element1;
integer element2;
integer sum;
for e = 0 to elements-1
  element1 = Int(Elem[operand1, e, esize], unsigned);
  element2 = Int(Elem[operand2, e, esize], unsigned);
  if sub_op then
    sum = element1 - element2;
  else
    sum = element1 + element2;
  Elem[result, e, 2*esize] = sum<2*esize-1:0>;
V[d] = result;
```

**Operational information**

If PSTATE.DIT is 1:
- The execution time of this instruction is independent of:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
- The response of this instruction to asynchronous exceptions does not vary based on:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.

Internal version only: isa v30.25v28.05, AdvSIMD v27.01v26.0, pseudocode v85-xml-00bet8_rc3v30.3 ; Build timestamp: 2018-09-13T13

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SSUBW, SSUBW2

Signed Subtract Wide. This instruction subtracts each vector element in the lower or upper half of the second source SIMD&FP register from the corresponding vector element in the first source SIMD&FP register, places the result in a vector, and writes the vector to the SIMD&FP destination register. All the values in this instruction are signed integer values.

The SSUBW instruction extracts the second source vector from the lower half of the second source register, while the SSUBW2 instruction extracts the second source vector from the upper half of the second source register.

Depending on the settings in the \textit{CPACR\_EL1}, \textit{CPTR\_EL2}, and \textit{CPTR\_EL3} registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

<table>
<thead>
<tr>
<th>31</th>
<th>30</th>
<th>29</th>
<th>28</th>
<th>27</th>
<th>26</th>
<th>25</th>
<th>24</th>
<th>23</th>
<th>22</th>
<th>21</th>
<th>20</th>
<th>19</th>
<th>18</th>
<th>17</th>
<th>16</th>
<th>15</th>
<th>14</th>
<th>13</th>
<th>12</th>
<th>11</th>
<th>10</th>
<th>9</th>
<th>8</th>
<th>7</th>
<th>6</th>
<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Q</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>Rm</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>Rn</td>
<td>Rd</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Three registers, not all the same type

\texttt{SSUBW[2]} <\texttt{Vd}>.\texttt{<Ta>}, <\texttt{Vn}>.\texttt{<Ta>}, <\texttt{Vm}>.\texttt{<Tb>}

\begin{verbatim}
integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rm);

if size == '11' then UNDEFINED;
integer esize = 8 << if size == '11' then ReservedValue();
integer data size = 64;
integer part = UInt(Q);
integer elements = data size DIV esize;

boolean sub_op = (o1 == '1');
boolean unsigned = (U == '1');
\end{verbatim}

Assembler Symbols

Is the second and upper half specifier. If present it causes the operation to be performed on the upper 64 bits of the registers holding the narrower elements, and is encoded in “Q”:

<table>
<thead>
<tr>
<th>Q</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>[absent]</td>
</tr>
<tr>
<td>1</td>
<td>[present]</td>
</tr>
</tbody>
</table>

<\texttt{Vd}> Is the name of the SIMD&FP destination register, encoded in the "Rd" field.

<\texttt{Ta}> Is an arrangement specifier, encoded in “size”:

\begin{verbatim}
size  <\texttt{Ta}>
00  8H
01  4S
10  2D
11  RESERVED
\end{verbatim}

<\texttt{Vn}> Is the name of the first SIMD&FP source register, encoded in the "Rn" field.

<\texttt{Vm}> Is the name of the second SIMD&FP source register, encoded in the "Rm" field.

<\texttt{Tb}> Is an arrangement specifier, encoded in “size:Q”:

\begin{verbatim}
size  Q  <\texttt{Tb}>
00  0  8H
00  1  16H
01  0  4H
01  1  8H
10  0  2S
10  1  4S
11  x  RESERVED
\end{verbatim}
Operation

```c
CheckFPAdvSIMDEnabled64();
bits(2*datasize) operand1 = V[n];
bits(datasize) operand2 = Vpart[m, part];
bits(2*datasize) result;
integer element1;
integer element2;
integer sum;

for e = 0 to elements-1
    element1 = Int(Elem[operand1, e, 2*esize], unsigned);
    element2 = Int(Elem[operand2, e, esize], unsigned);
    if sub_op then
        sum = element1 - element2;
    else
        sum = element1 + element2;
    Elem[result, e, 2*esize] = sum<2*esize-1:0>;
V[d] = result;
```

Operational information

If PSTATE.DIT is 1:

- The execution time of this instruction is independent of:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
- The response of this instruction to asynchronous exceptions does not vary based on:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
ST1 (multiple structures)

Store multiple single-element structures from one, two, three, or four registers. This instruction stores elements to memory from one, two, three, or four SIMD&FP registers, without interleaving. Every element of each register is stored. Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

It has encodings from 2 classes: No offset and Post-index

No offset

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0  | 0  | 0  | 1  | 1  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | x  | x  | 1  | x  | size | Rn |     | Rt |
| L  |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |

One register (opcode == 0111)

\[
\text{ST1 \{ <Vt>.<T> \}, [<Xn|SP>]} \\
\]

Two registers (opcode == 1010)

\[
\text{ST1 \{ <Vt>.<T>, <Vt2>.<T> \}, [<Xn|SP>]} \\
\]

Three registers (opcode == 0110)

\[
\text{ST1 \{ <Vt>.<T>, <Vt2>.<T>, <Vt3>.<T> \}, [<Xn|SP>]} \\
\]

Four registers (opcode == 0010)

\[
\text{ST1 \{ <Vt>.<T>, <Vt2>.<T>, <Vt3>.<T>, <Vt4>.<T> \}, [<Xn|SP>]} \\
\]

\[
\begin{align*}
\text{integer } t &= \text{UInt}(Rt); \\
\text{integer } n &= \text{UInt}(Rn); \\
\text{integer } m &= \text{integer \text{UNKNOWN}}; \\
\text{boolean } wback &= \text{FALSE}; \\
\end{align*}
\]

Post-index

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0  | 0  | 0  | 1  | 1  | 0  | 0  | 0  | 1  | 0  | 0  | Rm | x  | x  | 1  | x  | size | Rn |     | Rt |
| L  |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |

ST1 (multiple structures)
One register, immediate offset (Rm == 11111 && opcode == 0111)

\[
\text{ST1}\: \{\:\text{<Vt>}.\text{T}, \: [\text{<Xn|SP>}], \: \text{<imm>}\}
\]

One register, register offset (Rm != 11111 && opcode == 0111)

\[
\text{ST1}\: \{\:\text{<Vt>}.\text{T}, \: [\text{<Xn|SP>}], \: \text{Xm}\}
\]

Two registers, immediate offset (Rm == 11111 && opcode == 1010)

\[
\text{ST1}\: \{\:\text{<Vt>}.\text{T}, \: \text{<Vt2>}.\text{T}, \: [\text{<Xn|SP>}], \: \text{<imm>}\}
\]

Two registers, register offset (Rm != 11111 && opcode == 1010)

\[
\text{ST1}\: \{\:\text{<Vt>}.\text{T}, \: \text{<Vt2>}.\text{T}, \: [\text{<Xn|SP>}], \: \text{Xm}\}
\]

Three registers, immediate offset (Rm == 11111 && opcode == 0110)

\[
\text{ST1}\: \{\:\text{<Vt>}.\text{T}, \: \text{<Vt2>}.\text{T}, \: \text{<Vt3>}.\text{T}, \: [\text{<Xn|SP>}], \: \text{<imm>}\}
\]

Three registers, register offset (Rm != 11111 && opcode == 0110)

\[
\text{ST1}\: \{\:\text{<Vt>}.\text{T}, \: \text{<Vt2>}.\text{T}, \: \text{<Vt3>}.\text{T}, \: [\text{<Xn|SP>}], \: \text{Xm}\}
\]

Four registers, immediate offset (Rm == 11111 && opcode == 0010)

\[
\text{ST1}\: \{\:\text{<Vt>}.\text{T}, \: \text{<Vt2>}.\text{T}, \: \text{<Vt3>}.\text{T}, \: \text{<Vt4>}.\text{T}, \: [\text{<Xn|SP>}], \: \text{<imm>}\}
\]

Four registers, register offset (Rm != 11111 && opcode == 0010)

\[
\text{ST1}\: \{\:\text{<Vt>}.\text{T}, \: \text{<Vt2>}.\text{T}, \: \text{<Vt3>}.\text{T}, \: \text{<Vt4>}.\text{T}, \: [\text{<Xn|SP>}], \: \text{Xm}\}
\]

integer t = UInt(Rt);
integer n = UInt(Rn);
integer m = UInt(Rm);
boolean wback = TRUE;

Assembler Symbols

<\text{Vt}> Is the name of the first or only SIMD&FP register to be transferred, encoded in the "Rt" field.

<\text{T}> Is an arrangement specifier, encoded in “size:Q”:

<table>
<thead>
<tr>
<th>size</th>
<th>Q</th>
<th>&lt;T&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>0</td>
<td>8B</td>
</tr>
<tr>
<td>00</td>
<td>1</td>
<td>16B</td>
</tr>
<tr>
<td>01</td>
<td>0</td>
<td>4H</td>
</tr>
<tr>
<td>01</td>
<td>1</td>
<td>8H</td>
</tr>
<tr>
<td>10</td>
<td>0</td>
<td>2S</td>
</tr>
<tr>
<td>10</td>
<td>1</td>
<td>4S</td>
</tr>
<tr>
<td>11</td>
<td>0</td>
<td>1D</td>
</tr>
<tr>
<td>11</td>
<td>1</td>
<td>2D</td>
</tr>
</tbody>
</table>

<\text{Vt2}> Is the name of the second SIMD&FP register to be transferred, encoded as “Rt” plus 1 modulo 32.

<\text{Vt3}> Is the name of the third SIMD&FP register to be transferred, encoded as “Rt” plus 2 modulo 32.

<\text{Vt4}> Is the name of the fourth SIMD&FP register to be transferred, encoded as "Rt" plus 3 modulo 32.

<\text{Xn|SP}> Is the 64-bit name of the general-purpose base register or stack pointer, encoded in the "Rn" field.

<\text{imm}> For the one register, immediate offset variant: is the post-index immediate offset, encoded in “Q”:
For the two registers, immediate offset variant: is the post-index immediate offset, encoded in “Q”:

\[ \begin{array}{c|c|c}
\text{Q} & \text{<imm>} \\
0 & 8 \\
1 & 16 \\
\end{array} \]

For the three registers, immediate offset variant: is the post-index immediate offset, encoded in “Q”:

\[ \begin{array}{c|c|c}
\text{Q} & \text{<imm>} \\
0 & 16 \\
1 & 32 \\
\end{array} \]

For the four registers, immediate offset variant: is the post-index immediate offset, encoded in “Q”:

\[ \begin{array}{c|c|c}
\text{Q} & \text{<imm>} \\
0 & 24 \\
1 & 48 \\
\end{array} \]

\text{<Xm>}

Is the 64-bit name of the general-purpose post-index register, excluding XZR, encoded in the “Rm” field.

\textbf{Shared Decode}

\begin{verbatim}
MemOp memop = if L == '1' then MemOp_LOAD else MemOp_STORE;
integer datasize = if Q == '1' then 128 else 64;
integer esize = 8 << UInt(size);
integer elements = datasize DIV esize;

integer rpt; // number of iterations
integer selem; // structure elements

case opcode of
    when '0000' rpt = 1; selem = 4;  // LD/ST4 (4 registers)
    when '0010' rpt = 4; selem = 1;  // LD/ST1 (4 registers)
    when '0100' rpt = 1; selem = 3;  // LD/ST3 (3 registers)
    when '0110' rpt = 3; selem = 1;  // LD/ST1 (3 registers)
    when '0111' rpt = 1; selem = 1;  // LD/ST1 (1 register)
    when '1000' rpt = 1; selem = 2;  // LD/ST2 (2 registers)
    when '1010' rpt = 2; selem = 1;  // LD/ST1 (2 registers)
otherwise UNDEFINED;

// .1D format only permitted with LD1 & ST1
if size:Q == '110' && selem != 1 then UNDEFINED; otherwise UnallocatedEncoding();
end
\end{verbatim}
Operation

```c
CheckFPAdvSIMEnabled64();

bits(64) address;
bits(64) offs;
bits(datasize) rval;
integer tt;
integer e, r, s, tt;
constant integer ebytes = esize DIV 8;

if n == 31 then
    if HaveMTEExt() then
        SetNotTagCheckedInstruction(!wback && n == 31);
    end if
else
    address = X[n];
end if
offs = zeros();
for r = 0 to rpt-1
    for e = 0 to elements-1
        for s = 0 to selem-1
            tt = (t + r) MOD 32;
            rval = V[tt];
            if memop == MemOp_LOAD then
                Elem[rval, e, esize] = Mem[address + offs, ebytes, AccType_VEC];
                V[tt] = rval;
            else
                Mem[address + offs, ebytes, AccType_VEC] = Elem[rval, e, esize];
            end if
            offs = offs + ebytes;
            tt = (tt + 1) MOD 32;
        end for
    end for
end for
if wback then
    if m != 31 then
        offs = X[m];
    end if
    if n == 31 then
        SP[] = address + offs;
    else
        X[n] = address + offs;
    end if
end if
```

Operational information

If PSTATE.DIT is 1, the timing of this instruction is insensitive to the value of the data being loaded or stored.
ST1 (single structure)

Store a single-element structure from one lane of one register. This instruction stores the specified element of a SIMD&FP register to memory. Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

It has encodings from 2 classes: No offset and Post-index

No offset

<table>
<thead>
<tr>
<th>31</th>
<th>30</th>
<th>29</th>
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<th>27</th>
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</table>

L  R  opcode

8-bit (opcode == 000)

\[
\text{ST1 } \{ \text{<Vt>.B } \}[\text{<index>}], \ [\text{<Xn|SP>}] 
\]

16-bit (opcode == 010 && size == x0)

\[
\text{ST1 } \{ \text{<Vt>.H } \}[\text{<index>}], \ [\text{<Xn|SP>}] 
\]

32-bit (opcode == 100 && size == 00)

\[
\text{ST1 } \{ \text{<Vt>.S } \}[\text{<index>}], \ [\text{<Xn|SP>}] 
\]

64-bit (opcode == 100 && S == 0 && size == 01)

\[
\text{ST1 } \{ \text{<Vt>.D } \}[\text{<index>}], \ [\text{<Xn|SP>}] 
\]

integer \( t = \text{UInt}(\text{Rt}); \)
integer \( n = \text{UInt}(\text{Rn}); \)
integer \( m = \text{integer UNKNOWN}; \)
boolean \( \text{wback} = \text{FALSE}; \)

Post-index

<table>
<thead>
<tr>
<th>31</th>
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<tbody>
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<td>0</td>
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<td>x</td>
<td>x</td>
<td>0</td>
<td>S</td>
<td>size</td>
<td>Rn</td>
<td>Rt</td>
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</tbody>
</table>

L  R  opcode
8-bit, immediate offset (Rm == 11111 && opcode == 000)

ST1 { <Vt>.B ][<index>], [Xn|SP] }, #1

8-bit, register offset (Rm != 11111 && opcode == 000)

ST1 { <Vt>.B ][<index>], [Xn|SP], <Xm>

16-bit, immediate offset (Rm == 11111 && opcode == 010 && size == x0)

ST1 { <Vt>.H ][<index>], [Xn|SP], #2

16-bit, register offset (Rm != 11111 && opcode == 010 && size == x0)

ST1 { <Vt>.H ][<index>], [Xn|SP], <Xm>

32-bit, immediate offset (Rm == 11111 && opcode == 100 && size == 00)

ST1 { <Vt>.S ][<index>], [Xn|SP], #4

32-bit, register offset (Rm != 11111 && opcode == 100 && size == 00)

ST1 { <Vt>.S ][<index>], [Xn|SP], <Xm>

64-bit, immediate offset (Rm == 11111 && opcode == 100 && S == 0 && size == 01)

ST1 { <Vt>.D ][<index>], [Xn|SP], #8

64-bit, register offset (Rm != 11111 && opcode == 100 && S == 0 && size == 01)

ST1 { <Vt>.D ][<index>], [Xn|SP], <Xm>

integer t = UInt(Rt);
integer n = UInt(Rn);
integer m = UInt(Rm);
boolean wback = TRUE;

Assembler Symbols

<Vt> Is the name of the first or only SIMD&FP register to be transferred, encoded in the "Rt" field.

<index> For the 8-bit variant: is the element index, encoded in "Q:S:size".
For the 16-bit variant: is the element index, encoded in "Q:S:size<1>".
For the 32-bit variant: is the element index, encoded in "Q:S".
For the 64-bit variant: is the element index, encoded in "Q".

<Xn|SP> Is the 64-bit name of the general-purpose base register or stack pointer, encoded in the "Rn" field.

<Xm> Is the 64-bit name of the general-purpose post-index register, excluding XZR, encoded in the "Rm" field.
integer scale = \texttt{UInt}(\text{opcode}<2:1>); \\
integer selem = \texttt{UInt}(\text{opcode}<0>:R) + 1; \\
boolean replicate = FALSE; \\
integer index; \\

case scale of
  when 3
    // load and replicate
    if L == '0' || S == '1' then UNDEFINED;
    scale = if L == '0' || S == '1' then \texttt{UnallocatedEncoding}();
    scale = \texttt{UInt}(\text{size});
    replicate = TRUE;
  when 0
    index = \texttt{UInt}(Q:S:size);  // B[0-15]
  when 1
    if size<0> == '1' then UNDEFINED;
    index = if size<0> == '1' then \texttt{UnallocatedEncoding}();
    index = \texttt{UInt}(Q:S:size<1>);  // H[0-7]
  when 2
    if size<1> == '1' then UNDEFINED;
    if size<0> == '0' then
      index = if size<1> == '1' then \texttt{UnallocatedEncoding}();
      index = \texttt{UInt}(Q:S);  // S[0-3]
    else
      if S == '1' then \texttt{UnallocatedEncoding}(Q:S);  // S[0-3]
      if S == '1' then UNDEFINED;
    else
      index = \texttt{UInt}(Q);  // D[0-1]
  end

\texttt{MemOp memop = if L == '1' then MemOp\ LOAD else MemOp\ STORE;}
integer datasize = if Q == '1' then 128 else 64;
integer esize = 8 << scale;
if HaveMTEExt() then
  SetNotTagCheckedInstruction(!wback && n == 31);

CheckFPAdvSIMDEnabled64();

bits(64) address;
bits(64) offs;
bits(128) rval;
bits(esize) element;
integer s;
constant integer ebytes = esize DIV 8;

if n == 31 then
  CheckSPAlignment();
  address = SP[];
else
  address = X[n];

offs = Zeros();
if replicate then
  // load and replicate to all elements
  for s = 0 to selem-1
    element = Mem[address + offs, ebytes, AccType_VEC];
  // replicate to fill 128- or 64-bit register
  V[t] = Replicate(element, datasize DIV esize);
  offs = offs + ebytes;
  t = (t + 1) MOD 32;
else
  // load/store one element per register
  for s = 0 to selem-1
    rval = V[t];
    if memop == MemOp_LOAD then
      // insert into one lane of 128-bit register
      Elem[rval, index, esize] = Mem[address + offs, ebytes, AccType_VEC];
      V[t] = rval;
    else // memop == MemOp_STORE
      // extract from one lane of 128-bit register
      Mem[address + offs, ebytes, AccType_VEC] = Elem[rval, index, esize];
    offs = offs + ebytes;
    t = (t + 1) MOD 32;
if wback then
  if m != 31 then
    offs = X[m];
  if n == 31 then
    SP[] = address + offs;
  else
    X[n] = address + offs;

Operational information

If PSTATE.DIT is 1, the timing of this instruction is insensitive to the value of the data being loaded or stored.
ST2 (multiple structures)

Store multiple 2-element structures from two registers. This instruction stores multiple 2-element structures from two SIMD&FP registers to memory, with interleaving. Every element of each register is stored.

Depending on the settings in the `CPACR_EL1`, `CPTR_EL2`, and `CPTR_EL3` registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

It has encodings from 2 classes: No offset and Post-index

### No offset

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
|    |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |

<table>
<thead>
<tr>
<th>L</th>
<th>opcode</th>
</tr>
</thead>
</table>

```plaintext
No offset

ST2 { <Vt>.<T>, <Vt2>.<T> }, [<Xn|SP>]

integer t = UInt(Rt);
integer n = UInt(Rn);
integer m = integer UNKNOWN;
boolean wback = FALSE;
```

### Post-index

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
|    |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |

<table>
<thead>
<tr>
<th>L</th>
<th>opcode</th>
</tr>
</thead>
</table>

#### Immediate offset (Rm == 1111)

ST2 { <Vt>.<T>, <Vt2>.<T> }, [<Xn|SP>], <imm>

#### Register offset (Rm != 1111)

ST2 { <Vt>.<T>, <Vt2>.<T> }, [<Xn|SP>], <Xm>

```plaintext
Register offset (Rm != 1111)

ST2 { <Vt>.<T>, <Vt2>.<T> }, [<Xn|SP>], <Xm>

integer t = UInt(Rt);
integer n = UInt(Rn);
integer m = UInt(Rm);
boolean wback = TRUE;
```

### Assembler Symbols

<vt> Is the name of the first or only SIMD&FP register to be transferred, encoded in the "Rt" field.

<T> Is an arrangement specifier, encoded in "size:Q":

<table>
<thead>
<tr>
<th>size</th>
<th>Q</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>8B</td>
</tr>
<tr>
<td>00</td>
<td>16B</td>
</tr>
<tr>
<td>01</td>
<td>4H</td>
</tr>
<tr>
<td>01</td>
<td>8H</td>
</tr>
<tr>
<td>10</td>
<td>2S</td>
</tr>
<tr>
<td>10</td>
<td>4S</td>
</tr>
<tr>
<td>11</td>
<td>RESERVED</td>
</tr>
<tr>
<td>11</td>
<td>2D</td>
</tr>
</tbody>
</table>

<vt2> Is the name of the second SIMD&FP register to be transferred, encoded as "Rt" plus 1 modulo 32.
<Xn>SP> Is the 64-bit name of the general-purpose base register or stack pointer, encoded in the "Rn" field.

<imm> Is the post-index immediate offset, encoded in "Q":

<table>
<thead>
<tr>
<th>Q</th>
<th>&lt;imm&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>#16</td>
</tr>
<tr>
<td>1</td>
<td>#32</td>
</tr>
</tbody>
</table>

<Xm> Is the 64-bit name of the general-purpose post-index register, excluding XZR, encoded in the "Rm" field.

**Shared Decode**

```
MemOp memop = if L == '1' then MemOp LOAD else MemOp STORE;
integer datasize = if Q == '1' then 128 else 64;
integer esize = 8 << UInt(size);
integer elements = datasize DIV esize;
integer rpt; // number of iterations
integer selem; // structure elements

case opcode of
  when '0000' rpt = 1; selem = 4; // LD/ST4 (4 registers)
  when '0010' rpt = 4; selem = 1; // LD/ST1 (4 registers)
  when '0100' rpt = 1; selem = 3; // LD/ST3 (3 registers)
  when '0110' rpt = 3; selem = 1; // LD/ST1 (3 registers)
  when '0111' rpt = 1; selem = 1; // LD/ST1 (1 register)
  when '1000' rpt = 1; selem = 2; // LD/ST2 (2 registers)
  when '1010' rpt = 2; selem = 1; // LD/ST1 (2 registers)
otherwise UNDEFINED;

// .1D format only permitted with LD1 & ST1
if size:Q == '110' && selem != 1 then UNDEFINED; otherwise UnallocatedEncoding();
// .1D format only permitted with LD1 & ST1
if size:Q == '110' && selem != 1 then ReservedValue();
```

ST2 (multiple structures)
Operation

```c
CheckFPAdvSIMDEnabled64();

bits(64) address;
bits(64) offs;
bits(datasize) rval;
integer tt;
integer e, r, s, tt;

constant integer ebytes = esize DIV 8;

if (n == 31) then
    if HaveMTEExt() then
        SetNotTagCheckedInstruction(!wback && n == 31);
    if n == 31 then
        CheckSPAlignment();
        address = SP[];
    else
        address = X[n];
else
    offs = Zeros();
for r = 0 to rpt-1
    for e = 0 to elements-1
        tt = (t + r) MOD 32;
        for s = 0 to selem-1
            rval = V[tt];
            if memop == MemOp_LOAD then
                Elem[rval, e, esize] = Mem[address + offs, ebytes, AccType_VEC];
                V[tt] = rval;
            else // memop == MemOp_STORE
                Mem[address + offs, ebytes, AccType_VEC] = Elem[rval, e, esize];
                offs = offs + ebytes;
                tt = (tt + 1) MOD 32;
        if wback then
            if m != 31 then
                offs = X[m];
                if n == 31 then
                    SP[] = address + offs;
                else
                    X[n] = address + offs;
```
ST2 (single structure)

Store single 2-element structure from one lane of two registers. This instruction stores a 2-element structure to memory from corresponding elements of two SIMD&FP registers.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

It has encodings from 2 classes: No offset and Post-index

No offset

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9  | 8  | 7  | 6  | 5  | 4  | 3  | 2  | 1  | 0  |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| L  |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| R  |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| opcode |

8-bit (opcode == 000)

ST2 { <Vt>.B, <Vt2>.B }[<index>], [<Xn|SP>]

16-bit (opcode == 010 && size == x0)

ST2 { <Vt>.H, <Vt2>.H }[<index>], [<Xn|SP>]

32-bit (opcode == 100 && size == 00)

ST2 { <Vt>.S, <Vt2>.S }[<index>], [<Xn|SP>]

64-bit (opcode == 100 && S == 0 && size == 01)

ST2 { <Vt>.D, <Vt2>.D }[<index>], [<Xn|SP>]

integer t = UInt(Rt);
integer n = UInt(Rn);
integer m = integer UNKNOWN;
boolean wback = FALSE;

Post-index

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9  | 8  | 7  | 6  | 5  | 4  | 3  | 2  | 1  | 0  |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| L  |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| R  | Rm|   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| opcode |

integer t = UInt(Rt);
integer n = UInt(Rn);
integer m = integer UNKNOWN;
boolean wback = FALSE;
8-bit, immediate offset (Rm == 11111 && opcode == 000)

ST2 { <Vt>.B, <Vt2>.B }[<index>], [<Xn|SP>], #2

8-bit, register offset (Rm != 11111 && opcode == 000)

ST2 { <Vt>.B, <Vt2>.B }[<index>], [<Xn|SP>], <Xm>

16-bit, immediate offset (Rm == 11111 && opcode == 010 && size == x0)

ST2 { <Vt>.H, <Vt2>.H }[<index>], [<Xn|SP>], #4

16-bit, register offset (Rm != 11111 && opcode == 010 && size == x0)

ST2 { <Vt>.H, <Vt2>.H }[<index>], [<Xn|SP>], <Xm>

32-bit, immediate offset (Rm == 11111 && opcode == 100 && size == 00)

ST2 { <Vt>.S, <Vt2>.S }[<index>], [<Xn|SP>], #8

32-bit, register offset (Rm != 11111 && opcode == 100 && size == 00)

ST2 { <Vt>.S, <Vt2>.S }[<index>], [<Xn|SP>], <Xm>

64-bit, immediate offset (Rm == 11111 && opcode == 100 && S == 0 && size == 01)

ST2 { <Vt>.D, <Vt2>.D }[<index>], [<Xn|SP>], #16

64-bit, register offset (Rm != 11111 && opcode == 100 && S == 0 && size == 01)

ST2 { <Vt>.D, <Vt2>.D }[<index>], [<Xn|SP>], <Xm>

integer t = UInt(Rt);
integer n = UInt(Rn);
integer m = UInt(Rm);
boolean wback = TRUE;

Assembler Symbols

<Vt> Is the name of the first or only SIMD&FP register to be transferred, encoded in the "Rt" field.
<Vt2> Is the name of the second SIMD&FP register to be transferred, encoded as "Rt" plus 1 modulo 32.
:index> For the 8-bit variant: is the element index, encoded in "Q:S:size".
For the 16-bit variant: is the element index, encoded in "Q:S:size<1>".
For the 32-bit variant: is the element index, encoded in "Q:S".
For the 64-bit variant: is the element index, encoded in "Q".
<Xn|SP> Is the 64-bit name of the general-purpose base register or stack pointer, encoded in the "Rn" field.
<Xm> Is the 64-bit name of the general-purpose post-index register, excluding XZR, encoded in the "Rm" field.
integer scale = UInt(opcode<2:1>);
integer selem = UInt(opcode<0>:R) + 1;
boolean replicate = FALSE;
integer index;

case scale of
when 3 // load and replicate
    if L == '0' || S == '1' then UNDEFINED;
    scale = if L == '0' || S == '1' then UnallocatedEncoding();
    replicate = TRUE;
when 0
    index = UInt(Q:S:size); // B[0-15]
when 1
    if size<0> == '1' then UNDEFINED;
    index = if size<0> == '1' then UnallocatedEncoding();
    index = UInt(Q:S:size<1>); // H[0-7]
when 2
    if size<1> == '1' then UNDEFINED;
    if size<0> == '0' then
        index = if size<1> == '1' then UnallocatedEncoding();
        index = UInt(Q:S); // S[0-3]
    else
        if S == '1' then UnallocatedEncoding(Q:S); // S[0-3]
    else
        if S == '1' then UNDEFINED;
    end
    index = UInt(Q); // D[0-1]
scale = 3;
MemOp memop = if L == '1' then MemOp_LOAD else MemOp_STORE;
integer datasize = if Q == '1' then 128 else 64;
integer esize = 8 << scale;
if HaveMTEExt() then
    SetNotTagCheckedInstruction(!wback && n == 31);

CheckFPAdvSIMDEnabled64();

bits(64) address;
bits(64) offs;
bits(128) rval;
bits(esize) element;
integer sz
constant integer ebytes = esize DIV 8;

if n == 31 then
    CheckSPAlignment();
    address = SP[];
else
    address = X[n];

offs = Zeros();
if replicate then
    // load and replicate to all elements
    for s = 0 to selem-1
        element = Mem[address + offs, ebytes, AccType_VEC];
    // replicate to fill 128- or 64-bit register
    V[t] = Replicate(element, datasize DIV esize);
    offs = offs + ebytes;
    t = (t + 1) MOD 32;
else
    // load/store one element per register
    for s = 0 to selem-1
        rval = V[t];
    if memop == MemOp_LOAD then
        // insert into one lane of 128-bit register
        Elem[rval, index, esize] = Mem[address + offs, ebytes, AccType_VEC];
        V[t] = rval;
    else // memop == MemOp_STORE
        // extract from one lane of 128-bit register
        Mem[address + offs, ebytes, AccType_VEC] = Elem[rval, index, esize];
        offs = offs + ebytes;
        t = (t + 1) MOD 32;

if wback then
    if m != 31 then
        offs = X[m];
    if n == 31 then
        SP[] = address + offs;
    else
        X[n] = address + offs;

Operational information

If PSTATE.DIT is 1, the timing of this instruction is insensitive to the value of the data being loaded or stored.
ST2G

Store Allocation Tags stores an Allocation Tag to two Tag granules of memory. The address used for the store is calculated from the source register and an immediate signed offset scaled by the Tag granule. The Allocation Tag is calculated from the Logical Address Tag in the source register.

This instruction generates an Unchecked access.

It has encodings from 3 classes: Post-index, Pre-index and Signed offset

### Post-index (ARMv8.5)

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 1  | 1  | 1  | 1  | 0  | 1  | 1  | 0  | 1  | imm9| 0  | 1  | Xn | [(1)(1)(1)(1)](1) |
|    |    |    |    |    |    |    |    |    |    |    |    |    | (1)(1)(1)(1)(1) |

### Pre-index (ARMv8.5)

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 1  | 1  | 1  | 1  | 0  | 1  | 1  | 0  | 1  | imm9| 1  | 1  | Xn | [(1)(1)(1)(1)](1) |
|    |    |    |    |    |    |    |    |    |    |    |    |    | (1)(1)(1)(1)(1)(1) |

### Signed offset (ARMv8.5)

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 1  | 1  | 1  | 1  | 0  | 1  | 1  | 0  | 1  | imm9| 1  | 0  | Xn | [(1)(1)(1)(1)](1) |
|    |    |    |    |    |    |    |    |    |    |    |    |    | (1)(1)(1)(1)(1)(1) |

```c
integer n = UInt(Xn);
bids(64) offset = LSL(SignExtend(imm9, 64), LOG2_TAG_GRANULE);
boolean writeback = TRUE;
boolean postindex = TRUE;
boolean zero_data = FALSE;
```
Assembler Symbols

<Xn|SP>  Is the 64-bit name of the general-purpose base register or stack pointer, encoded in the "Xn" field.

<simm>  Is the optional signed immediate offset, a multiple of 16 in the range -4096 to 4080, defaulting to 0 and encoded in the "imm9" field.

Operation

```
bits(64) address;
bits(4) tag;

SetNotTagCheckedInstruction(TRUE);

if n == 31 then
    CheckSPAlignment();
    address = SP[];
else
    address = X[n];

if !postindex then
    address = address + offset;

if zero_data then
    Mem[address, TAG_GRANULE, AccType_NORMAL] = Zeros(8*TAG_GRANULE);
    Mem[address+TAG_GRANULE, TAG_GRANULE, AccType_NORMAL] = Zeros(8*TAG_GRANULE);

    tag = AllocationTagFromAddress(address);
    MemTag[address] = tag;
    MemTag[address+TAG_GRANULE] = tag;

if writeback then
    if postindex then
        address = address + offset;
    if n == 31 then
        SP[] = address;
    else
        X[n] = address;
```
ST3 (multiple structures)

Store multiple 3-element structures from three registers. This instruction stores multiple 3-element structures to memory from three SIMD&FP registers, with interleaving. Every element of each register is stored. Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

It has encodings from 2 classes: No offset and Post-index

No offset

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9  | 8  | 7  | 6  | 5  | 4  | 3  | 2  | 1  | 0  | L |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----| L |
| 0  | 0  | 0  | 1  | 1  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 1  | 0  | 0  | size | Rn | Rt | opcode |

No offset

\[
\text{ST3} \ {\langle Vt \rangle, <T>, <Vt2>.<T>, <Vt3>.<T> }, [<Xn|SP>] \\
\]

\[
\text{integer } t = \text{UInt}(Rt); \\
\text{integer } n = \text{UInt}(Rn); \\
\text{integer } m = \text{integer UNKNOWN}; \\
\text{boolean } wback = \text{FALSE};
\]

Post-index

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9  | 8  | 7  | 6  | 5  | 4  | 3  | 2  | 1  | 0  | L |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----| L |
| 0  | 0  | 0  | 1  | 1  | 0  | 0  | 1  | 0  | 0  | 0  | 0  | 0  | size | Rm | 0  | 1  | 0  | 0  | size | Rn | Rt | opcode |

Immediate offset (Rm == 11111)

\[
\text{ST3} \ {\langle Vt \rangle, <T>, <Vt2>.<T>, <Vt3>.<T> }, [<Xn|SP>], <imm>
\]

Register offset (Rm != 11111)

\[
\text{ST3} \ {\langle Vt \rangle, <T>, <Vt2>.<T>, <Vt3>.<T> }, [<Xn|SP>], <Xm>
\]

\[
\text{integer } t = \text{UInt}(Rt); \\
\text{integer } n = \text{UInt}(Rn); \\
\text{integer } m = \text{UInt}(Rm); \\
\text{boolean } wback = \text{TRUE};
\]

Assembler Symbols

\(<Vt>\) Is the name of the first or only SIMD&FP register to be transferred, encoded in the "Rt" field.

\(<T>\) Is an arrangement specifier, encoded in "size:Q"

<table>
<thead>
<tr>
<th>size</th>
<th>Q</th>
<th>(&lt;T&gt;)</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>0</td>
<td>8B</td>
</tr>
<tr>
<td>00</td>
<td>1</td>
<td>16B</td>
</tr>
<tr>
<td>01</td>
<td>0</td>
<td>4H</td>
</tr>
<tr>
<td>01</td>
<td>1</td>
<td>8H</td>
</tr>
<tr>
<td>10</td>
<td>0</td>
<td>2S</td>
</tr>
<tr>
<td>10</td>
<td>1</td>
<td>4S</td>
</tr>
<tr>
<td>11</td>
<td>0</td>
<td>RESERVED</td>
</tr>
<tr>
<td>11</td>
<td>1</td>
<td>2D</td>
</tr>
</tbody>
</table>

\(<Vt2>\) Is the name of the second SIMD&FP register to be transferred, encoded as "Rt" plus 1 modulo 32.
Is the name of the third SIMD&FP register to be transferred, encoded as "Rt" plus 2 modulo 32.

Is the 64-bit name of the general-purpose base register or stack pointer, encoded in the "Rn" field.

Is the post-index immediate offset, encoded in "Q":

<table>
<thead>
<tr>
<th>Q</th>
<th>&lt;imm&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>#24</td>
</tr>
<tr>
<td>1</td>
<td>#48</td>
</tr>
</tbody>
</table>

Is the 64-bit name of the general-purpose post-index register, excluding XZR, encoded in the "Rm" field.

**Shared Decode**

```plaintext
MemOp memop = if L == '1' then MemOp_LOAD else MemOp_STORE;
Integer datasize = if Q == '1' then 128 else 64;
integer esize = 8 << UInt(size);
integer elements = datasize DIV esize;
integer rpt; // number of iterations
integer selem; // structure elements

case opcode of
  when '0000' rpt = 1; selem = 4; // LD/ST4 (4 registers)
  when '0010' rpt = 4; selem = 1; // LD/ST1 (4 registers)
  when '0100' rpt = 1; selem = 3; // LD/ST3 (3 registers)
  when '0110' rpt = 3; selem = 1; // LD/ST1 (3 registers)
  when '0111' rpt = 3; selem = 1; // LD/ST1 (1 register)
  when '1000' rpt = 1; selem = 2; // LD/ST2 (2 registers)
  when '1010' rpt = 2; selem = 1; // LD/ST1 (2 registers)
  otherwise UNDEFINED;

// .ID format only permitted with LD1 & ST1
if size:Q == '110' && selem != 1 then UNDEFINED; otherwise UnallocatedEncoding();
// .ID format only permitted with LD1 & ST1
if size:Q == '110' && selem != 1 then ReservedValue();
```

ST3 (multiple structures)
Operation

```c
CheckFPAdvSIMDEnabled64();

bits(64) address;
bits(64) offs;
bits(datasize) rval;
integer tt;
integer e, r, s, tt;

constant integer ebytes = esize DIV 8;

if n == 31 then
  HaveMTEExt() then
  SetNotTagCheckedInstruction(!wback && n == 31);

if n == 31 then
  CheckSPLAlignment();
  address = SP[];
else
  address = X[n];

offs = Zeros();
for r = 0 to rpt-1
  for e = 0 to elements-1
    tt = (t + r) MOD 32;
    for s = 0 to selem-1
      rval = V[tt];
      if memop == MemOp_LOAD then
        Elem[rval, e, esize] = Mem[address + offs, ebytes, AccType_VEC];
      else // memop == MemOp_STORE
        Mem[address + offs, ebytes, AccType_VEC] = Elem[rval, e, esize];
      offs = offs + ebytes;
      tt = (tt + 1) MOD 32;
  if wback then
    if m != 31 then
      offs = X[m];
    if n == 31 then
      SP[] = address + offs;
    else
      X[n] = address + offs;
```

Operational information

If PSTATE.DIT is 1, the timing of this instruction is insensitive to the value of the data being loaded or stored.
ST3 (single structure)

Store single 3-element structure from one lane of three registers. This instruction stores a 3-element structure to memory from corresponding elements of three SIMD&FP registers.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

It has encodings from 2 classes: No offset and Post-index

No offset

<table>
<thead>
<tr>
<th>31</th>
<th>30</th>
<th>29</th>
<th>28</th>
<th>27</th>
<th>26</th>
<th>25</th>
<th>24</th>
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<th>9</th>
<th>8</th>
<th>7</th>
<th>6</th>
<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Q</td>
<td>0</td>
<td>1</td>
<td>0</td>
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<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>x</td>
<td>x</td>
<td>1</td>
<td>S</td>
<td>size</td>
<td>Rn</td>
<td>Rt</td>
<td></td>
<td></td>
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<td></td>
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<td></td>
</tr>
</tbody>
</table>

L   R   opcode

8-bit (opcode == 001)


16-bit (opcode == 011 && size == x0)

ST3 { <Vt>.H, <Vt2>.H, <Vt3>.H }[<index>], [Xn|SP]

32-bit (opcode == 101 && size == 00)

ST3 { <Vt>.S, <Vt2>.S, <Vt3>.S }[<index>], [Xn|SP]

64-bit (opcode == 101 && S == 0 && size == 01)

ST3 { <Vt>.D, <Vt2>.D, <Vt3>.D }[<index>], [Xn|SP]

integer t = UInt(Rt);
integer n = UInt(Rn);
integer m = integer UNKNOWN;
boolean wback = FALSE;

Post-index

<table>
<thead>
<tr>
<th>31</th>
<th>30</th>
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<th>27</th>
<th>26</th>
<th>25</th>
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<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Q</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>0</td>
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<td>x</td>
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<td>Rt</td>
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</tr>
</tbody>
</table>

L   R   opcode
8-bit, immediate offset (Rm == 11111 && opcode == 001)

ST3 { <Vt>.B, <Vt2>.B, <Vt3>.B }[<index>], [<Xn|SP>], #3

8-bit, register offset (Rm != 11111 && opcode == 001)

ST3 { <Vt>.B, <Vt2>.B, <Vt3>.B }[<index>], [<Xn|SP>], <Xm>

16-bit, immediate offset (Rm == 11111 && opcode == 011 && size == x0)

ST3 { <Vt>.H, <Vt2>.H, <Vt3>.H }[<index>], [<Xn|SP>], #6

16-bit, register offset (Rm != 11111 && opcode == 011 && size == x0)

ST3 { <Vt>.H, <Vt2>.H, <Vt3>.H }[<index>], [<Xn|SP>], <Xm>

32-bit, immediate offset (Rm == 11111 && opcode == 101 && size == 00)

ST3 { <Vt>.S, <Vt2>.S, <Vt3>.S }[<index>], [<Xn|SP>], #12

32-bit, register offset (Rm != 11111 && opcode == 101 && size == 00)

ST3 { <Vt>.S, <Vt2>.S, <Vt3>.S }[<index>], [<Xn|SP>], <Xm>

64-bit, immediate offset (Rm == 11111 && opcode == 101 && S == 0 && size == 01)

ST3 { <Vt>.D, <Vt2>.D, <Vt3>.D }[<index>], [<Xn|SP>], #24

64-bit, register offset (Rm != 11111 && opcode == 101 && S == 0 && size == 01)

ST3 { <Vt>.D, <Vt2>.D, <Vt3>.D }[<index>], [<Xn|SP>], <Xm>

integer t = UInt(Rt);
integer n = UInt(Rn);
integer m = UInt(Rm);
boolean wback = TRUE;

Assembler Symbols

<Vt> Is the name of the first or only SIMD&FP register to be transferred, encoded in the "Rt" field.
<Vt2> Is the name of the second SIMD&FP register to be transferred, encoded as "Rt" plus 1 modulo 32.
<Vt3> Is the name of the third SIMD&FP register to be transferred, encoded as "Rt" plus 2 modulo 32.
<index> For the 8-bit variant: is the element index, encoded in "Q:S:size".
For the 16-bit variant: is the element index, encoded in "Q:S:size<1>".
For the 32-bit variant: is the element index, encoded in "Q:S".
For the 64-bit variant: is the element index, encoded in "Q".
<Xn|SP> Is the 64-bit name of the general-purpose base register or stack pointer, encoded in the "Rn" field.
<Xm> Is the 64-bit name of the general-purpose post-index register, excluding XZR, encoded in the "Rm" field.
integer scale = UInt(opcode<2:1>);
integer selem = UInt(opcode<0>:R) + 1;
boolean replicate = FALSE;
integer index;

case scale of
  when 3
    // load and replicate
    if L == '0' || S == '1' then UNDEFINED;
    scale = if L == '0' || S == '1' then UnallocatedEncoding();
    scale = UInt(size);
    replicate = TRUE;
  when 0
    index = UInt(Q:S:size);         // B[0-15]
  when 1
    if size<0> == '1' then UNDEFINED;
    index = if size<0> == '1' then UnallocatedEncoding();
    index = UInt(Q:S:size<1>);      // H[0-7]
  when 2
    if size<1> == '1' then UNDEFINED;
    if size<0> == '0' then
      index = if size<1> == '1' then UnallocatedEncoding();
      index = UInt(Q:S);            // S[0-3]
    else
      if S == '1' then UnallocatedEncoding(Q:S);       // S[0-3]
      if S == '1' then UNDEFINED;
    end
  else
    index = UInt(Q);                 // D[0-1]
  end

MemOp memop = if L == '1' then MemOp_LOAD else MemOp_STORE;
integer datasize = if Q == '1' then 128 else 64;
integer esize = 8 << scale;
if HaveMTEExt() then
    SetNotTagCheckedInstruction(!wback && n == 31);

CheckFPAdvSIMDEnabled64();

bits(64) address;
bits(64) offs;
bits(128) rval;
bits(esize) element;
integer s;
constant integer ebytes = esize DIV 8;

if n == 31 then
    CheckSPAlignment();
    address = SP[];
else
    address = X[n];

offs = Zeros();
if replicate then
    // load and replicate to all elements
    for s = 0 to selem-1
        element = Mem[address + offs, ebytes, AccType_VEC];
    // replicate to fill 128- or 64-bit register
    V[t] = Replicate(element, datasize DIV esize);
    offs = offs + ebytes;
    t = (t + 1) MOD 32;
else
    // load/store one element per register
    for s = 0 to selem-1
        rval = V[t];
        if memop == MemOp_LOAD then
            // insert into one lane of 128-bit register
            Elem[rval, index, esize] = Mem[address + offs, ebytes, AccType_VEC];
            V[t] = rval;
        else // memop == MemOp_STORE
            // extract from one lane of 128-bit register
            Mem[address + offs, ebytes, AccType_VEC] = Elem[rval, index, esize];
        offs = offs + ebytes;
        t = (t + 1) MOD 32;
if wback then
    if m != 31 then
        offs = X[m];
    if n == 31 then
        SP[] = address + offs;
    else
        X[n] = address + offs;

Operational information

If PSTATE.DIT is 1, the timing of this instruction is insensitive to the value of the data being loaded or stored.
ST4 (multiple structures)

Store multiple 4-element structures from four registers. This instruction stores multiple 4-element structures to memory from four SIMD&FP registers, with interleaving. Every element of each register is stored.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

It has encodings from 2 classes: No offset and Post-index

**No offset**

|   | 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9  | 8  | 7  | 6  | 5  | 4  | 3  | 2  | 1  | 0  |
|---|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0 | 1  | 1  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 8B | 00  | 0  | 1  | 1  | 0  | 1  |
| L |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    | opcode

**Immediate offset (Rm == 11111)**

ST4 { <Vt>.<T>, <Vt2>.<T>, <Vt3>.<T>, <Vt4>.<T> }, [<Xn|SP>], <imm>

**Register offset (Rm != 11111)**

ST4 { <Vt>.<T>, <Vt2>.<T>, <Vt3>.<T>, <Vt4>.<T> }, [<Xn|SP>], <Xm>

|   | 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9  | 8  | 7  | 6  | 5  | 4  | 3  | 2  | 1  | 0  |
|---|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0 | 1  | 1  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0B | 00  | 0  | 1  | 1  | 0  | 1  | 0  | 1  | 0  | 1  |

**Assembler Symbols**

- **<Vt>**
  Is the name of the first or only SIMD&FP register to be transferred, encoded in the "Rt" field.

- **<T>**
  Is an arrangement specifier, encoded in "size:Q"

<table>
<thead>
<tr>
<th>size</th>
<th>Q</th>
<th>&lt;T&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>0</td>
<td>8B</td>
</tr>
<tr>
<td>00</td>
<td>1</td>
<td>16B</td>
</tr>
<tr>
<td>01</td>
<td>0</td>
<td>4H</td>
</tr>
<tr>
<td>01</td>
<td>1</td>
<td>8H</td>
</tr>
<tr>
<td>10</td>
<td>0</td>
<td>2S</td>
</tr>
<tr>
<td>10</td>
<td>1</td>
<td>4S</td>
</tr>
<tr>
<td>11</td>
<td>0</td>
<td>RESERVED</td>
</tr>
<tr>
<td>11</td>
<td>1</td>
<td>2D</td>
</tr>
</tbody>
</table>

- **<Vt2>**
  Is the name of the second SIMD&FP register to be transferred, encoded as "Rt" plus 1 modulo 32.
<Vt3> Is the name of the third SIMD&FP register to be transferred, encoded as "Rt" plus 2 modulo 32.
<Vt4> Is the name of the fourth SIMD&FP register to be transferred, encoded as "Rt" plus 3 modulo 32.
<Xn|SP> Is the 64-bit name of the general-purpose base register or stack pointer, encoded in the "Rn" field.
<imm> Is the post-index immediate offset, encoded in "Q":

<table>
<thead>
<tr>
<th>Q</th>
<th>&lt;imm&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>#32</td>
</tr>
<tr>
<td>1</td>
<td>#64</td>
</tr>
</tbody>
</table>
<Xm> Is the 64-bit name of the general-purpose post-index register, excluding XZR, encoded in the "Rm" field.

**Shared Decode**

```plaintext
MemOp memop = if L == '1' then MemOp LOAD else MemOp STORE;
integer datasize = if Q == '1' then 128 else 64;
integer esize = 8 << UInt(size);
integer elements = datasize DIV esize;
integer rpt; // number of iterations
integer selem; // structure elements

case opcode of
  when '0000' rpt = 1; selem = 4; // LD/ST4 (4 registers)
  when '0010' rpt = 4; selem = 1; // LD/ST1 (4 registers)
  when '0100' rpt = 1; selem = 3; // LD/ST3 (3 registers)
  when '0110' rpt = 3; selem = 1; // LD/ST1 (3 registers)
  when '0111' rpt = 1; selem = 2; // LD/ST2 (2 registers)
  when '1000' rpt = 1; selem = 2; // LD/ST1 (2 registers)
  otherwise UNDEFINED;

// .1D format only permitted with LD1 & ST1
if size:Q == '110' && selem != 1 then UNDEFINED; otherwise UnallocatedEncoding();

// .1D format only permitted with LD1 & ST1
if size:Q == '110' && selem != 1 then ReservedValue();
```

ST4 (multiple structures)
Operation

```c
CheckFPAdvSIMDEnabled64();

bits(64) address;
bits(64) offs;
bits(datasize) rval;
integer tt;
integer e, r, s, tt;
constant integer ebytes = esize DIV 8;

if n == 31 then
  HaveMTEExt() then
    SetNotTagCheckedInstruction(!wback && n == 31);
  endif
if n == 31 then
  CheckSPAlignment();
  address = SP[];
else
  address = X[n];
endif
offs = Zeros();
for r = 0 to rpt-1
  for e = 0 to elements-1
    tt = (t + r) MOD 32;
    for s = 0 to selem-1
      rval = V[tt];
      if memop == MemOp_LOAD then
        Elem[rval, e, esize] = Mem[address + offs, ebytes, AccType_VEC];
        V[tt] = rval;
      else // memop == MemOp_STORE
        Mem[address + offs, ebytes, AccType_VEC] = Elem[rval, e, esize];
      offs = offs + ebytes;
      tt = (tt + 1) MOD 32;
    endif
  endif
endif
offs = X[m];
if n == 31 then
  SP[] = address + offs;
else
  X[n] = address + offs;
```

Operational information

If PSTATE.DIT is 1, the timing of this instruction is insensitive to the value of the data being loaded or stored.

Internal version only: isa v30.25, AdvSIMD v27.01, pseudocode v85-xml-00bet8_rc3; Build timestamp: 2018-09-13 2018-06-16 04:45

Copyright © 2010-2018 ARM Limited or its affiliates. All rights reserved. This document is Non-Confidential.
ST4 (single structure)

Store single 4-element structure from one lane of four registers. This instruction stores a 4-element structure to memory from corresponding elements of four SIMD&FP registers.

Depending on the settings in the \textit{CPACR EL1}, \textit{CPTR EL2}, and \textit{CPTR EL3} registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

It has encodings from 2 classes: \textit{No offset} and \textit{Post-index}

No offset

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| Q  | 0  | 1  | 0  | 1  | 0  | 1  | 0  | 0  | 0  | 0  | 0  | x  | x  | 1  | S  | size | Rn | Rt |
| L  | R  | opcode |

8-bit (opcode \(= 001\))

\[
\text{ST4 \{ <Vt>._B, <Vt2>._B, <Vt3>._B, <Vt4>._B \}[[index]], \ [<Xn|SP>]}
\]

16-bit (opcode \(= 011 \&\& \text{size == x0}\))

\[
\text{ST4 \{ <Vt>._H, <Vt2>._H, <Vt3>._H, <Vt4>._H \}[[index]], \ [<Xn|SP>]}
\]

32-bit (opcode \(= 101 \&\& \text{size == 00}\))

\[
\text{ST4 \{ <Vt>._S, <Vt2>._S, <Vt3>._S, <Vt4>._S \}[[index]], \ [<Xn|SP>]}
\]

64-bit (opcode \(= 101 \&\& \text{S == 0 \&\& size == 01}\))

\[
\text{ST4 \{ <Vt>._D, <Vt2>._D, <Vt3>._D, <Vt4>._D \}[[index]], \ [<Xn|SP>]}
\]

\[
\text{integer \(t = \text{UInt}\( \text{Rt} \));}
\]
\[
\text{integer \(n = \text{UInt}\( \text{Rn} \));}
\]
\[
\text{integer \(m = \text{integer \text{UNKNOWN}}\));}
\]
\[
\text{boolean \(\text{wback = FALSE}\));}
\]

Post-index

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| Q  | 0  | 0  | 1  | 0  | 1  | 0  | 1  | Rm | x  | x  | 1  | S  | size | Rn | Rt |
| L  | R  | opcode |
8-bit, immediate offset (Rm == 11111 && opcode == 001)


8-bit, register offset (Rm != 11111 && opcode == 001)

\[ \text{ST4} \{ <Vt>.B, <Vt2>.B, <Vt3>.B, <Vt4>.B \} \{\text{index}\}, [\text{Xn}|\text{SP}], <\text{Xm}> \]

16-bit, immediate offset (Rm == 11111 && opcode == 011 && size == x0)

\[ \text{ST4} \{ <Vt>.H, <Vt2>.H, <Vt3>.H, <Vt4>.H \} \{\text{index}\}, [\text{Xn}|\text{SP}], \#8 \]

16-bit, register offset (Rm != 11111 && opcode == 011 && size == x0)

\[ \text{ST4} \{ <Vt>.H, <Vt2>.H, <Vt3>.H, <Vt4>.H \} \{\text{index}\}, [\text{Xn}|\text{SP}], <\text{Xm}> \]

32-bit, immediate offset (Rm == 11111 && opcode == 101 && size == 00)


32-bit, register offset (Rm != 11111 && opcode == 101 && size == 00)

\[ \text{ST4} \{ <Vt>.S, <Vt2>.S, <Vt3>.S, <Vt4>.S \} \{\text{index}\}, [\text{Xn}|\text{SP}], <\text{Xm}> \]

64-bit, immediate offset (Rm == 11111 && opcode == 101 && S == 0 && size == 01)

\[ \text{ST4} \{ <Vt>.D, <Vt2>.D, <Vt3>.D, <Vt4>.D \} \{\text{index}\}, [\text{Xn}|\text{SP}], \#32 \]

64-bit, register offset (Rm != 11111 && opcode == 101 && S == 0 && size == 01)

\[ \text{ST4} \{ <Vt>.D, <Vt2>.D, <Vt3>.D, <Vt4>.D \} \{\text{index}\}, [\text{Xn}|\text{SP}], <\text{Xm}> \]

\[
\begin{align*}
\text{integer } t &= \text{UInt}(\text{Rt}); \\
\text{integer } n &= \text{UInt}(\text{Rn}); \\
\text{integer } m &= \text{UInt}(\text{Rm}); \\
\text{boolean } \text{wback} &= \text{TRUE};
\end{align*}
\]

Assembler Symbols

\(<Vt>\quad \text{Is the name of the first or only SIMD\&FP register to be transferred, encoded in the "Rt" field.}\)

\(<Vt2>\quad \text{Is the name of the second SIMD\&FP register to be transferred, encoded as "Rt" plus 1 modulo 32.}\)

\(<Vt3>\quad \text{Is the name of the third SIMD\&FP register to be transferred, encoded as "Rt" plus 2 modulo 32.}\)

\(<Vt4>\quad \text{Is the name of the fourth SIMD\&FP register to be transferred, encoded as "Rt" plus 3 modulo 32.}\)

\(<\text{index}>\quad \text{For the 8-bit variant: is the element index, encoded in "Q:S:size".}\)

\(<\text{index}>\quad \text{For the 16-bit variant: is the element index, encoded in "Q:S:size<1>".}\)

\(<\text{index}>\quad \text{For the 32-bit variant: is the element index, encoded in "Q:S".}\)

\(<\text{index}>\quad \text{For the 64-bit variant: is the element index, encoded in "Q".}\)

\(<\text{Xn}|\text{SP}>\quad \text{Is the 64-bit name of the general-purpose base register or stack pointer, encoded in the "Rn" field.}\)

\(<\text{Xm}>\quad \text{Is the 64-bit name of the general-purpose post-index register, excluding XZR, encoded in the "Rm" field.}\)
integer scale = \texttt{UInt}(\text{opcode}<2:1>); \\
integer selem = \texttt{UInt}(\text{opcode}<0>:R) + 1; \\
boolean replicate = \texttt{FALSE}; \\
integer index; \\

\textbf{case scale of} \\
\quad \textbf{when 3} \\
\qquad \text{/ load and replicate} \\
\qquad \text{if } L == '0' || S == '1' \text{ then UNDEFINED;} \\
\qquad \text{scale = \texttt{UnallocatedEncoding}();} \\
\qquad \text{index = \texttt{UnallocatedEncoding}();} \\
\qquad \text{replicate = \texttt{TRUE};} \\
\quad \text{when 0} \\
\qquad \text{index = \texttt{UnallocatedEncoding}();} \\
\quad \text{when 1} \\
\qquad \text{if } \text{size}<0> == '1' \text{ then UNDEFINED;} \\
\qquad \text{index = \texttt{UnallocatedEncoding}();} \\
\textbf{when 2} \\
\text{if } \text{size}<0> == '1' \text{ then UNDEFINED;} \\
\text{if } \text{size}<0> == '0' \text{ then} \\
\quad \text{index = \texttt{UnallocatedEncoding}();} \\
\text{else} \\
\quad \text{if } S == '1' \text{ then UNDEFINED;} \\
\quad \text{else} \\
\quad \quad \text{index = \texttt{UnallocatedEncoding}();} \\
\textbf{else} \\
\quad \text{if } S == '1' \text{ then UNDEFINED;} \\
\quad \quad \text{index = \texttt{UnallocatedEncoding}();} \\
\quad \quad \text{scale = 3;} \\
\texttt{MemOp memop = if } L == '1' \text{ then MemOp\_LOAD else MemOp\_STORE;}
\texttt{integer datasize = if } Q == '1' \text{ then 128 else 64;}
\texttt{integer esize = 8 << scale;}

Operation

```c
if HaveMTEExt() then
    SetNotTagCheckedInstruction(!wback && n == 31);

CheckFPAdvSIMDEnabled64();

bits(64) address;
bits(64) offs;
bits(128) rval;
bits(esize) element;
integer ebytes

constant integer ebytes = esize DIV 8;

if n == 31 then
    CheckSPAlignment();
    address = SP[];
else
    address = X[n];

offs = Zeros();
if replicate then
    // load and replicate to all elements
    for s = 0 to selem-1
        element = Mem[address + offs, ebytes, AccType_VEC];
    // replicate to fill 128- or 64-bit register
    V[t] = Replicate(element, datasize DIV esize);
    offs = offs + ebytes;
    t = (t + 1) MOD 32;
else
    // load/store one element per register
    for s = 0 to selem-1
        rval = V[t];
        if memop == MemOp_LOAD then
            // insert into one lane of 128-bit register
            Elem[rval, index, esize] = Mem[address + offs, ebytes, AccType_VEC];
            V[t] = rval;
        else
            // memop == MemOp_STORE
            // extract from one lane of 128-bit register
            Mem[address + offs, ebytes, AccType_VEC] = Elem[rval, index, esize];
            offs = offs + ebytes;
            t = (t + 1) MOD 32;

if wback then
    if m != 31 then
        offs = X[m];
    if n == 31 then
        SP[] = address + offs;
    else
        X[n] = address + offs;
```

Operational information

If PSTATE.DIT is 1, the timing of this instruction is insensitive to the value of the data being loaded or stored.
STG

Store Allocation Tag stores an Allocation Tag to memory. The address used for the store is calculated from the source register and an immediate signed offset scaled by the Tag granule. The Allocation Tag is calculated from the Logical Address Tag in the source register.

This instruction generates an Unchecked access.

It has encodings from 3 classes: Post-index, Pre-index and Signed offset

Post-index

(ARMv8.5)

|   | 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|---|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
|   | 1  | 1  | 0  | 1  | 0  | 0  | 1  | 0  | 0  | 1  | imm9 | 0  | 1  | Xn | (1) (1) (1) (1) |
|   | (1)(1)(1)(1) |

Pre-index

(ARMv8.5)

|   | 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|---|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
|   | 1  | 1  | 0  | 1  | 0  | 0  | 1  | 0  | 0  | 1  | imm9 | 1  | 1  | Xn | (1) (1) (1) (1) |
|   | (1)(1)(1)(1) |

Pre-index

STG [Xn|SP], #<simm>

integer n = UInt(Xn);
bits(64) offset = LSL(SignExtend(imm9, 64), LOG2_TAG_GRANULE);
boolean writeback = TRUE;
boolean postindex = TRUE;
boolean zero_data = FALSE;

Signed offset

(ARMv8.5)

|   | 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|---|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
|   | 1  | 1  | 0  | 1  | 0  | 0  | 1  | 0  | 0  | 1  | imm9 | 1  | 0  | Xn | (1) (1) (1) (1) |
|   | (1)(1)(1)(1) |

Signed offset

STG [Xn|SP], #<simm>]

integer n = UInt(Xn);
bits(64) offset = LSL(SignExtend(imm9, 64), LOG2_TAG_GRANULE);
boolean writeback = FALSE;
boolean postindex = FALSE;
boolean zero_data = FALSE;
Assembler Symbols

<Xn\SP>
Is the 64-bit name of the general-purpose base register or stack pointer, encoded in the "Xn" field.

<simm>
Is the optional signed immediate offset, a multiple of 16 in the range -4096 to 4080, defaulting to 0 and encoded in the "imm9" field.

Operation

```c
bits(64) address;

SetNotTagCheckedInstruction(TRUE);

if n == 31 then
    CheckSPAlignment();
    address = SP[];
else
    address = X[n];

if !postindex then
    address = address + offset;

if zero_data then
    Mem[address, TAG_GRANULE, AccType_NORMAL] = Zeros(TAG_GRANULE * 8);
    MemTag[address] = AllocationTagFromAddress(address);

if writeback then
    if postindex then
        address = address + offset;
    if n == 31 then
        SP[] = address;
    else
        X[n] = address;
```

Copyright © 2010-2018 ARM Limited or its affiliates. All rights reserved. This document is Non-Confidential.
Store Allocation Tag and Pair of registers stores an Allocation Tag and two 64-bit doublewords to memory, from two registers. The address used for the store is calculated from the base register and an immediate signed offset scaled by the Tag granule. The Allocation Tag is calculated from the Logical Address Tag in the base register.

This instruction generates an Unchecked access.

It has encodings from 3 classes: Post-index, Pre-index and Signed offset

### Post-index (ARMv8.5)

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<table>
<thead>
<tr>
<th>31</th>
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</table>
```

STGP \(<Xt1>, <Xt2>, [<Xn|SP>], \#, \<imm>\)

- integer \(n = \text{UInt}(Xn)\);
- integer \(t = \text{UInt}(Xt)\);
- integer \(t2 = \text{UInt}(Xt2)\);
- bits(64) offset = \(\text{LSL}(\text{SignExtend}(\text{simm7, 64}), \text{LOG2_TAG_GRANULE})\);
- boolean writeback = TRUE;
- boolean postindex = TRUE;

### Pre-index (ARMv8.5)

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</tbody>
</table>
```

STGP \(<Xt1>, <Xt2>, [<Xn|SP>, \#, \<imm>]\)

- integer \(n = \text{UInt}(Xn)\);
- integer \(t = \text{UInt}(Xt)\);
- integer \(t2 = \text{UInt}(Xt2)\);
- bits(64) offset = \(\text{LSL}(\text{SignExtend}(\text{simm7, 64}), \text{LOG2_TAG_GRANULE})\);
- boolean writeback = TRUE;
- boolean postindex = FALSE;

### Signed offset (ARMv8.5)

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<table>
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```

STGP \(<Xt1>, <Xt2>, [<Xn|SP>{, \#, \<imm>}]\)

- integer \(n = \text{UInt}(Xn)\);
- integer \(t = \text{UInt}(Xt)\);
- integer \(t2 = \text{UInt}(Xt2)\);
- bits(64) offset = \(\text{LSL}(\text{SignExtend}(\text{simm7, 64}), \text{LOG2_TAG_GRANULE})\);
- boolean writeback = FALSE;
- boolean postindex = FALSE;
Assembler Symbols

<Xt1> Is the 64-bit name of the first general-purpose register to be transferred, encoded in the "Xt" field.

<Xt2> Is the 64-bit name of the second general-purpose register to be transferred, encoded in the "Xt2" field.

<Xn|SP> Is the 64-bit name of the general-purpose base register or stack pointer, encoded in the "Xn" field.

<imm> For the post-index and pre-index variant: is the signed immediate offset, in the range -64 to 63, encoded in the "simm7" field.
For the signed offset variant: is the optional signed immediate offset, in the range -64 to 63, defaulting to 0 and encoded in the "simm7" field.

Operation

```plaintext
bits(64) address;
bits(64) data1;
bits(64) data2;

SetNotTagCheckedInstruction(TRUE);

if n == 31 then
    CheckSPAlignment();
    address = SP[];
else
    address = X[n];

data1 = X[t];
data2 = X[t2];

if !postindex then
    address = address + offset;

Mem[address, 8, AccType_NORMAL] = data1;
Mem[address+8, 8, AccType_NORMAL] = data2;

MemTag[address] = AllocationTagFromAddress(address);

if writeback then
    if postindex then
        address = address + offset;

    if n == 31 then
        SP[] = address;
    else
        X[n] = address;
```

Internal version only: isa v30.25, AdvSIMD v27.01, pseudocode v85-xml-00bet8_rc3 ; Build timestamp: 2018-09-13T13:04
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STGV

Store Tag Vector reads from the second source register an IMPLEMENTATION DEFINED number of Allocation Tags and stores them to the naturally aligned array of 16 allocation tags which includes a tag whose address is the address in the first source register. The Allocation Tag at the address in the first source register is always stored, and the first source register is updated to the address of the first Allocation Tag at an address higher than the original address that was not loaded.

This instruction is UNDEFINED at EL0.

This instruction generates an Unchecked access.

**Integer**

(ARMv8.5)

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9  | 8  | 7  | 6  | 5  | 4  | 3  | 2  | 1  | 0  |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 1  | 1  | 0  | 1  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | Xn | ----| ----| ----| ----| ----| ----| ----| ----| ----| ----| ----| ----| ----| ----| ----| ----| ----| ----| ----| ----| ----|
| 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  |

**Assembler Symbols**

STGV <Xt>, [<Xn|SP>]!

integer t = UInt(Xt);
integer n = UInt(Xn);

Operation

```plaintext
bits(64) data = X[t];
bits(64) address;
if n == 31 then
    CheckSPAlignment();
    address = SP[];
else
    address = X[n];

// address<63:LOG2_TAG_GRANULE+4>:Zeros(LOG2_TAG_GRANULE+4) <= start <= address
// 0 < count <= 16-start<LOG2_TAG_GRANULE+3:LOG2_TAG_GRANULE>
integer count;
(address, count) = ImpDefTagArrayStartAndCount(address);
for i = 0 to count-1
    integer index = UInt(address<LOG2_TAG_GRANULE+3:LOG2_TAG_GRANULE>);
    bits(4) tag = data<(index*4)+3:index*4>;
    MemTag[address] = tag;
    address = address + TAG_GRANULE;
if n == 31 then
    SP[] = address;
else
    X[n] = address;
```

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STLLR

Store LORelease Register stores a 32-bit word or a 64-bit doubleword to a memory location, from a register. The instruction also has memory ordering semantics as described in Load LOAcquire, Store LORelease. For information about memory accesses, see Load/Store addressing modes.

No offset
(ARMv8.1)

| x | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | (1) | (1) | (1) | (1) | 0 | (1) | (1) | (1) | (1) | Rn | Rt |
|---|---|---|---|---|---|---|---|---|-----|-----|-----|-----|---|-----|-----|-----|-----|
| size | L | Rs | o0 | Rt2 |

32-bit (size == 10)

STLLR <Wt>, [<Xn|SP>{,#0}]

64-bit (size == 11)

STLLR <Xt>, [<Xn|SP>{,#0}]

```plaintext
integer n = UInt(Rn);
integer t = UInt(Rt);
integer t2 = UInt(Rt2); // ignored by load/store single register
integer s = UInt(Rs);   // ignored by all loads and store-release

AccType acctype = if o0 == '0' then AccType_LIMITEDORDERED else AccType_ORDERED;
MemOp memop = if L == '1' then MemOp_LOAD else MemOp_STORE;
integer elsize = 8 << UInt(size);
integer regsize = if elsize == 64 then 64 else 32;
integer datasize = elsize;
```

Assembler Symbols

<Wt> Is the 32-bit name of the general-purpose register to be transferred, encoded in the "Rt" field.
<Xt> Is the 64-bit name of the general-purpose register to be transferred, encoded in the "Rt" field.
<Xn|SP> Is the 64-bit name of the general-purpose base register or stack pointer, encoded in the "Rn" field.
Operation

bits(64) address;
bits(datasize) data;
constant integer dbytes = datasize DIV 8;

if n == 31 then HaveMTEExt() then
    SetNotTagCheckedInstruction(n == 31);
if n == 31 then
    CheckSPAlignment();
else
    address = X[n];

case memop of
    when MemOp_STORE
        data = X[t];
        Mem[address, dbytes, acctype] = data;
    when MemOp_LOAD
        data = Mem[address, dbytes, acctype];
        X[t] = ZeroExtend(data, regsize);

Operational information

If PSTATE.DIT is 1, the timing of this instruction is insensitive to the value of the data being loaded or stored.
STLLRB

Store LORelease Register Byte stores a byte from a 32-bit register to a memory location. The instruction also has memory ordering semantics as described in Load LOAcquire, Store LORelease. For information about memory accesses, see Load/Store addressing modes.

No offset
(ARMv8.1)

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9  | 8  | 7  | 6  | 5  | 4  | 3  | 2  | 1  | 0  |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|    |
| 0  | 0  | 0  | 1  | 0  | 0  | 0  | 1  | 0  | 0  | (1)| (1)| (1)| (1)| 0  | (1)| (1)| (1)| (1)|   |   |   |   |   |   |   |   |   |   |

size | L   | Rs  | o0  | Rt2 |

No offset

STLLRB <Wt>, [<Xn|SP>{,0}]

integer n = UInt(Rn);
integer t = UInt(Rt);
integer t2 = UInt(Rt2); // ignored by load/store single register
integer s = UInt(Rs);   // ignored by all loads and store-release

AccType acctype = if o0 == '0' then AccType_LIMITEDORDERED else AccType_ORDERED;
MemOp memop = if L == '1' then MemOp_LOAD else MemOp_STORE;
integer elsize = 8 << UInt(size);
integer regsize = if elsize == 64 then 64 else 32;
integer datasize = elsize;

Assembler Symbols

<Wt> Is the 32-bit name of the general-purpose register to be transferred, encoded in the "Rt" field.
<Xn|SP> Is the 64-bit name of the general-purpose base register or stack pointer, encoded in the "Rn" field.

Operation

bits(64) address;
bits(datasize) data;
constant integer dbytes = datasize DIV 8;

if n == 31 then
  HaveMTEExt() then
  SetNotTagCheckedInstruction(n == 31);
if n == 31 then
  CheckSPA();
  address = SP[];
else
  address = X[n];
case memop of
when MemOp_STORE
  data = X[t];
  Mem[address, dbytes, acctype] = data;
when MemOp_LOAD
  data = Mem[address, dbytes, acctype];
  X[t] = ZeroExtend(data, regsize);

Operational information

If PSTATE.DIT is 1, the timing of this instruction is insensitive to the value of the data being loaded or stored.
STLLRH

Store LORelease Register Halfword stores a halfword from a 32-bit register to a memory location. The instruction also has memory ordering semantics as described in Load LOAcquire, Store LORelease. For information about memory accesses, see Load/Store addressing modes.

No offset
(ARMv8.1)

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No offset

STLLRH <Wt>, [<Xn|SP>{,0}]

```plaintext
integer n = Uint(Rn);
integer t = Uint(Rt);
integer t2 = Uint(Rt2); // ignored by load/store single register
integer s = Uint(Rs);   // ignored by all loads and store-release

AccType acctype = if o0 == '0' then AccType_LIMITEDORDERED else AccType_ORDERED;
MemOp memop = if L == '1' then MemOp_LOAD else MemOp_STORE;
integer elsize = 8 << Uint(size);
integer regsize = if elsize == 64 then 64 else 32;
integer datasize = elsize;
```

Assembler Symbols

<Wt> Is the 32-bit name of the general-purpose register to be transferred, encoded in the "Rt" field.
<Xn|SP> Is the 64-bit name of the general-purpose base register or stack pointer, encoded in the "Rn" field.

Operation

```plaintext
bits(64) address;
bits(datasize) data;
constant integer dbytes = datasize DIV 8;

if n == 31 then HaveMTEExt() then
    SetNotTagCheckedInstruction(n == 31);

if n == 31 then
    CheckSPA()>();
    address = SP[];
else
    address = X[n];

case memop of
    when MemOp_STORE
        data = X[t];
        Mem[address, dbytes, acctype] = data;
    when MemOp_LOAD
        data = Mem[address, dbytes, acctype];
        X[t] = ZeroExtend(data, regsize);
```

Operational information

If PSTATE.DIT is 1, the timing of this instruction is insensitive to the value of the data being loaded or stored.
STLR

Store-Release Register stores a 32-bit word or a 64-bit doubleword to a memory location, from a register. The instruction also has memory ordering semantics as described in Load-Acquire, Store-Release. For information about memory accesses, see Load/Store addressing modes.

32-bit (size == 10)

STLR <Wt>, [<Xn|SP>{,#0}]

64-bit (size == 11)

STLR <Xt>, [<Xn|SP>{,#0}]

Assembler Symbols

<Wt> Is the 32-bit name of the general-purpose register to be transferred, encoded in the "Rt" field.
<Xt> Is the 64-bit name of the general-purpose register to be transferred, encoded in the "Rt" field.
<Xn|SP> Is the 64-bit name of the general-purpose base register or stack pointer, encoded in the "Rn" field.

Operation

```plaintext
bits(64) address;
bits(datasize) data;
constant integer dbytes = datasize DIV 8;

if n == 31 then HaveMTEExt() then
    SetNotTagCheckedInstruction(n == 31);

if n == 31 then
    CheckSPAAlignment();
    address = SP[];
else
    address = X[n];

case memop of
    when MemOp_STORE
        data = X[t];
        Mem[address, dbytes, acctype] = data;
    when MemOp LOAD
        data = Mem[address, dbytes, acctype];
        X[t] = ZeroExtend(data, regsize);
```

STLR Page 1215
Operational information

If PSTATE.DIT is 1, the timing of this instruction is insensitive to the value of the data being loaded or stored.
STLRB

Store-Release Register Byte stores a byte from a 32-bit register to a memory location. The instruction also has memory ordering semantics as described in Load-Acquire, Store-Release. For information about memory accesses, see Load/Store addressing modes.

| 31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0 |
|-----------------|-----------------|----------------|-----------------|----------------|-----------------|----------------|
| 0 0 0 1 0 0 0 1 0 0 0 0 1 0 0 0 1 1 0 0 0 0 0 0 0 0 0 1 1 1 1 1 1 1 1 1 1 |

No offset

STLRB $<Wt>$, [<Xn|SP>]{},#0

integer n = UInt(Rn);
integer t = UInt(Rt);
integer t2 = UInt(Rt2);  // ignored by load/store single register
integer s = UInt(Rs);  // ignored by all loads and store-release

AccType acctype = if o0 == '0' then AccType_LIMITEDORDERED else AccType_ORDERED;
MemOp memop = if L == '1' then MemOp_LOAD else MemOp_STORE;
integer elsize = 8 << UInt(size);
integer regsize = if elsize == 64 then 64 else 32;
integer datasize = elsize;

Assembler Symbols

$<Wt>$ Is the 32-bit name of the general-purpose register to be transferred, encoded in the "Rt" field.

$<Xn|SP>$ Is the 64-bit name of the general-purpose base register or stack pointer, encoded in the "Rn" field.

Operation

bits(64) address;
bits(datasize) data;
constant integer dbytes = datasize DIV 8;

if n == 31 then HaveMTEExt() then
   SetNotTagCheckedInstruction(n == 31);
if n == 31 then
   CheckSPAlignment();
else
   address = X[n];

case memop of
   when MemOp_STORE
      data = X[t];
      Mem[address, dbytes, acctype] = data;
   when MemOp_LOAD
      data = Mem[address, dbytes, acctype];
      X[t] = ZeroExtend(data, regsize);

Operational information

If PSTATE.DIT is 1, the timing of this instruction is insensitive to the value of the data being loaded or stored.
STLRH

Store-Release Register Halfword stores a halfword from a 32-bit register to a memory location. The instruction also has memory ordering semantics as described in Load-Acquire, Store-Release. For information about memory accesses, see Load/Store addressing modes.

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9  | 8  | 7  | 6  | 5  | 4  | 3  | 2  | 1  | 0  |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0  | 1  | 0  | 0  | 1  | 0  | 0  | 1  | 0  | 1  | 1  | (1) | (1) | (1) | (1) | 1  | (1) | (1) | (1) | (1) | Rn  |    |    |    |    |    |    |    |    |    |

No offset

STLRH <Wt>, [<Xn|SP>{,0}]

integer n = UInt(Rn);
integer t = UInt(Rt);
integer t2 = UInt(Rt2); // ignored by load/store single register
integer s = UInt(Rs);   // ignored by all loads and store-release
AccType acctype = if o0 == '0' then AccType_LIMITEDORDERED else AccType_ORDERED;
MemOp memop = if L == '1' then MemOp_LOAD else MemOp_STORE;
integer elsize = 8 << UInt(size);
integer regsize = if elsize == 64 then 64 else 32;
integer datasize = elsize;

Assembler Symbols

<Wt> Is the 32-bit name of the general-purpose register to be transferred, encoded in the "Rt" field.
<Xn|SP> Is the 64-bit name of the general-purpose base register or stack pointer, encoded in the "Rn" field.

Operation

bits(64) address;
bits(datasize) data;
constant integer dbytes = datasize DIV 8;

if n == 31 then HaveMTEExt() then
    SetNotTagCheckedInstruction(n == 31);
if n == 31 then
    CheckSPAlignment();
    address = SP[];
else
    address = X[n];
case memop of
    when MemOp_STORE
        data = X[t];
        Mem[address, dbytes, acctype] = data;
    when MemOp_LOAD
        data = Mem[address, dbytes, acctype];
        X[t] = ZeroExtend(data, regsize);

Operational information

If PSTATE.DIT is 1, the timing of this instruction is insensitive to the value of the data being loaded or stored.
STLUR

Store-Release Register (unscaled) calculates an address from a base register value and an immediate offset, and stores a 32-bit word or a 64-bit doubleword to the calculated address, from a register.

The instruction has memory ordering semantics as described in Load-Acquire, Load-AcquirePC, and Store-Release.

For information about memory accesses, see Load/Store addressing modes.

For 32-bit (size == 10):

\[
\text{STLUR } \langle Wt \rangle, [\langle Xn|SP \rangle, \#<\text{simm}>]
\]

For 64-bit (size == 11):

\[
\text{STLUR } \langle Xt \rangle, [\langle Xn|SP \rangle, \#<\text{simm}>]
\]

boolean wback = FALSE;
boolean postindex = FALSE;
integer scale = \text{UInt}(\text{size});
bits(64) offset = \text{SignExtend}(\text{imm9}, 64);

Assembler Symbols

\langle Wt \rangle \quad \text{Is the 32-bit name of the general-purpose register to be transferred, encoded in the "Rt" field.}

\langle Xt \rangle \quad \text{Is the 64-bit name of the general-purpose register to be transferred, encoded in the "Rt" field.}

\langle Xn|SP \rangle \quad \text{Is the 64-bit name of the general-purpose base register or stack pointer, encoded in the "Rn" field.}

\langle \text{simm} \rangle \quad \text{Is the optional signed immediate byte offset, in the range -256 to 255, defaulting to 0 and encoded in the "imm9" field.}
integer n = UInt(Rn);
integer t = UInt(Rt);
AccType acctype = AccType_ORDERED;
MemOp memop;
boolean signed;
integer regsize;

if opc<1> == '0' then
    // store or zero-extending load
    memop = if opc<0> == '1' then MemOp_LOAD else MemOp_STORE;
    regsize = if size == '11' then 64 else 32;
    signed = FALSE;
else
    if size == '11' then
        memop = MemOp_PREFETCH;
    else
        // sign-extending load
        memop = if opc<0> == '1' then UnallocatedEncoding();
        else
            // sign-extending load
            memop = MemOp_LOAD;
    if size == '10' && opc<0> == '1' then UnallocatedEncoding();
    if size == '10' && opc<0> == '1' then UNDEFINED;
    regsize = if opc<0> == '1' then 32 else 64;
    signed = TRUE;

integer datasize = 8 << scale;
Operation
if bits(64) address;
bite(datasize) data;
boolean wb_unknown = FALSE;
boolean rt_unknown = FALSE;

if memop == HaveMTEExt() then
    boolean is_load_store = memop IN {MemOp_STORE, MemOp_LOAD};
    SetNotTagCheckedInstruction(is_load_store && n == 31 && !wback);

bits(64) address;
bite(datasize) data;
boolean wb_unknown = FALSE;
boolean rt_unknown = FALSE;

if memop == MemOp_LOAD && wback && n == t && n != 31 then
    c = ConstrainUnpredictable(Unpredictable_WBOVERLAPLD);
    assert c IN {Constraint_WBSUPPRESS, Constraint_UNKNOWN, Constraint_UNDEF, Constraint_NOP};
    case c of
        when Constraint_WBSUPPRESS wback = FALSE; // writeback is suppressed
        when Constraint_UNKNOWN wb_unknown = TRUE; // writeback is UNKNOWN
        when Constraint_UNDEF
            UnallocatedEncoding();
        when Constraint_NOP EndOfInstruction();
    end;

if memop == MemOp_STORE && wback && n == t && n != 31 then
    c = ConstrainUnpredictable(Unpredictable_WBOVERLAPST);
    assert c IN {Constraint_NONE, Constraint_UNKNOWN, Constraint_UNDEF, Constraint_NOP};
    case c of
        when Constraint_NONE rt_unknown = FALSE; // value stored is original value
        when Constraint_UNKNOWN rt_unknown = TRUE; // value stored is UNKNOWN
        when Constraint_UNDEF
            UnallocatedEncoding();
        when Constraint_NOP EndOfInstruction();
    end;

if n == 31 then
    if memop != MemOp_PREFETCH then CheckSPAlignment();
    address = SP[];
else
    address = X[n];

if ! postindex then
    address = address + offset;

case memop of
    when MemOp_STORE
        if rt_unknown then
            data = bits(datasize) UNKNOWN;
        else
            data = X[t];
            Mem[address, datasize DIV 8, acctype] = data;
        when MemOp_LOAD
            data = Mem[address, datasize DIV 8, acctype];
            if signed then
                X[t] = SignExtend(data, regsize);
            else
                X[t] = ZeroExtend(data, regsize);
            when MemOp_PREFETCHPrefetch(address, t<4:0>);
    if ! wback then
        if wb_unknown then
            address = bits(64) UNKNOWN;
        elsif postindex then
            address = address + offset;
        if n == 31 then
            SP[] = address;
else
  \texttt{X[n] = address;}

\textbf{Operational information}

If \texttt{PSTATE.DIT} is 1, the timing of this instruction is insensitive to the value of the data being loaded or stored.
STLURB

Store-Release Register Byte (unscaled) calculates an address from a base register value and an immediate offset, and stores a byte to the calculated address, from a 32-bit register.

The instruction has memory ordering semantics as described in Load-Acquire, Load-AcquirePC, and Store-Release.

For information about memory accesses, see Load/Store addressing modes.

Unscaled offset

\[
\text{STLURB} <Wt>, [<Xn|SP>{, #<simm>}
\]

boolean wback = FALSE;
boolean postindex = FALSE;
integer scale = UInt(size);
bias(64) offset = SignExtend(imm9, 64);

Assembler Symbols

<Wt> Is the 32-bit name of the general-purpose register to be transferred, encoded in the "Rt" field.
<Xn|SP> Is the 64-bit name of the general-purpose base register or stack pointer, encoded in the "Rn" field.
<simm> Is the optional signed immediate byte offset, in the range -256 to 255, defaulting to 0 and encoded in the "imm9" field.

Shared Decode

integer n = UInt(Rn);
integer t = UInt(Rt);
AccType acctype = AccType_ORDERED;
MemOp memop;
boolean signed;
integer regsize;
if opc<1> == '0' then
  // store or zero-extending load
  memop = if opc<0> == '1' then MemOp_LOAD else MemOp_STORE;
  regsize = if size == '11' then 64 else 32;
  signed = FALSE;
else
  if size == '11' then
    memop = MemOp_PREFETCH;
  if opc<0> == '1' then UNDEFINED;
  else
    // sign-extending load
    memop = if opc<0> == '1' then UnallocatedEncoding();
    if size == '10' && opc<0> == '1' then UNDEFINED;
else
  // sign-extending load
  memop = MemOp_LOAD;
  if size == '10' && opc<0> == '1' then UnallocatedEncoding;
  if size == '10' && opc<0> == '1' then UNDEFINED;
  if opc<0> == '1' then 32 else 64;
  signed = TRUE;
integer datasize = 8 << scale;
if memop == HaveMTEExt() then
    boolean is_load_store = memop IN {MemOp_STORE, MemOp_LOAD};
    SetNotTagCheckedInstruction(is_load_store && n == 31 && !wback);

if memop == MemOp_LOAD && wback && n == t && n != 31 then
    c = ConstrainUnpredictable(Unpredictable_WBOVERLAPLD);
    assert c IN {Constraint_WBSUPPRESS, Constraint_UNKNOWN, Constraint_UNDEF, Constraint_NOP};
    case c of
        when Constraint_WBSUPPRESS wback = FALSE;       // writeback is suppressed
        when Constraint_UNKNOWN wb_unknown = TRUE;       // writeback is UNKNOWN
        when Constraint_UNDEF rt_unknown = FALSE;        // value stored is original value
        when UnallocatedEncoding();
        when Constraint_NOP             EndOfInstruction();

if memop == MemOp_STORE && wback && n == t && n != 31 then
    c = ConstrainUnpredictable(Unpredictable_WBOVERLAPST);
    assert c IN {Constraint_NONE, Constraint_UNKNOWN, Constraint_UNDEF, Constraint_NOP};
    case c of
        when Constraint_NONE           rt_unknown = FALSE;       // value stored is original value
        when Constraint_UNDEF           UNDEFINED;
        when Constraint_NOP             EndOfInstruction();

if n == 31 then
    if memop != MemOp_PREFETCH then CheckSPAlignment();
    address = SP[];
else
    address = X[n];
if ! postindex then
    address = address + offset;

case memop of
    when MemOp_STORE
        if rt_unknown then
            data = bits(datasize) UNKNOWN;
        else
            data = X[t];
            Mem[address, datasize DIV 8, acctype] = data;
    when MemOp_LOAD
        data = Mem[address, datasize DIV 8, acctype];
        if signed then
            X[t] = SignExtend(data, regsize);
        else
            X[t] = ZeroExtend(data, regsize);
        when MemOp_PREFETCHPrefetch(address, t<4:0>);

if wback then
    if wb_unknown then
        address = bits(64) UNKNOWN;
    elif postindex then
        address = address + offset;
    if n == 31 then
        SP[] = address;
else

\( X[n] = \text{address}; \)

**Operational information**

If PSTATE.DIT is 1, the timing of this instruction is insensitive to the value of the data being loaded or stored.
STLURH

Store-Release Register Halfword (unscaled) calculates an address from a base register value and an immediate offset, and stores a halfword to the calculated address, from a 32-bit register.

The instruction has memory ordering semantics as described in Load-Acquire, Load-AcquirePC, and Store-Release.

For information about memory accesses, see Load/Store addressing modes.

### Assembler Symbols

- `<Wt>`: Is the 32-bit name of the general-purpose register to be transferred, encoded in the "Rt" field.
- `<Xn|SP>`: Is the 64-bit name of the general-purpose base register or stack pointer, encoded in the "Rn" field.
- `<simm>`: Is the optional signed immediate byte offset, in the range -256 to 255, defaulting to 0 and encoded in the "imm9" field.

#### Shared Decode

```java
integer n = UInt(Rn);
integer t = UInt(Rt);
AccType acctype = AccType_ORDERED;
MemOp memop;
boolean signed;
integer regsize;
if opc<1> == '0' then
  // store or zero-extending load
  memop = if opc<0> == '1' then MemOp_LOAD else MemOp_STORE;
  regsize = if size == '11' then 64 else 32;
  signed = FALSE;
else
  if size == '11' then
    memop = MemOp_PREFETCH;
  else
    if opc<0> == '1' then UNDEFINED;
    else
      // sign-extending load
      memop = if opc<0> == '1' then UnallocatedEncoding() else
      else
        // sign-extending load
        memop = MemOp_LOAD;
        if size == '10' && opc<0> == '1' then UnallocatedEncoding;
        if size == '10' && opc<0> == '1' then UNDEFINED;
        regsize = if opc<0> == '1' then 32 else 64;
        signed = TRUE;
  end
integer datasize = 8 << scale;
```
if (bits(64) address;
bits(datasize) data;
boolean wb_unknown = FALSE;
boolean rt_unknown = FALSE;

if memop == HaveMTEExt() then
    boolean is_load_store = memop IN {MemOp_STORE, MemOp_LOAD};
    SetNotTagCheckedInstruction(is_load_store && n == 31 && !wback);

bits(64) address;
bits(datasize) data;
boolean wb_unknown = FALSE;
boolean rt_unknown = FALSE;

if memop == MemOp_LOAD && wback && n == t && n != 31 then
    c = ConstrainUnpredictable(Unpredictable_WBOVERLAPLD);
    assert c IN {Constraint_WBSUPPRESS, Constraint_UNKNOWN, Constraint_UNDEF, Constraint_NOP};
    case c of
        when Constraint_WBSUPPRESS wback = FALSE; // writeback is suppressed
        when Constraint_UNKNOWN wb_unknown = TRUE; // writeback is UNKNOWN
        when Constraint_UNDEF rt_unknown = FALSE;  // value stored is original value
        when UnallocatedEncoding();
        when Constraint_NOP EndOfInstruction();

if memop == MemOp_STORE && wback && n == t && n != 31 then
    c = ConstrainUnpredictable(Unpredictable_WBOVERLAPST);
    assert c IN {Constraint_NONE, Constraint_UNKNOWN, Constraint_UNDEF, Constraint_NOP};
    case c of
        when Constraint_NONE rt_unknown = FALSE; // value stored is original value
        when Constraint_UNKNOWN rt_unknown = TRUE; // value stored is UNKNOWN
        when Constraint_UNDEF rt_unknown = FALSE;  // value stored is original value
        when UnallocatedEncoding();
        when Constraint_NOP EndOfInstruction();

if n == 31 then
    if memop != MemOp_PREFETCH then CheckSPAlignment();
    address = SP[];
else
    address = X[n];

if ! postindex then
    address = address + offset;

case memop of
    when MemOp_STORE
        if rt_unknown then
            data = bits(datasize) UNKNOWN;
        else
            data = X[t];
        Mem[address, datasize DIV 8, acctype] = data;
    when MemOp_LOAD
        data = Mem[address, datasize DIV 8, acctype];
        if signed then
            X[t] = SignExtend(data, regsize);
        else
            X[t] = ZeroExtend(data, regsize);
        when MemOp_PREFETCH Prefetch(address, t<4:0>);

if wback then
    if wb_unknown then
        address = bits(64) UNKNOWN;
    elsif postindex then
        address = address + offset;
    if n == 31 then
        SP[] = address;
else

\[ X[n] = \text{address}; \]

**Operational information**

If PSTATE.DIT is 1, the timing of this instruction is insensitive to the value of the data being loaded or stored.
STLXP

Store-Release Exclusive Pair of registers stores two 32-bit words or two 64-bit doublewords to a memory location if the PE has exclusive access to the memory address, from two registers, and returns a status value of 0 if the store was successful, or of 1 if no store was performed. See Synchronization and semaphores. A 32-bit pair requires the address to be doubleword aligned and is single-copy atomic at doubleword granularity. A 64-bit pair requires the address to be quadword aligned and, if the Store-Exclusive succeeds, it causes a single-copy atomic update of the 128-bit memory location being updated. The instruction also has memory ordering semantics as described in Load-Acquire, Store-Release. For information about memory accesses see Load/Store addressing modes.

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<tr>
<th>31</th>
<th>30</th>
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<tbody>
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</tr>
</tbody>
</table>

L  o0

32-bit (sz == 0)

STLXP <Ws>, <Wt1>, <Wt2>, [<Xn|SP>{,#0}]

64-bit (sz == 1)

STLXP <Ws>, <Xt1>, <Xt2>, [<Xn|SP>{,#0}]

integer n = UInt(Rn);
integer t = UInt(Rt);
integer t2 = UInt(Rt2); // ignored by load/store single register
integer s = UInt(Rs);   // ignored by all loads and store-release

AccType acctype = if o0 == '1' then AccType_ORDERED_ATOMIC else AccType_ATOMIC;
boolean pair = TRUE;
MemOp memop = if L == '1' then MemOp_LOAD else MemOp_STORE;
integer elsize = 32 << UInt(sz);
integer datasize = if pair then elsize * 2 else elsize;

For information about the CONSTRAINED UNPREDICTABLE behavior of this instruction, see Architectural Constraints on UNPREDICTABLE behaviors, and particularly STLXP.

Assembler Symbols

<Ws> Is the 32-bit name of the general-purpose register into which the status result of the store exclusive is written, encoded in the "Rs" field. The value returned is:

0  If the operation updates memory.

1  If the operation fails to update memory.

<Xt1> Is the 64-bit name of the first general-purpose register to be transferred, encoded in the "Rt" field.

<Xt2> Is the 64-bit name of the second general-purpose register to be transferred, encoded in the "Rt2" field.

<Wt1> Is the 32-bit name of the first general-purpose register to be transferred, encoded in the "Rt" field.

<Wt2> Is the 32-bit name of the second general-purpose register to be transferred, encoded in the "Rt2" field.

<Xn|SP> Is the 64-bit name of the general-purpose base register or stack pointer, encoded in the "Rn" field.

Aborts and alignment

If a synchronous Data Abort exception is generated by the execution of this instruction:

- Memory is not updated.
- <Ws> is not updated.

Accessing an address that is not aligned to the size of the data being accessed causes an Alignment fault Data Abort exception to be generated, subject to the following rules:

- If AArch64.ExclusiveMonitorsPass() returns TRUE, the exception is generated.
• Otherwise, it is IMPLEMENTATION DEFINED whether the exception is generated.

If AArch64.ExclusiveMonitorsPass() returns FALSE and the memory address, if accessed, would generate a synchronous Data Abort exception, it is IMPLEMENTATION DEFINED whether the exception is generated.
Operation
bits(64) address;
brights(datasize) data;
constant integer dbytes = datasize DIV 8;
boolean rt_unknown = FALSE;
boolean rn_unknown = FALSE;

if memop == HaveMTEExt() then 
    boolean is_load_store = memop IN {MemOp STORE, MemOp LOAD} ;
    SetNotTagCheckedInstruction(is_load_store && n == 31);
if memop == MemOp STORE then
    if s == t || (pair && s == t2) then
        case memop of
            when MemOp STORE if rt_unknown then
                data = bits(datasize) UNKNOWN;
            elsif pair then
                bits(datasize DIV 2) el1 = X[t];
                bits(datasize DIV 2) el2 = X[t2];
                data = if BigEndian() then el1 : el2 else el2 : el1;
            else
                data = X[t];
        bit status = '1';
    // Check whether the Exclusives monitors are set to include the
    // physical memory locations corresponding to virtual address
    // range [address, address+dbytes-1].
    if AArch64.ExclusiveMonitorsPass(address, dbytes) then
        // This atomic write will be rejected if it does not refer
        // to the same physical locations after address translation.
        Mem[address, dbytes, acctype] = data;
        status = ExclusiveMonitorsStatus();
        X[s] = ZeroExtend(status, 32);
    when MemOp LOAD

Tell the Exclusives monitors to record a sequence of one or more atomic memory reads from virtual address range \([\text{address}, \text{address}+\text{dbytes}-1]\). The Exclusives monitor will only be set if all the reads are from the same dbytes-aligned physical address, to allow for the possibility of an atomicity break if the translation is changed between reads.

\[
\text{AArch64.SetExclusiveMonitors(address, dbytes)};
\]

if pair then
    if rt_unknown then
        // ConstrainedUNPREDICTABLE case
        \[ X[t] = \text{bits(datasize)}\text{ UNKNOWN}; \]
    elsif elsize == 32 then
        // 32-bit load exclusive pair (atomic)
        data = \text{Mem}[\text{address, dbytes, acctype}];
        if BigEndian() then
            \[ X[t] = \text{data<datasize-1:elsize>;} \]
            \[ X[t2] = \text{data<elsize-1:0>;} \]
        else
            \[ X[t] = \text{data<elsize-1:0>;} \]
            \[ X[t2] = \text{data<datasize-1:elsize>;} \]
        end
    end // elsize == 64
    // 64-bit load exclusive pair (not atomic), but must be 128-bit aligned
    if address != \text{Align}(\text{address, dbytes}) then
        iswrite = FALSE;
        secondstage = FALSE;
        \text{AArch64.Abort(address, AArch64.AlignmentFault(acctype, iswrite, secondstage))};
        \[ X[t] = \text{Mem}[\text{address} + 0, 8, \text{acctype}]; \]
        \[ X[t2] = \text{Mem}[\text{address} + 8, 8, \text{acctype}]; \]
    else
        data = \text{Mem}[\text{address, dbytes, acctype}];
        \[ X[t] = \text{ZeroExtend(data, regsize)}; \]
    end

**Operational information**

If PSTATE.DIT is 1, the timing of this instruction is insensitive to the value of the data being loaded or stored.
**STLXR**

Store-Release Exclusive Register stores a 32-bit word or a 64-bit doubleword to memory if the PE has exclusive access to the memory address, from two registers, and returns a status value of 0 if the store was successful, or of 1 if no store was performed. See *Synchronization and semaphores*. The memory access is atomic. The instruction also has memory ordering semantics as described in *Load-Acquire, Store-Release*. For information about memory accesses see *Load/Store addressing modes*.

<table>
<thead>
<tr>
<th>size</th>
<th>L</th>
<th>o0</th>
<th>Rt2</th>
</tr>
</thead>
<tbody>
<tr>
<td>32-bit (size == 10)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>STLXR &lt;Ws&gt;, &lt;Wt&gt;, [&lt;Xn</td>
<td>SP&gt;]{,#0}</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>size</th>
<th>L</th>
<th>o0</th>
<th>Rt2</th>
</tr>
</thead>
<tbody>
<tr>
<td>64-bit (size == 11)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>STLXR &lt;Ws&gt;, &lt;Xt&gt;, [&lt;Xn</td>
<td>SP&gt;]{,#0}</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

```plaintext
integer n = Uint(Rn);
integer t = Uint(Rt);
integer t2 = Uint(Rt2); // ignored by load/store single register
integer s = Uint(Rs);   // ignored by all loads and store-release

AccType acctype = if o0 == '1' then AccType_ORDEREDATOMIC else AccType_ATOMIC;
boolean pair = FALSE;
MemOp memop = if L == '1' then MemOp_LOAD else MemOp_STORE;
integer elsize = 8 << Uint(size);
integer regsize = if elsize == 64 then 64 else 32;
integer datasize = if pair then elsize * 2 else elsize;
```

For information about the CONSTRAINED UNPREDICTABLE behavior of this instruction, see *Architectural Constraints on UNPREDICTABLE behaviors*, and particularly *STLXR*.

### Assembler Symbols

- **&lt;Ws&gt;** Is the 32-bit name of the general-purpose register into which the status result of the store exclusive is written, encoded in the "Rs" field. The value returned is:
  - 0 If the operation updates memory.
  - 1 If the operation fails to update memory.

- **&lt;Xt&gt;** Is the 64-bit name of the general-purpose register to be transferred, encoded in the "Rt" field.

- **&lt;Wt&gt;** Is the 32-bit name of the general-purpose register to be transferred, encoded in the "Rt" field.

- **&lt;Xn|SP&gt;** Is the 64-bit name of the general-purpose base register or stack pointer, encoded in the "Rt" field.

### Aborts and alignment

If a synchronous Data Abort exception is generated by the execution of this instruction:
- Memory is not updated.
- &lt;Ws&gt; is not updated.

Accessing an address that is not aligned to the size of the data being accessed causes an Alignment fault Data Abort exception to be generated, subject to the following rules:
- If AArch64.ExclusiveMonitorsPass() returns TRUE, the exception is generated.
- Otherwise, it is IMPLEMENTATION DEFINED whether the exception is generated.

If AArch64.ExclusiveMonitorsPass() returns FALSE and the memory address, if accessed, would generate a synchronous Data Abort exception, it is IMPLEMENTATION DEFINED whether the exception is generated.
bits(64) address;
bits(datasize) data;
constant integer dbytes = datasize DIV 8;
boolean rt_unknown = FALSE;
boolean rn_unknown = FALSE;

if memop == MemOp_Load then
  SetNotTagCheckedInstruction(is_load_store && n == 31);

if memop == MemOp_LOAD && pair && t == t2 then
  Constraint c = ConstrainUnpredictable(Unpredictable_LDPOVERLAP);
  assert c IN {Constraint_UNKNOWN, Constraint_UNDEF, Constraint_NOP};
  case c of
    when Constraint_UNKNOWN rt_unknown = TRUE; // result is UNKNOWN
    when Constraint_UNDEF rt := Undefined;
    when Constraint_NOP EndOfInstruction();

if memop == MemOp_STORE then
  if s == t || (pair && s == t2) then
    Constraint c = ConstrainUnpredictable(Unpredictable_DATAOVERLAP);
    assert c IN {Constraint_UNKNOWN, Constraint_NONE, Constraint_UNDEF, Constraint_NOP};
    case c of
      when Constraint_UNKNOWN rt_unknown = TRUE; // store UNKNOWN value
      when Constraint_NONE rt_unknown = FALSE; // store original value
      when Constraint_UNDEF EndOfInstruction();
  if s == n && n != 31 then
    Constraint c = ConstrainUnpredictable(Unpredictable_BASEOVERLAP);
    assert c IN {Constraint_UNKNOWN, Constraint_NONE, Constraint_UNDEF, Constraint_NOP};
    case c of
      when Constraint_UNKNOWN rn_unknown = TRUE; // address is UNKNOWN
      when Constraint_NONE rn_unknown = FALSE; // address is original base
      when Constraint_UNDEF unallocatedencoding() Undefined;
      when Constraint_NOP EndOfInstruction();

if n == 31 then
  CheckSPAlignment();
  address = X[n];
elsif rn_unknown then
  address = bits(64) UNKNOWN;
else
  address = X[n];

end case memop of
when MemOp_STORE
  if rt_unknown then
    data = bits(datasize) UNKNOWN;
  elsif pair then
    bits(datasize DIV 2) el1 = X[t];
    bits(datasize DIV 2) el2 = X[t2];
    data = if BigEndian() then el1 : el2 else el2 : el1;
  else
    data = X[t];
    bit status = '1';
    // Check whether the Exclusives monitors are set to include the
    // physical memory locations corresponding to virtual address
    // range [address, address+dbytes-1].
    if AArch64.ExclusiveMonitorsPass(address, dbytes) then
      // This atomic write will be rejected if it does not refer
      // to the same physical locations after address translation.
      Mem[address, dbytes, acctype] = data;
      status = ExclusiveMonitorsStatus();
      X[s] = ZeroExtend(status, 32);
  when MemOp_LOAD

}
// Tell the Exclusives monitors to record a sequence of one or more atomic
// memory reads from virtual address range [address, address+dbytes-1].
// The Exclusives monitor will only be set if all the reads are from the
// same dbytes-aligned physical address, to allow for the possibility of
// an atomicity break if the translation is changed between reads.
AArch64.SetExclusiveMonitors(address, dbytes);

if pair then
  if rt_unknown then
    // ConstrainedUNPREDICTABLE case
    X[t] = bits(datasize) UNKNOWN;
  elsif elsize == 32 then
    // 32-bit load exclusive pair (atomic)
    data = Mem[address, dbytes, acctype];
    if BigEndian() then
      X[t] = data<datasize-1:elsize>;
      X[t2] = data<elsize-1:0>;
    else
      X[t] = data<elsize-1:0>;
      X[t2] = data<datasize-1:elsize>;
    endelsize == 64
    // 64-bit load exclusive pair (not atomic),
    // but must be 128-bit aligned
    if address != Align(address, dbytes) then
      iswrite = FALSE;
      secondstage = FALSE;
      AArch64.Abort(address, AArch64.AlignmentFault(acctype, iswrite, secondstage));
    end
    X[t] = Mem[address + 0, 8, acctype];
    X[t2] = Mem[address + 8, 8, acctype];
  else // elsize == 64
    data = Mem[address, dbytes, acctype];
    X[t] = ZeroExtend(data, regsize);
  end

Operational information

If PSTATE.DIT is 1, the timing of this instruction is insensitive to the value of the data being loaded or stored.
STLXRB

Store-Release Exclusive Register Byte stores a byte from a 32-bit register to memory if the PE has exclusive access to the memory address, and returns a status value of 0 if the store was successful, or of 1 if no store was performed. See Synchronization and semaphores. The memory access is atomic. The instruction also has memory ordering semantics as described in Load-Acquire, Store-Release. For information about memory accesses see Load/Store addressing modes.

```
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</tbody>
</table>
```

No offset

STLXRB <Ws>, <Wt>, [<Xn|SP>],[#0]

```
integer n = UInt(Rn);
integer t = UInt(Rt);
integer t2 = UInt(Rt2); // ignored by load/store single register
integer s = UInt(Rs);  // ignored by all loads and store-release

AccType accctype = if o0 == '1' then AccType_ORDEREDATOMIC else AccType_ATOMIC;
boolean pair = FALSE;
MemOp memop = if L == '1' then MemOp_LOAD else MemOp_STORE;
integer elsize = 8 << UInt(size);
integer datasize = if pair then elsize * 2 else elsize;
```

For information about the constrained UNPREDICTABLE behavior of this instruction, see Architectural Constraints on UNPREDICTABLE behaviors, and particularly STLXRB.

Assembler Symbols

- `<Ws>`: Is the 32-bit name of the general-purpose register into which the status result of the store exclusive is written, encoded in the "Rs" field. The value returned is:
  - 0: If the operation updates memory.
  - 1: If the operation fails to update memory.

- `<Wt>`: Is the 32-bit name of the general-purpose register to be transferred, encoded in the "Rt" field.

- `<Xn|SP>`: Is the 64-bit name of the general-purpose base register or stack pointer, encoded in the "Rn" field.

Aborts

If a synchronous Data Abort exception is generated by the execution of this instruction:
- Memory is not updated.
- `<Ws>` is not updated.

If AArch64.ExclusiveMonitorsPass() returns FALSE and the memory address, if accessed, would generate a synchronous Data Abort exception, it is IMPLEMENTATION DEFINED whether the exception is generated.
bits(64) address;
bio(bits) data;
constant integer dbytes = datasize DIV 8;
boolean rt_unknown = FALSE;
boolean rn_unknown = FALSE;

if memop == HaveMTEExt() then
    boolean is_load_store = memop IN {MemOp STORE, MemOp LOAD};
    SetNotTagCheckedInstruction(is_load_store && n == 31);

if memop == MemOp LOAD && pair && t == t2 then
    Constraint c = ConstrainUnpredictable(Unpredictable_LDPOVERLAP);
    assert c IN {Constraint_UNKNOWN, Constraint_UNDEF, Constraint_NOP};
    case c of
        when Constraint_UNKNOWN rt_unknown = TRUE; // result is UNKNOWN
        when Constraint_UNDEF UNDEFINED;
        when Constraint_NOP EndOfInstruction();

if memop == MemOp STORE then
    if s == t || (pair && s == t2) then
        Constraint c = ConstrainUnpredictable(Unpredictable_DATAOVERLAP);
        assert c IN {Constraint_UNKNOWN, Constraint_NONE, Constraint_UNDEF, Constraint_NOP};
        case c of
            when Constraint_UNKNOWN rt_unknown = TRUE; // store UNKNOWN value
            when Constraint_NONE rt_unknown = FALSE; // store original value
            when Constraint_UNDEF UNDEFINED;
            when Constraint_NOP EndOfInstruction();
    if s == n && n != 31 then
        Constraint c = ConstrainUnpredictable(Unpredictable_BASEOVERLAP);
        assert c IN {Constraint_UNKNOWN, Constraint_NONE, Constraint_UNDEF, Constraint_NOP};
        case c of
            when Constraint_UNKNOWN rn_unknown = TRUE; // address is UNKNOWN
            when Constraint_NONE rn_unknown = FALSE; // address is original base
            when Constraint_UNDEF unallocatedencoding UNDEFINED;
            when Constraint_NOP EndOfInstruction();

if n == 31 then
    CheckSAPalignment();
    address = SP[];
elsif rn_unknown then
    address = bits(64) UNKNOWN;
else
    address = X[n];

case memop of
    when MemOp STORE
        if rt_unknown then
            data = bits(datasize) UNKNOWN;
        elsif pair then
            bits(datasize DIV 2) el1 = X[t];
bites(datasize DIV 2) el2 = X[t2];
data = if BigEndian() then el1 : el2 else el2 : el1;
        else
            data = X[t];
        end
    else
        bit status = '1';
        // Check whether the Exclusives monitors are set to include the
        // physical memory locations corresponding to virtual address
        // range [address, address+dbytes-1].
        if AArch64.ExclusiveMonitorsPass(address, dbytes) then
            // This atomic write will be rejected if it does not refer
            // to the same physical locations after address translation.
            Mem[address, dbytes, acctype] = data;
            status = ExclusiveMonitorsStatus();
            X[s] = ZeroExtend(status, 32);
        end
    end
    when MemOp LOAD
Tell the Exclusives monitors to record a sequence of one or more atomic memory reads from virtual address range [address, address+dbytes-1]. The Exclusives monitor will only be set if all the reads are from the same dbytes-aligned physical address, to allow for the possibility of an atomicity break if the translation is changed between reads.

`AArch64.SetExclusiveMonitors(address, dbytes);`

if pair then
  if rt_unknown then
    // ConstrainedUNPREDICTABLE case
    `X[t] = bits(datasize) UNKNOWN;`
  elsif elsize == 32 then
    // 32-bit load exclusive pair (atomic)
    data = `Mem[address, dbytes, acctype];`
    if BigEndian() then
      `X[t] = data<datasize-1:elsize>;`
      `X[t2] = data<elsize-1:0>;`
    else
      `X[t] = data<elsize-1:0>;`
      `X[t2] = data<datasize-1:elsize>;`
  else // elsize == 64
    // 64-bit load exclusive pair (not atomic), but must be 128-bit aligned
    if address != Align(address, dbytes) then
      iswrite = FALSE;
      secondstage = FALSE;
      `AArch64.Abort(address, AArch64.AlignmentFault(acctype, iswrite, secondstage));`
    else
      data = `Mem[address + 0, 8, acctype];`
      `X[t] = Mem[address + 8, 8, acctype];`
      `X[t2] = Mem[address + 0, 8, acctype];`
    end
  end

Operational information

If PSTATE.DIT is 1, the timing of this instruction is insensitive to the value of the data being loaded or stored.
STLXRH

Store-Release Exclusive Register Halfword stores a halfword from a 32-bit register to memory if the PE has exclusive access to the memory address, and returns a status value of 0 if the store was successful, or of 1 if no store was performed. See Synchronization and semaphores. The memory access is atomic. The instruction also has memory ordering semantics as described in Load-Acquire, Store-Release. For information about memory accesses see Load/Store addressing modes.

31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
| 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | Rs | 1 | (1) | (1) | (1) | (1) | Rn | Rt |
| size | L | o0 | Rt2 |

No offset

STLXRH <Ws>, <Wt>, [<Xn|SP>{,#0}]

integer n = UInt(Rn);
integer t = UInt(Rt);
ninteger t2 = UInt(Rt2); // ignored by load/store single register
integer s = UInt(Rs);   // ignored by all loads and store-release

AccType acctype = if o0 == '1' then AccType.ORDERED_ATOMIC else AccType_ATOMIC;
boolean pair = FALSE;
MemOp memop = if L == '1' then MemOp_LOAD else MemOp_STORE;
integer elsize = 8 << UInt(size);
integer datasize = if pair then elsize * 2 else elsize;

For information about the CONSTRUANIED UNPREDICTABLE behavior of this instruction, see Architectural Constraints on UNPREDICTABLE behaviors, and particularly STLXRH.

Assembler Symbols

<Ws> Is the 32-bit name of the general-purpose register into which the status result of the store exclusive is written, encoded in the "Rs" field. The value returned is:

0 If the operation updates memory.

1 If the operation fails to update memory.

<Wt> Is the 32-bit name of the general-purpose register to be transferred, encoded in the "Rt" field.

<Xn|SP> Is the 64-bit name of the general-purpose base register or stack pointer, encoded in the "Rn" field.

Aborts and alignment

If a synchronous Data Abort exception is generated by the execution of this instruction:

• Memory is not updated.
• <Ws> is not updated.

A non halfword-aligned memory address causes an Alignment fault Data Abort exception to be generated, subject to the following rules:

• If AArch64.ExclusiveMonitorsPass() returns TRUE, the exception is generated.
• Otherwise, it is IMPLEMENTATION DEFINED whether the exception is generated.

If AArch64.ExclusiveMonitorsPass() returns FALSE and the memory address, if accessed, would generate a synchronous Data Abort exception, it is IMPLEMENTATION DEFINED whether the exception is generated.
bits(64) address;
bits(datasize) data;
constant integer dbytes = datasize DIV 8;
boolean rt_unknown = FALSE;
boolean rn_unknown = FALSE;

if memop == HaveMTEExt() then
    boolean is_load_store = memop IN {MemOp STORE, MemOp LOAD};
    SetNotTagCheckedInstruction(is_load_store && n == 31);
if memop == MemOp LOAD && pair && t == t2 then
    Constraint c = ConstrainUnpredictable(Unpredictable_LDPOVERLAP);
    assert c IN {Constraint_UNKNOWN, Constraint_UNDEF, Constraint_NOP};
    case c of
        when Constraint_UNKNOWN rt_unknown = TRUE; // result is UNKNOWN
        when Constraint_UNDEF UNDEFINED;
        when Constraint_NOP EndOfInstruction();
if memop == MemOp STORE then
    if s == t || (pair && s == t2) then
        Constraint c = ConstrainUnpredictable(Unpredictable_DATAOVERLAP);
        assert c IN {Constraint_UNKNOWN, Constraint_NONE, Constraint_UNDEF, Constraint_NOP};
        case c of
            when Constraint_UNKNOWN rt_unknown = TRUE; // store UNKNOWN value
            when Constraint_NONE rt_unknown = FALSE; // store original value
            when Constraint_UNDEF UNDEFINED;
            when Constraint_NOP EndOfInstruction();
if s == n && n != 31 then
    Constraint c = ConstrainUnpredictable(Unpredictable_BASEOVERLAP);
    assert c IN {Constraint_UNKNOWN, Constraint_NONE, Constraint_UNDEF, Constraint_NOP};
    case c of
        when Constraint_UNKNOWN rn_unknown = TRUE; // address is UNKNOWN
        when Constraint_NONE rn_unknown = FALSE; // address is original base
        when Constraint_UNDEF unallocatedencoding UNDEFINED;
        when Constraint_NOP EndOfInstruction();
if n == 31 then
    CheckSPAlignment();
    address = SP[];
elsif rn_unknown then
    address = bits(64) UNKNOWN;
else
    address = X[n];

case memop of
    when MemOp STORE
        if rt_unknown then
            data = bits(datasize) UNKNOWN;
        elsif pair then
            bits(datasize DIV 2) el1 = X[t];
            bits(datasize DIV 2) el2 = X[t2];
            data = if BigEndian() then el1 : el2 else el2 : el1;
        else
            data = X[t];
        endif
        bit status = '1';
        // Check whether the Exclusives monitors are set to include the
        // physical memory locations corresponding to virtual address
        // range [address, address+dbytes-1].
        if AArch64.ExclusiveMonitorsPass(address, dbytes) then
            // This atomic write will be rejected if it does not refer
            // to the same physical locations after address translation.
            Mem[address, dbytes, acctype] = data;
            status = ExclusiveMonitorsStatus();
            X[s] = ZeroExtend(status, 32);
        endif
    when MemOp LOAD
// Tell the Exclusives monitors to record a sequence of one or more atomic
// memory reads from virtual address range [address, address+dbytes-1].
// The Exclusives monitor will only be set if all the reads are from the
// same dbytes-aligned physical address, to allow for the possibility of
// an atomicity break if the translation is changed between reads.
AArch64.SetExclusiveMonitors(address, dbytes);

if pair then
  if rt_unknown then
    // ConstrainedUNPREDICTABLE case
    X[t] = bits(datasize) UNKNOWN;
  elsif elsize == 32 then
    // 32-bit load exclusive pair (atomic)
    data = Mem[address, dbytes, acctype];
    if BigEndian() then
      X[t] = data<datasize-1:elsingze>;
      X[t2] = data<elsingze-1:0>;
    else
      X[t] = data<elsingze-1:0>;
      X[t2] = data<elsingze-1:elsingze>;
  else // elsize == 64
    // 64-bit load exclusive pair (not atomic),
    // but must be 128-bit aligned
    if address != Align(address, dbytes) then
      iswrite = FALSE;
      secondstage = FALSE;
      AArch64.Abort(address, AArch64.AlignmentFault(acctype, iswrite, secondstage));
      X[t] = Mem[address + 0, 8, acctype];
      X[t2] = Mem[address + 8, 8, acctype];
    else
      data = Mem[address, dbytes, acctype];
      X[t] = ZeroExtend(data, regsize);
  end

Operational information

If PSTATE.DIT is 1, the timing of this instruction is insensitive to the value of the data being loaded or stored.
STNP (SIMD&FP)

Store Pair of SIMD&FP registers, with Non-temporal hint. This instruction stores a pair of SIMD&FP registers to memory, issuing a hint to the memory system that the access is non-temporal. The address used for the store is calculated from an address from a base register value and an immediate offset. For information about non-temporal pair instructions, see Load/Store SIMD and Floating-point Non-temporal pair.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

<table>
<thead>
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<th>imm7</th>
<th>Rt2</th>
<th>Rn</th>
<th>Rt</th>
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</tbody>
</table>

32-bit (opc == 00)

STNP <St1>, <St2>, [{Xn|SP}{, #imm}]

64-bit (opc == 01)

STNP <Dt1>, <Dt2>, [{Xn|SP}{, #imm}]

128-bit (opc == 10)

STNP <Qt1>, <Qt2>, [{Xn|SP}{, #imm}]

boolean wback = FALSE;
boolean postindex = FALSE;

Assembler Symbols

<Dt1> Is the 64-bit name of the first SIMD&FP register to be transferred, encoded in the "Rt" field.

<Dt2> Is the 64-bit name of the second SIMD&FP register to be transferred, encoded in the "Rt2" field.

<Qt1> Is the 128-bit name of the first SIMD&FP register to be transferred, encoded in the "Rt" field.

<Qt2> Is the 128-bit name of the second SIMD&FP register to be transferred, encoded in the "Rt2" field.

<St1> Is the 32-bit name of the first SIMD&FP register to be transferred, encoded in the "Rt" field.

<St2> Is the 32-bit name of the second SIMD&FP register to be transferred, encoded in the "Rt2" field.

<Xn|SP> Is the 64-bit name of the general-purpose base register or stack pointer, encoded in the "Rn" field.

<imm> For the 32-bit variant: is the optional signed immediate byte offset, a multiple of 4 in the range -256 to 252, defaulting to 0 and encoded in the "imm7" field as <imm>/4.

For the 64-bit variant: is the optional signed immediate byte offset, a multiple of 8 in the range -512 to 504, defaulting to 0 and encoded in the "imm7" field as <imm>/8.

For the 128-bit variant: is the optional signed immediate byte offset, a multiple of 16 in the range -1024 to 1008, defaulting to 0 and encoded in the "imm7" field as <imm>/16.

Shared Decode

```plaintext
integer n = UInt(Rn);
integer t = UInt(Rt);
integer t2 = UInt(Rt2);
AccType acctype = AccType_VECSTREAM;
MemOp memop = if L == '1' then MemOp_LOAD else MemOp_STORE;
if opc == '11' then UNDEFINED;
integer scale = 2 + UInt(opc);
integer datasize = 8 << scale;
bits(64) offset = LSL(SignExtend(imm7, 64), scale);
```
Operation

CheckFPAdvSIMDEnabled64();

bits(64) address;
bits(datasize) data1;
bits(datasize) data2;
constant integer dbytes = datasize DIV 8;
boolean rt_unknown = FALSE;

if memop == HaveMTEExt() then
    if memop == MemOp_STORE && memop == MemOp_LOAD then
        SetNotTagCheckedInstruction(is_load_store && n == 31 && !wback);

if memop == MemOp_LOAD && t == t2 then
    Constraint c = ConstrainUnpredictable(Unpredictable_LDPOVERLAP);
    assert c IN {Constraint_UNKNOWN, Constraint_UNDEF, Constraint_NOP};
    case c of
        when Constraint_UNKNOWN then rt_unknown = TRUE; // result is UNKNOWN
        when Constraint_UNDEF then UnallocatedEncoding = UNDEFINED;
        when Constraint_NOP then EndOfInstruction();

if n == 31 then
    CheckSPAlignment();
else
    address = X[n];
if ! postindex then
    address = address + offset;

case memop of
    when MemOp_STORE
        data1 = V[t];
        data2 = V[t2];
        Mem[address + 0, dbytes, acctype] = data1;
        Mem[address + dbytes, dbytes, acctype] = data2;
    when MemOp_LOAD
        data1 = Mem[address + 0, dbytes, acctype];
        data2 = Mem[address + dbytes, dbytes, acctype];
        if rt_unknown then
            data1 = bits(datasize) UNKNOWN;
            data2 = bits(datasize) UNKNOWN;
            V[t] = data1;
            V[t2] = data2;
        if wback then
            if postindex then
                address = address + offset;
            if n == 31 then
                SP[] = address;
            else
                X[n] = address;

Operational information

If PSTATE.DIT is 1, the timing of this instruction is insensitive to the value of the data being loaded or stored.
STNP

Store Pair of Registers, with non-temporal hint, calculates an address from a base register value and an immediate offset, and stores two 32-bit words or two 64-bit doublewords to the calculated address, from two registers. For information about memory accesses, see Load/Store addressing modes. For information about Non-temporal pair instructions, see Load/Store Non-temporal pair.

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9  | 8  | 7  | 6  | 5  | 4  | 3  | 2  | 1  | 0  |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| x  | 0  | 1  | 0  | 1  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | imm7 | Rt2 | Rn  | Rt  |
| opc| L  |

32-bit (opc == 00)

STNP <Wt1>, <Wt2>, [<Xn|SP>{, #<imm>}]

64-bit (opc == 10)

STNP <Xt1>, <Xt2>, [<Xn|SP>{, #<imm>}]

boolean wback = FALSE;
boolean postindex = FALSE;

Assembler Symbols

<Wt1> Is the 32-bit name of the first general-purpose register to be transferred, encoded in the "Rt" field.
<Wt2> Is the 32-bit name of the second general-purpose register to be transferred, encoded in the "Rt2" field.
<Xt1> Is the 64-bit name of the first general-purpose register to be transferred, encoded in the "Rt" field.
<Xt2> Is the 64-bit name of the second general-purpose register to be transferred, encoded in the "Rt2" field.
<Xn|SP> Is the 64-bit name of the general-purpose base register or stack pointer, encoded in the "Rn" field.
<imm> For the 32-bit variant: is the optional signed immediate byte offset, a multiple of 4 in the range -256 to 252, defaulting to 0 and encoded in the "imm7" field as <imm>/4.
For the 64-bit variant: is the optional signed immediate byte offset, a multiple of 8 in the range -512 to 504, defaulting to 0 and encoded in the "imm7" field as <imm>/8.

Shared Decode

```plaintext
integer n = UInt(Rn);
integer t = UInt(Rt);
integer t2 = UInt(Rt2);
AccType acctype = AccType_STREAM;
MemOp memop = if L == '1' then MemOp_LOAD else MemOp_STORE;
if opc<0> == '1' then UNDEFINED;
integer scale = 2 + if opc<0> == '1' then UnallocatedEncoding();
integer datasize = 8 << scale;
bits(64) offset = LSL(SignExtend(imm7, 64), scale);
```
Operation

bits(64) address;
bits(datasize) data1;
bits(datasize) data2;
constant integer dbytes = datasize DIV 8;
boolean rt_unknown = FALSE;

if memop == HaveMTEExt() then
  boolean is_load_store = memop IN {MemOp_STORE, MemOp_LOAD};
  SetNotTagCheckedInstruction(is_load_store && n == 31 && !wback);

if memop == MemOp_LOAD && t == t2 then
  Constraint c = ConstrainUnpredictable(Unpredictable_LDPOVERLAP);
  assert c IN {Constraint_UNKNOWN, Constraint_UNDEF, Constraint_NOP};
  case c of
    when Constraint_UNKNOWN rt_unknown = TRUE; // result is UNKNOWN
    when Constraint_UNDEF UnallocatedEncoding UNDEFINED;
  end;
    when Constraint_NOP EndOfInstruction();

if n == 31 then
  CheckSPAlignment();
  address = SP[];
else
  address = X[n];

if ! postindex then
  address = address + offset;

case memop of
  when MemOp_STORE
    if rt_unknown && t == n then
      data1 = bits(datasize) UNKNOWN;
    else
      data1 = X[t];
    if rt_unknown && t2 == n then
      data2 = bits(datasize) UNKNOWN;
    else
      data2 = X[t2];
    Mem[address + 0 , dbytes, acctype] = data1;
    Mem[address + dbytes, dbytes, acctype] = data2;
  when MemOp_LOAD
    data1 = Mem[address + 0 , dbytes, acctype];
    data2 = Mem[address + dbytes, dbytes, acctype];
    if rt_unknown then
      data1 = bits(datasize) UNKNOWN;
    data2 = bits(datasize) UNKNOWN;
    X[t] = data1;
    X[t2] = data2;

if wback then
  if postindex then
    address = address + offset;
  if n == 31 then
    SP[] = address;
else
    X[n] = address;

Operational information

If PSTATE.DIT is 1, the timing of this instruction is insensitive to the value of the data being loaded or stored.
**STP (SIMD&FP)**

Store Pair of SIMD&FP registers. This instruction stores a pair of SIMD&FP registers to memory. The address used for the store is calculated from a base register value and an immediate offset.

Depending on the settings in the `CPACR_EL1`, `CPTR_EL2`, and `CPTR_EL3` registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

It has encodings from 3 classes: Post-index, Pre-index and Signed offset

### Post-index

| opc  | 31  | 30  | 29  | 28  | 27  | 26  | 25  | 24  | 23  | 22  | 21  | 20  | 19  | 18  | 17  | 16  | 15  | 14  | 13  | 12  | 11  | 10  | 9   | 8   | 7   | 6   | 5   | 4   | 3   | 2   | 1   | 0   | L   |
|------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| imm7| Rt2 | Rn  | Rt  |

32-bit (opc == 00)

```
STP <St1>, <St2>, [<Xn|SP>], #<imm>
```

64-bit (opc == 01)

```
STP <Dt1>, <Dt2>, [<Xn|SP>], #<imm>
```

128-bit (opc == 10)

```
STP <Qt1>, <Qt2>, [<Xn|SP>], #<imm>
```

```java
boolean wback = TRUE;
boolean postindex = TRUE;
```

### Pre-index

| opc  | 31  | 30  | 29  | 28  | 27  | 26  | 25  | 24  | 23  | 22  | 21  | 20  | 19  | 18  | 17  | 16  | 15  | 14  | 13  | 12  | 11  | 10  | 9   | 8   | 7   | 6   | 5   | 4   | 3   | 2   | 1   | 0   | L   |
|------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| imm7| Rt2 | Rn  | Rt  |

32-bit (opc == 00)

```
STP <St1>, <St2>, [<Xn|SP>], #<imm>!
```

64-bit (opc == 01)

```
STP <Dt1>, <Dt2>, [<Xn|SP>], #<imm>!
```

128-bit (opc == 10)

```
STP <Qt1>, <Qt2>, [<Xn|SP>], #<imm>!
```

```java
boolean wback = TRUE;
boolean postindex = FALSE;
```

### Signed offset

| opc  | 31  | 30  | 29  | 28  | 27  | 26  | 25  | 24  | 23  | 22  | 21  | 20  | 19  | 18  | 17  | 16  | 15  | 14  | 13  | 12  | 11  | 10  | 9   | 8   | 7   | 6   | 5   | 4   | 3   | 2   | 1   | 0   | L   |
|------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| imm7| Rt2 | Rn  | Rt  |

It has encodings from 3 classes: Post-index, Pre-index and Signed offset.
32-bit (opc == 00)

`STP <St1>, <St2>, [<Xn|SP>{, #<imm>}]`

64-bit (opc == 01)

`STP <Dt1>, <Dt2>, [<Xn|SP>{, #<imm>}]`

128-bit (opc == 10)

`STP <Qt1>, <Qt2>, [<Xn|SP>{, #<imm>}]`

boolean wback = FALSE;
boolean postindex = FALSE;

**Assembler Symbols**

- `<Dt1>`: Is the 64-bit name of the first SIMD&FP register to be transferred, encoded in the "Rt" field.
- `<Dt2>`: Is the 64-bit name of the second SIMD&FP register to be transferred, encoded in the "Rt2" field.
- `<Qt1>`: Is the 128-bit name of the first SIMD&FP register to be transferred, encoded in the "Rt" field.
- `<Qt2>`: Is the 128-bit name of the second SIMD&FP register to be transferred, encoded in the "Rt2" field.
- `<St1>`: Is the 32-bit name of the first SIMD&FP register to be transferred, encoded in the "Rt" field.
- `<St2>`: Is the 32-bit name of the second SIMD&FP register to be transferred, encoded in the "Rt2" field.
- `<Xn|SP>`: Is the 64-bit name of the general-purpose base register or stack pointer, encoded in the "Rn" field.
- `<imm>`: For the 32-bit post-index and 32-bit pre-index variant: is the signed immediate byte offset, a multiple of 4 in the range -256 to 252, encoded in the "imm7" field as <imm>/4.
  
  For the 32-bit signed offset variant: is the optional signed immediate byte offset, a multiple of 4 in the range -256 to 252, defaulting to 0 and encoded in the "imm7" field as <imm>/4.

  For the 64-bit post-index and 64-bit pre-index variant: is the signed immediate byte offset, a multiple of 8 in the range -512 to 504, encoded in the "imm7" field as <imm>/8.

  For the 64-bit signed offset variant: is the optional signed immediate byte offset, a multiple of 8 in the range -512 to 504, defaulting to 0 and encoded in the "imm7" field as <imm>/8.

  For the 128-bit post-index and 128-bit pre-index variant: is the signed immediate byte offset, a multiple of 16 in the range -1024 to 1008, encoded in the "imm7" field as <imm>/16.

  For the 128-bit signed offset variant: is the optional signed immediate byte offset, a multiple of 16 in the range -1024 to 1008, defaulting to 0 and encoded in the "imm7" field as <imm>/16.

**Shared Decode**

```plaintext
integer n = UInt(Rn);
integer t = UInt(Rt);
integer t2 = UInt(Rt2);
AccType acctype = AccType_VEC;
MemOp memop = if L == '1' then MemOp_LOAD else MemOp_STORE;
if opc == '11' then UNDEFINED;
integer scale = 2 + if opc == '11' then UnallocatedEncoding() else UInt(opc);
integer datasize = 8 << scale;
bits(64) offset = LSL(SignExtend(imm7, 64), scale);
```
Operation

```c
CheckFPAdvSIMDEnabled64();

bits(64) address;
bias(datasize) data1;
bias(datasize) data2;
constant integer dbytes = datasize DIV 8;
boolean rt_unknown = FALSE;

if memop == HaveMTEExt() then
    boolean is_load_store = memop IN {MemOp STORE, MemOp LOAD};
    SetNotTagCheckedInstruction(is_load_store && n == 31 && !wback);

if memop == MemOp STORE && t == t2 then
    Constraint c = ConstrainUnpredictable(Unpredictable_LDPOVERLAP);
    assert c IN {Constraint_UNKNOWN, Constraint_UNDEF, Constraint_NOP};
    case c of
        when Constraint_UNKNOWN rt_unknown = TRUE; // result is UNKNOWN
        when Constraint_UNDEF UnallocatedEncoding UNDEFINED;
        end;
        when Constraint_NOP EndOfInstruction();

if n == 31 then
    CheckSPAlignment();
else
    address = X[n];
if ! postindex then
    address = address + offset;
end;

case memop of
    when MemOp STORE
        data1 = V[t];
        data2 = V[t2];
        Mem[address + 0 , dbytes, acctype] = data1;
        Mem[address + dbytes, dbytes, acctype] = data2;
    when MemOp LOAD
        data1 = Mem[address + 0 , dbytes, acctype];
        data2 = Mem[address + dbytes, dbytes, acctype];
        if rt_unknown then
            data1 = bits(datasize) UNKNOWN;
            data2 = bits(datasize) UNKNOWN;
            V[t] = data1;
            V[t2] = data2;
        end;
        if wback then
            if postindex then
                address = address + offset;
            if n == 31 then
                SP[] = address;
            else
                X[n] = address;
        end;
```
STP

Store Pair of Registers calculates an address from a base register value and an immediate offset, and stores two 32-bit words or two 64-bit doublewords to the calculated address, from two registers. For information about memory accesses, see *Load/Store addressing modes*. It has encodings from 3 classes: Post-index, Pre-index and Signed offset.

### Post-index

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| x  | 0  | 1  | 0  | 1  | 0  | 0  | 1  | 0  | imm7 | Rt2 | Rn | Rt |
| opc| L  |

**32-bit (opc == 00)**

```plaintext
STP <Wt1>, <Wt2>, [<Xn|SP>], #<imm>
```

**64-bit (opc == 10)**

```plaintext
STP <Xt1>, <Xt2>, [<Xn|SP>], #<imm>
```

```plaintext
boolean wback = TRUE;
boolean postindex = TRUE;
```

### Pre-index

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| x  | 0  | 1  | 0  | 1  | 0  | 0  | 1  | 1  | imm7 | Rt2 | Rn | Rt |
| opc| L  |

**32-bit (opc == 00)**

```plaintext
STP <Wt1>, <Wt2>, [<Xn|SP>], #<imm>!
```

**64-bit (opc == 10)**

```plaintext
STP <Xt1>, <Xt2>, [<Xn|SP>], #<imm>!
```

```plaintext
boolean wback = TRUE;
boolean postindex = FALSE;
```

### Signed offset

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| x  | 0  | 1  | 0  | 1  | 0  | 0  | 1  | 0  | imm7 | Rt2 | Rn | Rt |
| opc| L  |

**32-bit (opc == 00)**

```plaintext
STP <Wt1>, <Wt2>, [<Xn|SP>], #<imm>!
```

**64-bit (opc == 10)**

```plaintext
STP <Xt1>, <Xt2>, [<Xn|SP>], #<imm>!
```

```plaintext
boolean wback = FALSE;
boolean postindex = FALSE;
```
For information about the CONSTRAINED UNPREDICTABLE behavior of this instruction, see *Architectural Constraints on UNPREDICTABLE behaviors*, and particularly *STP*.

**Assembler Symbols**

<Wt1> Is the 32-bit name of the first general-purpose register to be transferred, encoded in the "Rt" field.

<Wt2> Is the 32-bit name of the second general-purpose register to be transferred, encoded in the "Rt2" field.

<Xt1> Is the 64-bit name of the first general-purpose register to be transferred, encoded in the "Rt" field.

<Xt2> Is the 64-bit name of the second general-purpose register to be transferred, encoded in the "Rt2" field.

<Xn|SP> Is the 64-bit name of the general-purpose base register or stack pointer, encoded in the "Rn" field.

<imm> For the 32-bit post-index and 32-bit pre-index variant: is the signed immediate byte offset, a multiple of 4 in the range -256 to 252, encoded in the "imm7" field as <imm>/4.

For the 32-bit signed offset variant: is the optional signed immediate byte offset, a multiple of 4 in the range -256 to 252, defaulting to 0 and encoded in the "imm7" field as <imm>/4.

For the 64-bit post-index and 64-bit pre-index variant: is the signed immediate byte offset, a multiple of 8 in the range -512 to 504, encoded in the "imm7" field as <imm>/8.

For the 64-bit signed offset variant: is the optional signed immediate byte offset, a multiple of 8 in the range -512 to 504, defaulting to 0 and encoded in the "imm7" field as <imm>/8.

**Shared Decode**

```plaintext
integer n = UInt(Rn);
integer t = UInt(Rt);
integer t2 = UInt(Rt2);
AccType acctype = AccType_NORMAL;
MemOp memop = if L == '1' then MemOp_LOAD else MemOp_STORE;
if L:opc<0> == '01' || opc == '11' then UNDEFINED;
boolean signed = (opc<0> != '0');
integer scale = 2 + if L:opc<0> == '01' || opc == '11' then UnallocatedEncoding() else UInt(opc<1>);
integer datasize = 8 << scale;
bits(64) offset = LSL(SignExtend(imm7, 64), scale);
```
bits(64) address;
bite(data) data1;
bite(data) data2;
constant integer dbytes = datasize DIV 8;
boolean rt_unknown = FALSE;
boolean wb_unknown = FALSE;

if memop == MemOp_STORE() then
  boolean is_load_store = memop IN {MemOp_STORE, MemOp_LOAD};
  SetNotTagCheckedInstruction(is_load_store && n == 31 && !wback);

boolean wb_unknown = FALSE;
if memop == MemOp_LOAD && wback && (t == n || t2 == n) && n != 31 then
  Constraint c = ConstrainUnpredictable(Unpredictable_WBOVERLAPLD);
  assert c IN {Constraint_WBSUPPRESS, Constraint_UNKNOWN, Constraint_UNDEF, Constraint_NOP};
  case c of
    when Constraint_WBSUPPRESS wback = FALSE; // writeback is suppressed
    when Constraint_UNKNOWN wb_unknown = TRUE; // writeback is UNKNOWN
    when Constraint_UNDEF UNDEFINED;
    when UnallocatedEncoding();
    when Constraint_NOP EndOfInstruction();
  end;

if memop == MemOp_STORE && wback && (t == n || t2 == n) && n != 31 then
  Constraint c = ConstrainUnpredictable(Unpredictable_WBOVERLAPST);
  assert c IN {Constraint_NONE, Constraint_UNKNOWN, Constraint_UNDEF, Constraint_NOP};
  case c of
    when Constraint_NONE rt_unknown = FALSE; // value stored is pre-writeback
    when Constraint_UNKNOWN rt_unknown = TRUE; // value stored is UNKNOWN
    when Constraint_UNDEF UNDEFINED;
    when UnallocatedEncoding();
    when Constraint_NOP EndOfInstruction();
  end;

if memop == MemOp_LOAD && t == t2 then
  Constraint c = ConstrainUnpredictable(Unpredictable_LDPOVERLAP);
  assert c IN {Constraint_UNKNOWN, Constraint_UNDEF, Constraint_NOP};
  case c of
    when Constraint_UNKNOWN rt_unknown = TRUE; // result is UNKNOWN
    when Constraint_UNDEF UNDEFINED;
    when Constraint_NOP EndOfInstruction();
  end;

if n == 31 then
  CheckSPAlignment();
  address = SP[];
else
  address = X[n];

if ! postindex then
  address = address + offset;

case memop of
  when MemOp_STORE
    if rt_unknown && t == n then
      data1 = bits(datasize) UNKNOWN;
    else
      data1 = X[t];
    if rt_unknown && t2 == n then
      data2 = bits(datasize) UNKNOWN;
    else
      data2 = X[t2];
      Mem[address + 0 , dbytes, acctype] = data1;
      Mem[address + dbytes, dbytes, acctype] = data2;
    end;
  when MemOp_LOAD
    data1 = Mem[address + 0 , dbytes, acctype];
    data2 = Mem[address + dbytes, dbytes, acctype];
    if rt_unknown then
      data1 = bits(datasize) UNKNOWN;
      data2 = bits(datasize) UNKNOWN;
if signed then
    X[t] = SignExtend(data1, 64);
    X[t2] = SignExtend(data2, 64);
else
    X[t] = data1;
    X[t2] = data2;

if wback then
    if wb_unknown then
        address = bits(64) UNKNOWN;
    elsif postindex then
        address = address + offset;
    if n == 31 then
        SP[] = address;
    else
        X[n] = address;

Operational information

If PSTATE.DIT is 1, the timing of this instruction is insensitive to the value of the data being loaded or stored.
STR (immediate, SIMD&FP)

Store SIMD&FP register (immediate offset). This instruction stores a single SIMD&FP register to memory. The address that is used for the store is calculated from a base register value and an immediate offset. Depending on the settings in the $CPACR_{EL1}$, $CPTR_{EL2}$, and $CPTR_{EL3}$ registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

It has encodings from 3 classes: Post-index, Pre-index, and Unsigned offset.

### Post-index

<table>
<thead>
<tr>
<th>size</th>
<th>1</th>
<th>1</th>
<th>1</th>
<th>0</th>
<th>0</th>
<th>0</th>
<th>0</th>
<th>imm9</th>
<th>0</th>
<th>1</th>
<th>Rn</th>
<th>Rt</th>
</tr>
</thead>
</table>

opc

8-bit (size == 00 && opc == 00)

\[ \text{STR} \ <Bt>, \ [<Xn|SP>], \ #<simm> \]

16-bit (size == 01 && opc == 00)

\[ \text{STR} \ <Ht>, \ [<Xn|SP>], \ #<simm> \]

32-bit (size == 10 && opc == 00)

\[ \text{STR} \ <St>, \ [<Xn|SP>], \ #<simm> \]

64-bit (size == 11 && opc == 00)

\[ \text{STR} \ <Dt>, \ [<Xn|SP>], \ #<simm> \]

128-bit (size == 00 && opc == 10)

\[ \text{STR} \ <Qt>, \ [<Xn|SP>], \ #<simm> \]

boolean wback = TRUE;
boolean postindex = TRUE;
integer scale = Uint(opc<1>:size);
if scale > 4 then UNDEFINED;
bits(64) offset = if scale = 1 then UnallocatedEncoding();
bites(64) offset = SignExtend(imm9, 64);

### Pre-index

<table>
<thead>
<tr>
<th>size</th>
<th>1</th>
<th>1</th>
<th>1</th>
<th>0</th>
<th>0</th>
<th>0</th>
<th>imm9</th>
<th>1</th>
<th>1</th>
<th>Rn</th>
<th>Rt</th>
</tr>
</thead>
</table>

opc

Pre-index
8-bit (size == 00 && opc == 00)

```
STR <Bt>, [<Xn|SP>, #<simm>]
```

16-bit (size == 01 && opc == 00)

```
STR <Ht>, [<Xn|SP>, #<simm>]
```

32-bit (size == 10 && opc == 00)

```
STR <St>, [<Xn|SP>, #<simm>]
```

64-bit (size == 11 && opc == 00)

```
STR <Dt>, [<Xn|SP>, #<simm>]
```

128-bit (size == 00 && opc == 10)

```
STR <Qt>, [<Xn|SP>, #<simm>]
```

```
boolean wback = TRUE;
boolean postindex = FALSE;
integer scale = UInt(opc<1>:size);
if scale > 4 then UNDEFINED;
bits(64) offset = if scale > 4 then UnallocatedEncoding()
bits(64) offset = SignExtend(imm9, 64);
```

Unsigned offset

```

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9  | 8  | 7  | 6  | 5  | 4  | 3  | 2  | 1  | 0  |
|-----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| size| 1  | 1  | 1  | 0  | 1  | x  | 0  | imm12| Rn |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| opc |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
```

8-bit (size == 00 && opc == 00)

```
STR <Bt>, [<Xn|SP>{, #<pimm}>]
```

16-bit (size == 01 && opc == 00)

```
STR <Ht>, [<Xn|SP>{, #<pimm}>]
```

32-bit (size == 10 && opc == 00)

```
STR <St>, [<Xn|SP>{, #<pimm}>]
```

64-bit (size == 11 && opc == 00)

```
STR <Dt>, [<Xn|SP>{, #<pimm}>]
```

128-bit (size == 00 && opc == 10)

```
STR <Qt>, [<Xn|SP>{, #<pimm}>]
```

```
boolean wback = FALSE;
boolean postindex = FALSE;
integer scale = UInt(opc<1>:size);
if scale > 4 then UNDEFINED;
bits(64) offset = if scale > 4 then UnallocatedEncoding()
bits(64) offset = LSL(ZeroExtend(imm12, 64), scale);
```
Assembler Symbols

<Bit> Is the 8-bit name of the SIMD&FP register to be transferred, encoded in the "Rt" field.

<Dt> Is the 64-bit name of the SIMD&FP register to be transferred, encoded in the "Rt" field.

<It> Is the 16-bit name of the SIMD&FP register to be transferred, encoded in the "Rt" field.

<Qt> Is the 128-bit name of the SIMD&FP register to be transferred, encoded in the "Rt" field.

<St> Is the 32-bit name of the SIMD&FP register to be transferred, encoded in the "Rt" field.

<Xn|SP> Is the 64-bit name of the general-purpose base register or stack pointer, encoded in the "Rn" field.

<simm> Is the signed immediate byte offset, in the range -256 to 255, encoded in the "imm9" field.

<pimm> For the 8-bit variant: is the optional positive immediate byte offset, in the range 0 to 4095, defaulting to 0 and encoded in the "imm12" field.

For the 16-bit variant: is the optional positive immediate byte offset, a multiple of 2 in the range 0 to 8190, defaulting to 0 and encoded in the "imm12" field as <pimm>/2.

For the 32-bit variant: is the optional positive immediate byte offset, a multiple of 4 in the range 0 to 16380, defaulting to 0 and encoded in the "imm12" field as <pimm>/4.

For the 64-bit variant: is the optional positive immediate byte offset, a multiple of 8 in the range 0 to 32760, defaulting to 0 and encoded in the "imm12" field as <pimm>/8.

For the 128-bit variant: is the optional positive immediate byte offset, a multiple of 16 in the range 0 to 65520, defaulting to 0 and encoded in the "imm12" field as <pimm>/16.

Shared Decode

```
integer n = UInt(Rn);
integer t = UInt(Rt);
AccType acctype = AccType_VEC;
MemOp memop = if opc<0> == '1' then MemOp_LOAD else MemOp_STORE;
integer datasize = 8 << scale;
```
Operation

```c
if HaveMTEExt() then
  boolean is_load_store = memop IN {MemOp_STORE, MemOp_LOAD};
  SetNotTagCheckedInstruction(is_load_store && n == 31 && !wback);
CheckFPAdvSIMDEnabled64();
bits(64) address;
bits(datasize) data;
if n == 31 then
  CheckSPAignment();
  address = SP[];
else
  address = X[n];
if ! postindex then
  address = address + offset;
case memop of
  when MemOp_STORE
    data = V[t];
    Mem[address, datasize DIV 8, acctype] = data;
  when MemOp_LOAD
    data = Mem[address, datasize DIV 8, acctype];
    V[t] = data;
if wback then
  if postindex then
    address = address + offset;
  if n == 31 then
    SP[] = address;
  else
    X[n] = address;
```

Operational information

If PSTATE.DIT is 1, the timing of this instruction is insensitive to the value of the data being loaded or stored.
STR (immediate)

Store Register (immediate) stores a word or a doubleword from a register to memory. The address that is used for the store is calculated from a base register and an immediate offset. For information about memory accesses, see Load/Store addressing modes.

It has encodings from 3 classes: Post-index, Pre-index and Unsigned offset.

**Post-index**

```
<table>
<thead>
<tr>
<th>31</th>
<th>30</th>
<th>29</th>
<th>28</th>
<th>27</th>
<th>26</th>
<th>25</th>
<th>24</th>
<th>23</th>
<th>22</th>
<th>21</th>
<th>20</th>
<th>19</th>
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<th>17</th>
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<th>10</th>
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<th>8</th>
<th>7</th>
<th>6</th>
<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>imm9</td>
<td>0</td>
<td>1</td>
<td>Rn</td>
<td>Rt</td>
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<td></td>
</tr>
</tbody>
</table>
```

32-bit (size == 10)

```
STR <Wt>, [<Xn|SP>], #<simm>
```

64-bit (size == 11)

```
STR <Xt>, [<Xn|SP>], #<simm>
```

```java
boolean wback = TRUE;
boolean postindex = TRUE;
integer scale = UInt(size);
bits(64) offset = SignExtend(imm9, 64);
```

**Pre-index**

```
<table>
<thead>
<tr>
<th>31</th>
<th>30</th>
<th>29</th>
<th>28</th>
<th>27</th>
<th>26</th>
<th>25</th>
<th>24</th>
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<th>7</th>
<th>6</th>
<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
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<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
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<td></td>
<td></td>
</tr>
</tbody>
</table>
```

32-bit (size == 10)

```
STR <Wt>, [<Xn|SP>], #<simm>!
```

64-bit (size == 11)

```
STR <Xt>, [<Xn|SP>], #<simm>!
```

```java
boolean wback = true;
boolean postindex = false;
integer scale = UInt(size);
bits(64) offset = SignExtend(imm9, 64);
```

**Unsigned offset**

```
<table>
<thead>
<tr>
<th>31</th>
<th>30</th>
<th>29</th>
<th>28</th>
<th>27</th>
<th>26</th>
<th>25</th>
<th>24</th>
<th>23</th>
<th>22</th>
<th>21</th>
<th>20</th>
<th>19</th>
<th>18</th>
<th>17</th>
<th>16</th>
<th>15</th>
<th>14</th>
<th>13</th>
<th>12</th>
<th>11</th>
<th>10</th>
<th>9</th>
<th>8</th>
<th>7</th>
<th>6</th>
<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>imm12</td>
<td>Rn</td>
<td>Rt</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
```

```java
```
32-bit (size == 10)

```plaintext
STR <Wt>, [<Xn|SP>{, #<pimm>}]
```

64-bit (size == 11)

```plaintext
STR <Xt>, [<Xn|SP>{, #<pimm>}]
```

```plaintext
boolean wback = FALSE;
boolean postindex = FALSE;
integer scale = UInt(size);
bits(64) offset = LSL(ZeroExtend(imm12, 64), scale);
```

**Assembler Symbols**

- `<Wt>`: Is the 32-bit name of the general-purpose register to be transferred, encoded in the "Rt" field.
- `<Xt>`: Is the 64-bit name of the general-purpose register to be transferred, encoded in the "Rt" field.
- `<Xn|SP>`: Is the 64-bit name of the general-purpose base register or stack pointer, encoded in the "Rn" field.
- `<simm>`: Is the signed immediate byte offset, in the range -256 to 255, encoded in the "imm9" field.
- `<pimm>`: For the 32-bit variant: is the optional positive immediate byte offset, a multiple of 4 in the range 0 to 16380, defaulting to 0 and encoded in the "imm12" field as `<pimm>/4`. For the 64-bit variant: is the optional positive immediate byte offset, a multiple of 8 in the range 0 to 32760, defaulting to 0 and encoded in the "imm12" field as `<pimm>/8`.

**Shared Decode**

```plaintext
integer n = UInt(Rn);
integer t = UInt(Rt);
AccType acctype = AccType_NORMAL;
MemOp memop;
boolean signed;
integer regsize;
if opc<1> == '0' then
  // store or zero-extending load
  memop = if opc<0> == '1' then MemOp_LOAD else MemOp_STORE;
  regsize = if size == '11' then 64 else 32;
  signed = FALSE;
else
  if size == '11' then UNDEFINED;
  else
    // sign-extending load
    memop = if size == '11' then UnallocatedEncoding();
    else
      // sign-extending load
      memop = MemOp_LOAD;
      if size == '10' && opc<0> == '1' then UnallocatedEncoding();
      if size == '10' && opc<0> == '1' then UNDEFINED;
  end;
  regsize = if opc<0> == '1' then 32 else 64;
  signed = TRUE;
integer datasize = 8 << scale;
```
if bits(64) address;
bits(datasize) data;
boolean wb_unknown = FALSE;
boolean rt_unknown = FALSE;

if memop == HaveMTEExt() then
    boolean is_load_store = memop IN {MemOp STORE, MemOp LOAD};
    SetNotTagCheckedInstruction(is_load_store && n == 31 && !wback);

bits(64) address;
bits(datasize) data;
boolean wb_unknown = FALSE;
boolean rt_unknown = FALSE;

if memop == MemOp LOAD && wback && n == t && n != 31 then
    c = ConstranUnpredictable(Unpredictable_WBOVERLAPLD);
assert c IN {Constraint_WBSUPPRESS, Constraint_UNKNOWN, Constraint_UNDEF, Constraint_NOP};
case c of
when Constraint_WBSUPPRESS wback = FALSE;       // writeback is suppressed
when Constraint_UNKNOWN wb_unknown = TRUE;       // writeback is UNKNOWN
when Constraint_UNDEF rt_unknown = TRUE;       // value stored is UNKNOWN
when UnallocatedEncoding();
when Constraint_NOP      EndOfInstruction();

if memop == MemOp STORE && wback && n == t && n != 31 then
    c = ConstranUnpredictable(Unpredictable_WBOVERLAPST);
assert c IN {Constraint_NONE, Constraint_UNKNOWN, Constraint_UNDEF, Constraint_NOP};
case c of
when Constraint_NONE rt_unknown = FALSE;       // value stored is original value
when Constraint_UNKNOWN rt_unknown = TRUE;       // value stored is UNKNOWN
when Constraint_UNDEF rt_unknown = TRUE;       // value is UNDEFINED;
when UnallocatedEncoding();
when Constraint_NOP      EndOfInstruction();

if n == 31 then
if memop != MemOp_PREFETCH then CheckSPAlignment();
address = SP[];
else
    address = X[n];
if ! postindex then
    address = address + offset;

case memop of
    when MemOp STORE
        if rt_unknown then
            data = bits(datasize) UNKNOWN;
        else
            data = X[t];
            Mem[address, datasize DIV 8, acctype] = data;
        when MemOp LOAD
            data = Mem[address, datasize DIV 8, acctype];
        if signed then
            X[t] = SignExtend(data, regsize);
        else
            X[t] = ZeroExtend(data, regsize);
        when MemOp_PREFETCHPrefetch(address, t<4:0>);

if wback then
    if wb_unknown then
        address = bits(64) UNKNOWN;
    elsif postindex then
        address = address + offset;
    if n == 31 then
        SP[] = address;
else
    X[n] = address;

Operational information

If PSTATE.DIT is 1, the timing of this instruction is insensitive to the value of the data being loaded or stored.
STR (register, SIMD&FP)

Store SIMD&FP register (register offset). This instruction stores a single SIMD&FP register to memory. The address that is used for the store is calculated from a base register value and an offset register value. The offset can be optionally shifted and extended.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

<table>
<thead>
<tr>
<th>size</th>
<th>1</th>
<th>1</th>
<th>1</th>
<th>0</th>
<th>0</th>
<th>x</th>
<th>0</th>
<th>1</th>
<th>Rm</th>
<th>option</th>
<th>S</th>
<th>1</th>
<th>0</th>
<th>Rn</th>
<th>Rt</th>
</tr>
</thead>
<tbody>
<tr>
<td>opc</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

8-fsreg, STR-8-fsreg (size == 00 && opc == 00 && option != 011)

\[
\text{STR} <Bt>, [<Xn|SP>, (Wm|Xm)], <\text{extend}> \{<\text{amount}>\}
\]

8-fsreg, STR-8-fsreg (size == 00 && opc == 00 && option == 011)

\[
\text{STR} <Bt>, [<Xn|SP>, Xm], \{\text{LSL} <\text{amount}>\}
\]

16-fsreg, STR-16-fsreg (size == 01 && opc == 00)

\[
\text{STR} <Ht>, [<Xn|SP>, (Wm|Xm)], \{<\text{extend}> \{<\text{amount}>\}\}
\]

32-fsreg, STR-32-fsreg (size == 10 && opc == 00)

\[
\text{STR} <St>, [<Xn|SP>, (Wm|Xm)], \{<\text{extend}> \{<\text{amount}>\}\}
\]

64-fsreg, STR-64-fsreg (size == 11 && opc == 00)

\[
\text{STR} <Dt>, [<Xn|SP>, (Wm|Xm)], \{<\text{extend}> \{<\text{amount}>\}\}
\]

128-fsreg, STR-128-fsreg (size == 00 && opc == 10)

\[
\text{STR} <Qt>, [<Xn|SP>, (Wm|Xm)], \{<\text{extend}> \{<\text{amount}>\}\}
\]

boolean wback = FALSE;
boolean postindex = FALSE;
integer scale = UInt(opc<1>:size);
if scale > 4 then UNDEFINED;
if option<1> == '0' then UNDEFINED; // sub-word index if scale > 4 then
UnallocatedEncoding();
if option<1> == '1' then UnallocatedEncoding(); // sub-word index
EndType extend_type = DecodeRegExtend(option);
Integer shift = if S == '1' then scale else 0;

Assembler Symbols

\(<Bt>\) Is the 8-bit name of the SIMD&FP register to be transferred, encoded in the "Rt" field.
\(<Dt>\) Is the 64-bit name of the SIMD&FP register to be transferred, encoded in the "Rt" field.
\(<Ht>\) Is the 16-bit name of the SIMD&FP register to be transferred, encoded in the "Rt" field.
\(<Qt>\) Is the 128-bit name of the SIMD&FP register to be transferred, encoded in the "Rt" field.
\(<St>\) Is the 32-bit name of the SIMD&FP register to be transferred, encoded in the "Rt" field.
\(<Xn|SP>\) Is the 64-bit name of the general-purpose base register or stack pointer, encoded in the "Rn" field.
\(<Wm>\) When option<0> is set to 0, is the 32-bit name of the general-purpose index register, encoded in the "Rm" field.
When option<0> is set to 1, is the 64-bit name of the general-purpose index register, encoded in the "Rm" field.

For the 8-bit variant: is the index extend specifier, encoded in “option”:

<table>
<thead>
<tr>
<th>option</th>
<th>&lt;extend&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>010</td>
<td>UXTW</td>
</tr>
<tr>
<td>110</td>
<td>SXTW</td>
</tr>
<tr>
<td>111</td>
<td>SXTX</td>
</tr>
</tbody>
</table>

For the 128-bit, 16-bit, 32-bit and 64-bit variant: is the index extend/shift specifier, defaulting to LSL, and which must be omitted for the LSL option when <amount> is omitted. encoded in “option”:

<table>
<thead>
<tr>
<th>option</th>
<th>&lt;extend&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>010</td>
<td>UXTW</td>
</tr>
<tr>
<td>011</td>
<td>LSL</td>
</tr>
<tr>
<td>110</td>
<td>SXTW</td>
</tr>
<tr>
<td>111</td>
<td>SXTX</td>
</tr>
</tbody>
</table>

For the 8-bit variant: is the index amount, it must be #0, encoded in "S" as 0 if omitted, or as 1 if present.

For the 16-bit variant: is the index shift amount, optional only when <extend> is not LSL. Where it is permitted to be optional, it defaults to #0. It is encoded in “S”:

<table>
<thead>
<tr>
<th>S</th>
<th>&lt;amount&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>#0</td>
</tr>
<tr>
<td>1</td>
<td>#1</td>
</tr>
</tbody>
</table>

For the 32-bit variant: is the index shift amount, optional only when <extend> is not LSL. Where it is permitted to be optional, it defaults to #0. It is encoded in “S”:

<table>
<thead>
<tr>
<th>S</th>
<th>&lt;amount&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>#0</td>
</tr>
<tr>
<td>1</td>
<td>#2</td>
</tr>
</tbody>
</table>

For the 64-bit variant: is the index shift amount, optional only when <extend> is not LSL. Where it is permitted to be optional, it defaults to #0. It is encoded in “S”:

<table>
<thead>
<tr>
<th>S</th>
<th>&lt;amount&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>#0</td>
</tr>
<tr>
<td>1</td>
<td>#3</td>
</tr>
</tbody>
</table>

For the 128-bit variant: is the index shift amount, optional only when <extend> is not LSL. Where it is permitted to be optional, it defaults to #0. It is encoded in “S”:

<table>
<thead>
<tr>
<th>S</th>
<th>&lt;amount&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>#0</td>
</tr>
<tr>
<td>1</td>
<td>#4</td>
</tr>
</tbody>
</table>

**Shared Decode**

```plaintext
type Integer = UInt
integer n = UInt(Rn);
integer t = UInt(Rt);
integer m = UInt(Rm);
AccType acctype = AccType_VEC;
MemOp memop = if opc<0> == 'I' then MemOp_LOAD else MemOp_STORE;
integer datasize = 8 << scale;
```
Operation

```c
bits(64) offset = ExtendReg(m, extend_type, shift);
if m, extend_type, shift: HaveMTEExt() then

    boolean is_load_store = memop IN {MemOp_STORE, MemOp_LOAD};
    SetNotTagCheckedInstruction(is_load_store && n == 31 && !wback);

    CheckFPAvSIMDEnabled64();
    bits(64) address;
    bits(datasize) data;

    if n == 31 then
        CheckSPAlignment();
        address = SP[];
    else
        address = X[n];

    if ! postindex then
        address = address + offset;

    case memop of
        when MemOp_STORE
            data = V[t];
            Mem[address, datasize DIV 8, acctype] = data;
        when MemOp_LOAD
            data = Mem[address, datasize DIV 8, acctype];
            V[t] = data;

    if wback then
        if postindex then
            address = address + offset;
        if n == 31 then
            SP[] = address;
        else
            X[n] = address;
```

Operational information

If PSTATE.DIT is 1, the timing of this instruction is insensitive to the value of the data being loaded or stored.
STR (register)

Store Register (register) calculates an address from a base register value and an offset register value, and stores a 32-bit word or a 64-bit doubleword to the calculated address, from a register. For information about memory accesses, see Load/Store addressing modes.

The instruction uses an offset addressing mode, that calculates the address used for the memory access from a base register value and an offset register value. The offset can be optionally shifted and extended.

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9  | 8  | 7  | 6  | 5  | 4  | 3  | 2  | 1  | 0  |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|---|---|
| x  | 1  | 1  | 1  | 0  | 0  | 0  | 0  | 1  | Rm | option | S | 1 | 0 | Rn | Rt |

32-bit (size == 10)

```
STR <Wt>, [<Xn|SP>, (Wm|Xm)], <extend> {<amount>}
```

64-bit (size == 11)

```
STR <Xt>, [Xn|SP>, (Wm|Xm)], <extend> {<amount>}
```

boolean wback = FALSE;
boolean postindex = FALSE;
integer scale = UInt(size);
if option<1> == '0' then UNDEFINED; // sub-word index
ExtendType extend_type = DecodeRegExtend(option);
integer shift = if S == '1' then scale else 0;

Assembler Symbols

<Wt> Is the 32-bit name of the general-purpose register to be transferred, encoded in the "Rt" field.

<Xt> Is the 64-bit name of the general-purpose register to be transferred, encoded in the "Rt" field.

<Xn|SP> Is the 64-bit name of the general-purpose base register or stack pointer, encoded in the "Rn" field.

<Wm> When option<0> is set to 0, is the 32-bit name of the general-purpose index register, encoded in the "Rm" field.

<Xm> When option<0> is set to 1, is the 64-bit name of the general-purpose index register, encoded in the "Rm" field.

<extend> Is the index extend/shift specifier, defaulting to LSL, and which must be omitted for the LSL option when <amount> is omitted. encoded in "option":

<table>
<thead>
<tr>
<th>option</th>
<th>&lt;extend&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>010</td>
<td>UXTW</td>
</tr>
<tr>
<td>011</td>
<td>LSL</td>
</tr>
<tr>
<td>110</td>
<td>SXTW</td>
</tr>
<tr>
<td>111</td>
<td>SXTX</td>
</tr>
</tbody>
</table>

<amount> For the 32-bit variant: is the index shift amount, optional only when <extend> is not LSL. Where it is permitted to be optional, it defaults to #0. It is encoded in “S”:

<table>
<thead>
<tr>
<th>S</th>
<th>&lt;amount&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>#0</td>
</tr>
<tr>
<td>1</td>
<td>#2</td>
</tr>
</tbody>
</table>

For the 64-bit variant: is the index shift amount, optional only when <extend> is not LSL. Where it is permitted to be optional, it defaults to #0. It is encoded in “S”:

<table>
<thead>
<tr>
<th>S</th>
<th>&lt;amount&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>#0</td>
</tr>
<tr>
<td>1</td>
<td>#3</td>
</tr>
</tbody>
</table>
integer n = UInt(Rn);
integer t = UInt(Rt);
integer m = UInt(Rm);
AccType acctype = AccType_NORMAL;
MemOp memop;
boolean signed;
integer regsize;

if opc<1> == '0' then
  // store or zero-extending load
  memop = if opc<0> == '1' then MemOp_LOAD else MemOp_STORE;
  regsize = if size == '11' then 64 else 32;
  signed = FALSE;
else
  if size == '11' then
    memop = MemOp_PREFetch;
  if opc<0> == '1' then UNDEFINED;
else
  // sign-extending load
  memop = if opc<0> == '1' then UnallocatedEncoding();
  else
    if size == '10' && opc<0> == '1' then UNDEFINED;
    regsize = if opc<0> == '1' then 32 else 64;
    signed = TRUE;

integer datasize = 8 << scale;
bits(64) offset = ExtendReg(m, extend_type, shift);
if bits(64) address;
    bits(datasize) data;
    boolean wb_unknown = FALSE;
    boolean rt_unknown = FALSE;
if memop == HaveMTEExt() then
    boolean is_load_store = memop IN {MemOp STORE, MemOp LOAD};
    SetNotTagCheckedInstruction(is_load_store && n == 31 && !wback);
bits(64) address;
bits(datasize) data;
boolean wb_unknown = FALSE;
boolean rt_unknown = FALSE;
if memop == MemOp LOAD && wback && n == t && n != 31 then
    c = ConstrainUnpredictable(Unpredictable_WBOVERLAPLD);
assert c IN {Constraint_WBSUPPRESS, Constraint_UNKNOWN, Constraint_UNDEF, Constraint_NOP};
case c of
    when Constraint_WBSUPPRESS          wback = FALSE;  // writeback is suppressed
    when Constraint_UNKNOWN             wb_unknown = TRUE;  // writeback is UNKNOWN
    when Constraint_UNDEF               UNDEFINED;
    when UnallocatedEncoding()         c = MemOp_LOAD;  // value stored is original value
    when Constraint_NOP                EndOfInstruction();
if memop == MemOp STORE && wback && n == t && n != 31 then
    c = ConstrainUnpredictable(Unpredictable_WBOVERLAPST);
assert c IN {Constraint_NONE, Constraint_UNKNOWN, Constraint_UNDEF, Constraint_NOP};
case c of
    when Constraint_NONE                rt_unknown = FALSE;  // value stored is original value
    when Constraint_UNKNOWN             rt_unknown = TRUE;  // value stored is UNKNOWN
    when Constraint_UNDEF               UNDEFINED;
    when Constraint_NOP                EndOfInstruction();
if n == 31 then
    if memop != MemOp_PREFETCH then CheckSPAlignment();
    address = SP[];
else
    address = X[n];
if ! postindex then
    address = address + offset;
case memop of
    when MemOp_STORE
        if rt_unknown then
            data = bits(datasize) UNKNOWN;
        else
            data = X[t];
        Mem[address, datasize DIV 8, acctype] = data;
    when MemOp_LOAD
        data = Mem[address, datasize DIV 8, acctype];
    if signed then
        X[t] = SignExtend(data, regsize);
    else
        X[t] = ZeroExtend(data, regsize);
    when MemOp_PREFETCHPrefetch(address, t<4:0>);
if wback then
    if wb unknown then
        address = bits(64) UNKNOWN;
    elsif postindex then
        address = address + offset;
    if n == 31 then
        SP[] = address;
else
  \( X[n] = \text{address}; \)

### Operational information

If PSTATE.DIT is 1, the timing of this instruction is insensitive to the value of the data being loaded or stored.
STRB (immediate)

Store Register Byte (immediate) stores the least significant byte of a 32-bit register to memory. The address that is used for the store is calculated from a base register and an immediate offset. For information about memory accesses, see Load/Store addressing modes.

It has encodings from 3 classes: Post-index, Pre-index and Unsigned offset

### Post-index

<table>
<thead>
<tr>
<th>31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 0 1 1 0 0 0 0</td>
</tr>
</tbody>
</table>

```java
size opc
```

```java
boolean wback = TRUE;
boolean postindex = TRUE;
integer scale = UInt(size);
bits(64) offset = SignExtend(imm9, 64);
```

### Pre-index

<table>
<thead>
<tr>
<th>31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 0 1 1 0 0 0 0</td>
</tr>
</tbody>
</table>

```java
size opc
```

```java
boolean wback = TRUE;
boolean postindex = FALSE;
integer scale = UInt(size);
bits(64) offset = SignExtend(imm9, 64);
```

### Unsigned offset

<table>
<thead>
<tr>
<th>31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 0 1 1 0 0 1 0</td>
</tr>
</tbody>
</table>

```java
size opc
```

```java
boolean wback = FALSE;
boolean postindex = FALSE;
integer scale = UInt(size);
bits(64) offset = LSL(ZeroExtend(imm12, 64), scale);
```

For information about the constrained unpredictable behavior of this instruction, see Architectural Constraints on UNPREDICTABLE behaviors, and particularly STRB (immediate).

### Assembler Symbols

`<Wt>` Is the 32-bit name of the general-purpose register to be transferred, encoded in the "Rt" field.
Is the 64-bit name of the general-purpose base register or stack pointer, encoded in the "Rn" field.

Is the signed immediate byte offset, in the range -256 to 255, encoded in the "imm9" field.

Is the optional positive immediate byte offset, in the range 0 to 4095, defaulting to 0 and encoded in the "imm12" field.

**Shared Decode**

```c
integer n = UInt(Rn);
integer t = UInt(Rt);
AccType acctype = AccType_NORMAL;
MemOp memop;
boolean signed;
integer regsize;

if opc<1> == '0' then
    // store or zero-extending load
    memop = if opc<0> == '1' then MemOp_LOAD else MemOp_STORE;
    regsize = if size == '11' then 64 else 32;
    signed = FALSE;
else
    if size == '11' then UNDEFINED;
    else
        // sign-extending load
        memop = if size == '11' then UnallocatedEncoding();
        else
            // sign-extending load
            memop = MemOp_LOAD;
            if size == '11' && opc<0> == '1' then UnallocatedEncoding();
            if size == '10' && opc<0> == '1' then UNDEFINED;
        end;
        regsize = if opc<0> == '1' then 32 else 64;
        signed = TRUE;

integer datasize = 8 << scale;
```
Operation

STRB (immediate)
if bits(64) address;
bis(datasize) data;
boolean wb_unknown = FALSE;
boolean rt_unknown = FALSE;

if memop == HaveMTEExt() then
  boolean is_load_store = memop IN {MemOp STORE, MemOp LOAD};
  SetNotTagCheckedInstruction(is_load_store && n == 31 && !wback);

bits(64) address;
bis(datasize) data;
boolean wb_unknown = FALSE;
boolean rt_unknown = FALSE;

if memop == MemOp LOAD && wback && t & t n != 31 then
  c = MemOp_Load && wback && t & t n != 31 then
    c = ConstrainUnpredictable
  assert c IN {Constraint_WBSUPPRESS, Constraint_UNKNOWN, Constraint_UNDEF, Constraint_NOP};
  case c of
    when Constraint_WBSUPPRESS wback = FALSE; // writeback is suppressed
    when Constraint_UNKNOWN wb_unknown = TRUE; // writeback is UNKNOWN
    when Constraint_UNDEF UNDEFINED;
    when UnallocatedEncoding();
    when Constraint_NOP EndOfInstruction();
  endcase;

if memop == MemOp STORE && wback && t & t n != 31 then
  c = ConstrainUnpredictable
  assert c IN {Constraint_NONE, Constraint_UNKNOWN, Constraint_UNDEF, Constraint_NOP};
  case c of
    when Constraint_NONE rt_unknown = FALSE; // value stored is original value
    when Constraint_UNKNOWN rt_unknown = TRUE; // value stored is UNKNOWN
    when Constraint_UNDEF UnallocatedEncoding UNDEFINED;
  endcase;

if n == 31 then
  if memop != MemOp_PREFETCH then CheckSPAlignment();
  address = SP[];
else
  address = X[n];
endif
if ! postindex then
  address = address + offset;
endif

if memop == MemOp STORE
  if rt_unknown then
    data = bits(data) UNKNOWN;
  else
    data = X[t];
    Mem[address, datarize DIV 8, acctype] = data;
  when MemOp LOAD
    data = Mem[address, datarize DIV 8, acctype];
  if signed then
    X[t] = SignExtend(data, regsize);
  else
    X[t] = ZeroExtend(data, regsize);
  when MemOp_PREFETCHPrefetch(address, t<4:0>);

if wback then
  if wb_unknown then
    address = bits(64) UNKNOWN;
  elsif postindex then
    address = address + offset;
  if n == 31 then
    SP[] = address;
else
    X[n] = address;

Operational information

If PSTATE.DIT is 1, the timing of this instruction is insensitive to the value of the data being loaded or stored.
STRB (register)

Store Register Byte (register) calculates an address from a base register value and an offset register value, and stores a byte from a 32-bit register to the calculated address. For information about memory accesses, see Load/Store addressing modes. The instruction uses an offset addressing mode, that calculates the address used for the memory access from a base register value and an offset register value. The offset can be optionally shifted and extended.

```
|   31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0 |
|-------------------------------------------|---------------------------------------------|
| 0 0 1 1 0 0 0 0 1 | Rm | option | S | 1 | 0 | Rn |   | Rt |
| size | opc |
```

Extended register (option != 011)

```
STRB <Wt>, [<Xn|SP>, (<Wm>|<Xm>), <extend> {<amount>}]  
```

Shifted register (option == 011)

```
STRB <Wt>, [<Xn|SP>, <Xm>{, LSL <amount>}]  
```

Assembler Symbols

- `<Wt>`: Is the 32-bit name of the general-purpose register to be transferred, encoded in the "Rt" field.
- `<Xn|SP>`: Is the 64-bit name of the general-purpose base register or stack pointer, encoded in the "Rn" field.
- `<Wm>`: When option<0> is set to 0, is the 32-bit name of the general-purpose index register, encoded in the "Rm" field.
- `<Xm>`: When option<0> is set to 1, is the 64-bit name of the general-purpose index register, encoded in the "Rm" field.
- `<extend>`: Is the index extend specifier, encoded in "option":

<table>
<thead>
<tr>
<th>option</th>
<th>&lt;extend&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>010</td>
<td>UXTW</td>
</tr>
<tr>
<td>110</td>
<td>SXTW</td>
</tr>
<tr>
<td>111</td>
<td>SXTX</td>
</tr>
</tbody>
</table>

- `<amount>`: Is the index shift amount, it must be #0, encoded in "S" as 0 if omitted, or as 1 if present.
integer n = UInt(Rn);
integer t = UInt(Rt);
integer m = UInt(Rm);
AccType accType = AccType_NORMAL;
MemOp memop;
boolean signed;
integer regsize;

if opc<1> == '0' then
  // store or zero-extending load
  memop = if opc<0> == '1' then MemOp_LOAD else MemOp_STORE;
  regsize = if size == '11' then 64 else 32;
  signed = FALSE;
else
  if size == '11' then
    memop = MemOp_PREFETCH;
    if opc<0> == '1' then UNDEFINED;
  else
    // sign-extending load
    memop = if opc<0> == '1' then UnallocatedEncoding();
    if size == '10' && opc<0> == '1' then UNDEFINED;
  end
  regsize = if opc<0> == '1' then 32 else 64;
  signed = TRUE;

integer datasize = 8 << scale;
bits(64) ofset = ExtendReg(m, extend_type, shift);
if bits(64) address
bits(datasize) data;
boolean wb_unknown = FALSE;
boolean rt_unknown = FALSE;

if memop == MemOp STORE && wback && t == 31 then
    if rt_unknown then
        data = bits(datasize) UNKNOWN;
    else
        data = X[t];
    Mem[address, datasize DIV 8, acctype] = data;

when MemOp LOAD
    data = Mem[address, datasize DIV 8, acctype];
    if signed then
        X[t] = SignExtend(data, regsize);
    else
        X[t] = ZeroExtend(data, regsize);

    when MemOp_PREFETCHPrefetch(address, t<4:0>);

if wb then
    if wb unknown then
        address = bits(64) UNKNOWN;
    elsif postindex then
        address = address + offset;
    if n == 31 then
        SP[] = address;
else  \( X[n] = \text{address}; \)

**Operational information**

If PSTATE.DIT is 1, the timing of this instruction is insensitive to the value of the data being loaded or stored.
**STRH (immediate)**

Store Register Halfword (immediate) stores the least significant halfword of a 32-bit register to memory. The address that is used for the store is calculated from a base register and an immediate offset. For information about memory accesses, see Load/Store addressing modes.

It has encodings from 3 classes: **Post-index**, **Pre-index** and **Unsigned offset**

### Post-index

|   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | imm9 | 0 | 1 | Rn | Rt |
| size | opc |

**STRH <Wt>, [<Xn|SP>], #<simm>**

```cpp
boolean wback = TRUE;
boolean postindex = TRUE;
integer scale = UInt(size);
bits(64) offset = SignExtend(imm9, 64);
```

### Pre-index

|   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | imm9 | 1 | 1 | Rn | Rt |
| size | opc |

**STRH <Wt>, [<Xn|SP>], #<simm>!**

```cpp
boolean wback = TRUE;
boolean postindex = FALSE;
integer scale = UInt(size);
bits(64) offset = SignExtend(imm9, 64);
```

### Unsigned offset

|   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | imm12 | Rn | Rt |
| size | opc |

**STRH <Wt>, [<Xn|SP>{, #<pimm}>]**

```cpp
boolean wback = FALSE;
boolean postindex = FALSE;
integer scale = UInt(size);
bits(64) offset = LSL(ZeroExtend(imm12, 64), scale);
```

For information about the CONSTRAINED UNPREDICTABLE behavior of this instruction, see Architectural Constraints on UNPREDICTABLE behaviors, and particularly **STRH (immediate)**.

**Assembler Symbols**

<Wt> Is the 32-bit name of the general-purpose register to be transferred, encoded in the "Rt" field.
Is the 64-bit name of the general-purpose base register or stack pointer, encoded in the "Rn" field.

Is the signed immediate byte offset, in the range -256 to 255, encoded in the "imm9" field.

Is the optional positive immediate byte offset, a multiple of 2 in the range 0 to 8190, defaulting to 0 and encoded in the "imm12" field as <pimm>/2.

**Shared Decode**

```plaintext
integer n = UInt(Rn);
integer t = UInt(Rt);
AccType accType = AccType_NORMAL;
MemOp memop;
boolean signed;
integer regsize;
if opc<1> == '0' then
  // store or zero-extending load
  memop = if opc<0> == '1' then MemOp_LOAD else MemOp_STORE;
  regsize = if size == '11' then 64 else 32;
  signed = FALSE;
else
  if size == '11' then
    UNDEFINED;
  else
    // sign-extending load
    memop = if size == '11' then UnallocatedEncoding else MemOp_LOAD;
    regsize = if opc<0> == '1' then 32 else 64;
    signed = TRUE;
integer datasize = 8 << scale;
```
if memop == MemOp_STORE && wback && n == 31 then
    c = ConstrainUnpredictable(Unpredictable_WBOVERLAPST);
    assert c IN {Constraint_NONE, Constraint_UNKNOWN, Constraint_UNDEF, Constraint_NOP};
    case c of
        when Constraint_NONE       rt_unknown = FALSE;  // value stored is original value
        when Constraint_UNKNOWN    rt_unknown = TRUE;   // value stored is UNKNOWN
        when Constraint_UNDEF      EndOfInstruction();
        | when Constraint_NOP       EndOfInstruction();
if n == 31 then
    if memop != MemOp_PREFETCH then CheckSPAlignment();
    address = SP[];
else
    address = X[n];
if ! postindex then
    address = address + offset;

case memop of
when MemOp_STORE
    if rt_unknown then
        data = bits(datasize) UNKNOWN;
    else
        data = X[t];
        Mem[address, datasize DIV 8, acctype] = data;
    when MemOp_LOAD
        data = Mem[address, datasize DIV 8, acctype];
        if signed then
            X[t] = SignExtend(data, regsize);
        else
            X[t] = ZeroExtend(data, regsize);
        when MemOp_PREFETCH
            Prefetch(address, t<4:0>);
if wback then
    if wb_unknown then
        address = bits(64) UNKNOWN;
    elsif postindex then
        address = address + offset;
    if n == 31 then
        SP[] = address;
else
   \( X[n] = \text{address}; \)

Operational information

If PSTATE.DIT is 1, the timing of this instruction is insensitive to the value of the data being loaded or stored.
STRH (register)

Store Register Halfword (register) calculates an address from a base register value and an offset register value, and stores a halfword from a 32-bit register to the calculated address. For information about memory accesses, see Load/Store addressing modes.

The instruction uses an offset addressing mode, that calculates the address used for the memory access from a base register value and an offset register value. The offset can be optionally shifted and extended.

```
  31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
size opc
  0 1 1 1 0 0 0 0 0 1  Rm  option  S  1  0  Rn  Rt
  0 1 1 1 0 0 0 0 0 1  Rm  option  S  1  0  Rn  Rt
```

32-bit

STRH <Wt>, [<Xn|SP>, (<Wm>|<Xm>)], <extend> {<amount>}

boolean wback = FALSE;
boolean postindex = FALSE;
integer scale = UInt(size);
if option<1> == '0' then UNDEFINED; // sub-word index
UnallocatedEncoding(); // sub-word index
ExtendType extend_type = DecodeRegExtend(option);
integer shift = if S == '1' then scale else 0;

Assembler Symbols

- `<Wt>`: Is the 32-bit name of the general-purpose register to be transferred, encoded in the "Rt" field.
- `<Xn|SP>`: Is the 64-bit name of the general-purpose base register or stack pointer, encoded in the "Rn" field.
- `<Wm>`: When option<0> is set to 0, is the 32-bit name of the general-purpose index register, encoded in the "Rm" field.
- `<Xm>`: When option<0> is set to 1, is the 64-bit name of the general-purpose index register, encoded in the "Rm" field.
- `<extend>`: Is the index extend/shift specifier, defaulting to LSL, and which must be omitted for the LSL option when `<amount>` is omitted.

<table>
<thead>
<tr>
<th>option</th>
<th>extend</th>
</tr>
</thead>
<tbody>
<tr>
<td>000</td>
<td>UXTW</td>
</tr>
<tr>
<td>001</td>
<td>LSL</td>
</tr>
<tr>
<td>010</td>
<td>SXTW</td>
</tr>
<tr>
<td>011</td>
<td>SXTX</td>
</tr>
</tbody>
</table>

- `<amount>`: Is the index shift amount, optional only when `<extend>` is not LSL. Where it is permitted to be optional, it defaults to #0. It is encoded in “S”:

<table>
<thead>
<tr>
<th>S</th>
<th>&lt;amount&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>#0</td>
</tr>
<tr>
<td>1</td>
<td>#1</td>
</tr>
</tbody>
</table>
integer n = UInt(Rn);
integer t = UInt(Rt);
integer m = UInt(Rm);
AccType acctype = AccType_NORMAL;
MemOp memop;
boolean signed;
integer regsize;

if opc<1> == '0' then
  // store or zero-extending load
  memop = if opc<0> == '1' then MemOp_LOAD else MemOp_STORE;
  regsize = if size == '11' then 64 else 32;
  signed = FALSE;
else
  if size == '11' then
    memop = MemOp_PREFETCH;
  if opc<0> == '1' then UNDEFINED;
  else
    // sign-extending load
    memop = if opc<0> == '1' then UnallocatedEncoding();
    else
      // sign-extending load
      memop = if size == '10' && opc<0> == '1' then UnallocatedEncoding;
      if size == '10' && opc<0> == '1' then UNDEFINED;
      else
        regsize = if opc<0> == '1' then 32 else 64;
        signed = TRUE;

integer datasize = 8 << scale;
bits(64) offset = $\text{ExtendReg}(m, \text{extend\_type}, \text{shift})$;

if $\text{memop} = \text{MemOp\_STORE} \&\& \text{wback} \&\& n = t \&\& t \neq 31$ then
  $c = \text{ConstrainUnpredictable(Unpredictable\_WBOVERLAPST)}$;
  assert $c$ IN {\text{Constraint\_NONE}, \text{Constraint\_UNKNOWN}, \text{Constraint\_UNDEF}, \text{Constraint\_NOP}};

if $\text{memop} = \text{MemOp\_STORE} \&\& \text{wback} \&\& n = t \&\& t \neq 31$ then
  data = $\text{Mem}[\text{address, datasize DIV 8, acctype}]$;
  if signed then
    $X[t]$ = $\text{SignExtend}(data, \text{regsize})$;
  else
    $X[t]$ = $\text{ZeroExtend}(data, \text{regsize})$;

if $\text{wback}$ then
  if $\text{wb\_unknown}$ then
    address = bits(64) UNKNOWN;
  else
    address = $X[n]$;

if ! postindex then
  address = address + offset;

case $\text{memop}$ of
  when $\text{MemOp\_STORE}$
    if $\text{rt\_unknown}$ then
      data = bits(datasize) UNKNOWN;
    else
      $X[t]$ = $\text{Mem}[\text{address, datasize DIV 8, acctype}]$;

  when $\text{MemOp\_LOAD}$
    data = $\text{Mem}[\text{address, datasize DIV 8, acctype}]$;
    if signed then
      $X[t]$ = $\text{SignExtend}(data, \text{regsize})$;
    else
      $X[t]$ = $\text{ZeroExtend}(data, \text{regsize})$;

  when $\text{MemOp\_PREFETCH\_Prefetch}$
    $\text{address, t<4:0>}$;

if $\text{wback}$ then
  if $\text{wb\_unknown}$ then
    address = bits(64) UNKNOWN;
  else
    address = address + offset;

if $n = 31$ then
  if $\text{memop} = \text{MemOp\_STORE}$ then
    $\text{CheckSPA\_Alignment}()$;
  elseif $\text{SP}[]$

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    $\text{CheckSPA\_Alignment}()$;
  elseif $\text{SP}[]$

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  if $\text{memop} = \text{MemOp\_STORE}$ then
    $\text{CheckSPA\_Alignment}()$;
  elseif $\text{SP}[]$

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    $\text{CheckSPA\_Alignment}()$;
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  if $\text{memop} = \text{MemOp\_STORE}$ then
    $\text{CheckSPA\_Alignment}()$;
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    $\text{CheckSPA\_Alignment}()$;
  elseif $\text{SP}[]$

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  if $\text{memop} = \text{MemOp\_STORE}$ then
    $\text{CheckSPA\_Alignment}()$;
  elseif $\text{SP}[]$

if $n = 31$ then
  if $\text{memop} = \text{MemOp\_STORE}$ then
    $\text{CheckSPA\_Alignment}()$;
  elseif $\text{SP}[]$
else
    \( X[n] = \text{address}; \)

Operational information

If PSTATE.DIT is 1, the timing of this instruction is insensitive to the value of the data being loaded or stored.
STTR

Store Register (unprivileged) stores a word or doubleword from a register to memory. The address that is used for the store is calculated from a base register and an immediate offset.

Memory accesses made by the instruction behave as if the instruction was executed at EL0 if the Effective value of PSTATE.UAO is 0 and either:
  • The instruction is executed at EL1.
  • The instruction is executed at EL2 when the Effective value of HCR_EL2.{E2H, TGE} is {1, 1}.

Otherwise, the memory access operates with the restrictions determined by the Exception level at which the instruction is executed. For information about memory accesses, see Load/Store addressing modes.

31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0

<table>
<thead>
<tr>
<th>size</th>
<th>opc</th>
<th>imm9</th>
<th>Rn</th>
<th>Rt</th>
</tr>
</thead>
</table>

32-bit (size == 10)

STTR <Wt>, [<Xn|SP>{, #<simm}>]

64-bit (size == 11)

STTR <Xt>, [<Xn|SP>{, #<simm}>]

boolean wback = FALSE;
boolean postindex = FALSE;
integer scale = UInt(size);
bits(64) offset = SignExtend(imm9, 64);

Assembler Symbols

<Wt> Is the 32-bit name of the general-purpose register to be transferred, encoded in the "Rt" field.
<Xt> Is the 64-bit name of the general-purpose register to be transferred, encoded in the "Rt" field.
<Xn|SP> Is the 64-bit name of the general-purpose base register or stack pointer, encoded in the "Rn" field.
<simm> Is the optional signed immediate byte offset, in the range -256 to 255, defaulting to 0 and encoded in the "imm9" field.
integer n = UInt(Rn);
integer t = UInt(Rt);

unpriv_at_el1 = PSTATE.EL == (Rt) && EL1AccType && !((acctype = EL2Enabled && Acctype_UNPRIV) &&
HaveNVExt() && HCR_EL2.<NV,NV1> == '11');
unpriv_at_el2 = HaveEL(EL2) && HCR_EL2.NE == 1 && HCR_EL2.NU == 1) then
acctype = HaveVirtHostExt() && PSTATE.EL == EL2 && HCR_EL2.<E2H,TGE> == '11';

user_access_override = HaveUAOExt() && PSTATE.UAO == '1';
if !user_access_override && (unpriv_at_el1 || unpriv_at_el2) then
acctype = Acctype_UNPRIV;
else
acctype = Acctype_NORMAL;

MemOp memop;
boolean signed;
integer regsize;

if opc<1> == '0' then
// store or zero-extending load
memop = if opc<0> == '1' then MemOp_LOAD else MemOp_STORE;
regsize = if size == '11' then 64 else 32;
signed = FALSE;
else
if size == '11' then
UNDEFINED;
else
// sign-extending load
memop = if size == '11' then UnallocatedEncoding();
else
// sign-extending load
memop = MemOp_LOAD;
if size == '10' && opc<0> == '1' then UnallocatedEncoding;
if size == '10' && opc<0> == '1' then UNDEFINED;
regsize = if opc<0> == '1' then 32 else 64;
signed = TRUE;

integer datasize = 8 << scale;
if

bits(64) address;
bdata(datasize) data;
boolean wb_unknown = FALSE;
boolean rt_unknown = FALSE;

if memop == HaveMTEExt() then
  boolean is_load_store = memop IN {MemOp STORE, MemOp LOAD};
  SetNotTagCheckedInstruction(is_load_store && n == 31 && !wback);

bits(64) address;
bdata(datasize) data;
boolean wb_unknown = FALSE;
boolean rt_unknown = FALSE;

if memop == MemOp LOAD && wback && n == 31 then
  c = ConstrainUnpredictable(Unpredictable_WBOVERLAPLD);
  assert c IN {Constraint_WBSUPPRESS, Constraint_UNKNOWN, Constraint_UNDEF, Constraint_NOP};
  case c of
    when Constraint_WBSUPPRESS
      wback = FALSE; // writeback is suppressed
    when Constraint_UNKNOWN
      wb_unknown = TRUE; // writeback is UNKNOWN
    when Constraint_UNDEF
      UNDEFINED;
    when UnallocatedEncoding()
    when Constraint_NOP
      EndOfInstruction();

if memop == MemOp STORE && wback && n == 31 then
  c = ConstrainUnpredictable(Unpredictable_WBOVERLAPST);
  assert c IN {Constraint_NONE, Constraint_UNKNOWN, Constraint_UNDEF, Constraint_NOP};
  case c of
    when Constraint_NONE
      rt_unknown = FALSE; // value stored is original value
    when Constraint_UNKNOWN
      rt_unknown = TRUE; // value stored is UNKNOWN
    when Constraint_UNDEF
      UnallocatedEncoding();
    when Constraint_NOP
      EndOfInstruction();

if n == 31 then
  if memop != MemOp_PREFETCH then CheckSPathalignment();
  address = SP[];
else
  address = X[n];

if ! postindex then
  address = address + offset;

case memop of
  when MemOp STORE
    if rt_unknown then
      data = bits(datasize) UNKNOWN;
    else
      data = X[t];
      Mem[address, datasize DIV 8, acctype] = data;
  when MemOp LOAD
    data = Mem[address, datasize DIV 8, acctype];
    if signed then
      X[t] = SignExtend(data, regsize);
    else
      X[t] = ZeroExtend(data, regsize);
    when MemOp_PREFETCH
      Prefetch(address, t<4:0>);

if wback then
  if wb_unknown then
    address = bits(64) UNKNOWN;
  elsif postindex then
    address = address + offset;
  if n == 31 then
    SP[] = address;
else
    X[n] = address;

Operational information

If PSTATE.DIT is 1, the timing of this instruction is insensitive to the value of the data being loaded or stored.
STTRB

Store Register Byte (unprivileged) stores a byte from a 32-bit register to memory. The address that is used for the store is calculated from a base register and an immediate offset.

Memory accesses made by the instruction behave as if the instruction was executed at EL0 if the Effective value of PSTATE.UAO is 0 and either:

- The instruction is executed at EL1.
- The instruction is executed at EL2 when the Effective value of HCR_EL2.{E2H, TGE} is \{1, 1\}.

Otherwise, the memory access operates with the restrictions determined by the Exception level at which the instruction is executed. For information about memory accesses, see Load/Store addressing modes.

### Unscaled offset

```
STTRB <Wt>, [<Xn|SP>{, #<simm>}
```

```java
boolean wback = FALSE;
boolean postindex = FALSE;
integer scale = UInt(size);
bits(64) offset = SignExtend(imm9, 64);
```

### Assembler Symbols

- \(<Wt>\) Is the 32-bit name of the general-purpose register to be transferred, encoded in the "Rt" field.
- \(<Xn|SP>\) Is the 64-bit name of the general-purpose base register or stack pointer, encoded in the "Rn" field.
- \(<simm>\) Is the optional signed immediate byte offset, in the range -256 to 255, defaulting to 0 and encoded in the "imm9" field.
integer n = UInt(Rn);
integer t = UInt(Rt);

unpriv_at_el1 = PSTATE.EL == EL1AccType && !acctype || EL2EnabledAccType_UNPRIV() &
& HaveNVExt() && HCR_EL2.<NV,NV1> == '11';
unpriv_at_el2 = & & HaveEL(EL2) & & HCR_EL2.NU == 1 & & HCR_EL2.NU1 == 1 & &
& HaveVirtHostExt() & & PSTATE.EL == EL2 & & HCR_EL2.<E2H,TGE> == '11';

user_access_override = HaveUAOExt() & & PSTATE.UAO == '1';
if !user_access_override & & (unpriv_at_el1 || unpriv_at_el2) then
    acctype = AccType_UNPRIV;
else
    acctype = AccType_NORMAL;

MemOp memop;
boolean signed;
integer regsize;

if opc<1> == '0' then
    // store or zero-extending load
    memop = if opc<0> == '1' then MemOp_LOAD else MemOp_STORE;
    regsize = if size == '11' then 64 else 32;
    signed = FALSE;
else
    if size == '11' then
        UNDEFINED;
    else
        // sign-extending load
        memop = if size == '11' then UnallocatedEncoding else
    else
        // sign-extending load
        memop = MemOp_LOAD;
        if size == '10' && opc<0> == '1' then UnallocatedEncoding;
        if size == '10' && opc<0> == '1' then UNDEFINED;
        if size == '10' && opc<0> == '1' then UNDEFINED;

        regsize = if opc<0> == '1' then 32 else 64;
        signed = TRUE;

integer datasize = 8 << scale;
if bits(64) address;
bits(datasize) data;
boolean wb_unknown = FALSE;
boolean rt_unknown = FALSE;
if memop == HaveMTEExt() then
  boolean is_load_store = memop IN {MemOp STORE, MemOp LOAD};
  SetNotTagCheckedInstruction(is_load_store && n == 31 && !wback);
bits(64) address;
bits(datasize) data;
boolean wb_unknown = FALSE;
boolean rt_unknown = FALSE;
if memop == MemOp LOAD && wback && n == t && n != 31 then
  c = ConstrainUnpredictable(Unpredictable_WBOVERLAPLD);
  assert c IN {Constraint_WBSUPPRESS, Constraint_UNKNOWN, Constraint_UNDEF, Constraint_NOP};
case c of
    when Constraint_WBSUPPRESS wback = FALSE; // writeback is suppressed
    when Constraint UNKNOWN wb_unknown = TRUE; // writeback is UNKNOWN
    when Constraint_UNDEF rt_unknown = TRUE; // value stored is UNDEFINED;
    when UnallocatedEncoding() EndOfInstruction();
    when Constraint_NOP EndOfInstruction();
if memop == MemOp STORE && wback && n == t && n != 31 then
  c = ConstrainUnpredictable(Unpredictable_WBOVERLAFLD);
  assert c IN {Constraint_NONE, Constraint_UNKNOWN, Constraint_UNDEF, Constraint_NOP};
case c of
    when Constraint_NONE rt_unknown = FALSE; // value stored is original value
    when Constraint_UNKNOWN rt_unknown = TRUE; // value stored is UNKNOWN
    when Constraint_UNDEF EndOfInstruction();
    when Constraint_NOP EndOfInstruction();
if n == 31 then
  if memop != MemOp_PREFETCH then CheckSPAlignment();
  address = SP[];
else
  address = X[n];
if ! postindex then
  address = address + offset;
case memop of
  when MemOp STORE
    if rt_unknown then
      data = bits(datasize) UNKNOWN;
    else
      data = X[t];
      Mem[address, datasize DIV 8, acctype] = data;
    when MemOp LOAD
      data = Mem[address, datasize DIV 8, acctype];
      if signed then
        X[t] = SignExtend(data, regsize);
      else
        X[t] = ZeroExtend(data, regsize);
    when MemOp_PREFETCH
      Prefetch(address, t<4:0>);
if wb unknown then
  address = bits(64) UNKNOWN;
elsif postindex then
  address = address + offset;
if n == 31 then
  SP[] = address;
else

\[ X[n] = \text{address}; \]

**Operational information**

If PSTATE.DIT is 1, the timing of this instruction is insensitive to the value of the data being loaded or stored.
STTRH

Store Register Halfword (unprivileged) stores a halfword from a 32-bit register to memory. The address that is used for the store is calculated from a base register and an immediate offset.

Memory accesses made by the instruction behave as if the instruction was executed at EL0 if the *Effective value* of PSTATE.UAO is 0 and either:
- The instruction is executed at EL1.
- The instruction is executed at EL2 when the *Effective value* of HCR_EL2.{E2H, TGE} is {1, 1}.

Otherwise, the memory access operates with the restrictions determined by the Exception level at which the instruction is executed. For information about memory accesses, see *Load/Store addressing modes*.

| 31  | 30  | 29  | 28  | 27  | 26  | 25  | 24  | 23  | 22  | 21  | 20  | 19  | 18  | 17  | 16  | 15  | 14  | 13  | 12  | 11  | 10  | 9   | 8   | 7   | 6   | 5   | 4   | 3   | 2   | 1   | 0   |
|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| 0   | 1   | 1   | 1   | 0   | 0   | 0   | 0   | 0   | 0   | 0   | imm9| 1   | 0   | Rn  | Rt  |

Unscaled offset

STTRH <Wt>, [<Xn|SP>{, #<simm>}]}

```java
boolean wback = FALSE;
boolean postindex = FALSE;
integer scale = UInt(size);
bits(64) offset = SignExtend(imm9, 64);
```

Assembler Symbols

- `<Wt>` Is the 32-bit name of the general-purpose register to be transferred, encoded in the "Rt" field.
- `<Xn|SP>` Is the 64-bit name of the general-purpose base register or stack pointer, encoded in the "Rn" field.
- `<simm>` Is the optional signed immediate byte offset, in the range -256 to 255, defaulting to 0 and encoded in the "imm9" field.
integer n = UInt(Rn);
integer t = UInt(Rt);

unpriv_at_el1 = PSTATE.EL == EL1AccType && !accType(EL2EnabledAccType_UNPRIV) &&
           HaveNVExt() && HCR_EL2.NV, NV1 == '11';
unpriv_at_el2 = !HaveEL(EL2) && HCR_EL2.NV == 1 && HCR_EL2.NV1 == 1) then
               acctype = HaveVirtHostExt() && PSTATE.EL == EL2 && HCR_EL2.<E2H,TGE> == '11';

user_access_override = HaveUAOExt() && PSTATE.UAO == '1';
if !user_access_override && (unpriv_at_el1 || unpriv_at_el2) then
    acctype = AccType_UNPRIV;
else
    acctype = AccType_NORMAL;

MemOp memop;
boolean signed;
integer regsize;

if opc<1> == '0' then
    // store or zero-extending load
    memop = if opc<0> == '1' then MemOp_LOAD else MemOp_STORE;
    regsize = if size == '11' then 64 else 32;
    signed = FALSE;
else
    if size == '11' then UNDEFINED;
else
    // sign-extending load
    memop = if size == '11' then UnallocatedEncoding();
    if size == '10' && opc<0> == '1' then UNDEFINED;
else
    // sign-extending load
    memop = MemOp_LOAD;
    if size == '10' && opc<0> == '1' then UnallocatedEncoding();
    if size == '10' && opc<0> == '1' then UNDEFINED;

    regsize = if opc<0> == '1' then 32 else 64;
    signed = TRUE;

integer datasize = 8 << scale;
if bits(64) address;
bits(datasize) data;
boolean wb_unknown = FALSE;
boolean rt_unknown = FALSE;

if memop == HaveMTEExt() then
    boolean is_load_store = memop IN {MemOp STORE; MemOp LOAD};
    SetNotTagCheckedInstruction(is_load_store && n == 31 && !wback);

bits(64) address;
bits(datasize) data;
boolean wb_unknown = FALSE;
boolean rt_unknown = FALSE;

if memop == rt wback && t && n != 31 then
    c = Construn predictable(Unpredictable_WBORDERLD);
    assert c IN {Constraint_WBSUPPRESS, Constraint_UNKNOWN, Constraint_UNDEF, Constraint_NOP};
    case c of
        when Constraint_WBSUPPRESS wback = FALSE;       // writeback is suppressed
        when Constraint_UNKNOWN wb_unknown = TRUE;       // writeback is UNKNOWN
        when Constraint_UNDEF rt_unknown = TRUE;        // value stored is UNKNOWN
        when UnallocatedEncoding();
        when Constraint_NOP EndOfInstruction();

if memop == MemOp STORE && wback && t && n != 31 then
    c = Construn predictable(Unpredictable_WBORDERLPST);
    assert c IN {Constraint_NONE, Constraint_UNKNOWN, Constraint_UNDEF, Constraint_NOP};
    case c of
        when Constraint_NONE rt_unknown = FALSE;        // value stored is original value
        when Constraint_UNKNOWN rt_unknown = TRUE;       // value stored is UNKNOWN
        when Constraint_UNDEF UnallocatedEncoding() UNDEFINED;
        when Constraint_NOP EndOfInstruction();

if n == 31 then
    if memop != MemOp_PREFETCH then CheckSPAlignment();
    address = SP[];
else
    address = X[n];

if ! postindex then
    address = address + offset;

case memop of
    when MemOp STORE
        if rt_unknown then
            data = bits(datasize) UNKNOWN;
        else
            data = X[t];
            Mem[address, datasize DIV 8, acctype] = data;
    when MemOp LOAD
        data = Mem[address, datasize DIV 8, acctype];
        if signed then
            X[t] = SignExtend(data, regsize);
        else
            X[t] = ZeroExtend(data, regsize);
    when MemOp_PREFETCHPrefetch(address, t<4:0>);

if wback then
    if wb_unknown then
        address = bits(64) UNKNOWN;
    elsif postindex then
        address = address + offset;
    if n == 31 then
        SP[] = address;
else
    \( X[n] = \text{address}; \)

Operational information

If PSTATE.DIT is 1, the timing of this instruction is insensitive to the value of the data being loaded or stored.
STUR (SIMD&FP)

Store SIMD&FP register (unscaled offset). This instruction stores a single SIMD&FP register to memory. The address that is used for the store is calculated from a base register value and an optional immediate offset.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

8-bit (size == 00 && opc == 00)

STUR <Bt>, [<Xn|SP>?, #<simm>]

16-bit (size == 01 && opc == 00)

STUR <Ht>, [<Xn|SP>?, #<simm>]

32-bit (size == 10 && opc == 00)

STUR <St>, [<Xn|SP>?, #<simm>]

64-bit (size == 11 && opc == 00)

STUR <Dt>, [<Xn|SP>?, #<simm>]

128-bit (size == 00 && opc == 10)

STUR <Qt>, [<Xn|SP>?, #<simm>]

boolean wback = FALSE;
boolean postindex = FALSE;
integer scale = UInt(opc<1>:size);
if scale > 4 then UNDEFINED;
bits(64) offset = if scale > 4 then UnallocatedEncoding();
bits(64) offset = SignExtend(imm9, 64);

Assembler Symbols

<Bt> Is the 8-bit name of the SIMD&FP register to be transferred, encoded in the "Rt" field.
<Dt> Is the 64-bit name of the SIMD&FP register to be transferred, encoded in the "Rt" field.
<Ht> Is the 16-bit name of the SIMD&FP register to be transferred, encoded in the "Rt" field.
<Qt> Is the 128-bit name of the SIMD&FP register to be transferred, encoded in the "Rt" field.
<S> Is the 32-bit name of the SIMD&FP register to be transferred, encoded in the "Rt" field.
<Xn|SP> Is the 64-bit name of the general-purpose base register or stack pointer, encoded in the "Rn" field.
<simm> Is the optional signed immediate byte offset, in the range -256 to 255, defaulting to 0 and encoded in the "imm9" field.

Shared Decode

integer n = UInt(Rn);
integer t = UInt(Rt);
AccType accctype = AccType_VEC;
MemOp memop = if opc<0> == '1' then MemOp_LOAD else MemOp_STORE;
integer datasize = 8 << scale;
Operation

```c
if HaveMTEExt() then
    boolean is_load_store = memop IN {MemOp_STORE, MemOp_LOAD};
    SetNotTagCheckedInstruction(is_load_store && n == 31 && !wback);

CheckFPAdvSIMDEnabled64();
bdirs(64) address;
bits(datasize) data;

if n == 31 then
    CheckSPAlignment();
    address = SP[];
else
    address = X[n];

if ! postindex then
    address = address + offset;

case memop of
    when MemOp_STORE
        data = V[t];
        Mem[address, datasize DIV 8, acctype] = data;
    when MemOp_LOAD
        data = Mem[address, datasize DIV 8, acctype];
        V[t] = data;

if wback then
    if postindex then
        address = address + offset;
    if n == 31 then
        SP[] = address;
    else
        X[n] = address;
```

Operational information

If PSTATE.DIT is 1, the timing of this instruction is insensitive to the value of the data being loaded or stored.
STUR

Store Register (unscaled) calculates an address from a base register value and an immediate offset, and stores a 32-bit word or a 64-bit doubleword to the calculated address, from a register. For information about memory accesses, see Load/Store addressing modes.

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|-----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 1   | x  | 1  | 1  | 0  | 0  | 0  | 0  | 0  | imm9 | 0  | 0  | Rn |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| size| opc|     |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |

32-bit (size == 10)

STUR <Wt>, [<Xn|SP>{, #<simm}>]

64-bit (size == 11)

STUR <Xt>, [<Xn|SP>{, #<simm}>]

boolean wback = FALSE;
boolean postindex = FALSE;
integer scale = UInt(size);
bits(64) offset = SignExtend(imm9, 64);

Assembler Symbols

<Wt> Is the 32-bit name of the general-purpose register to be transferred, encoded in the "Rt" field.
<Xt> Is the 64-bit name of the general-purpose register to be transferred, encoded in the "Rt" field.
<Xn|SP> Is the 64-bit name of the general-purpose base register or stack pointer, encoded in the "Rn" field.
<simm> Is the optional signed immediate byte offset, in the range -256 to 255, defaulting to 0 and encoded in the "imm9" field.
integer n = UInt(Rn);
integer t = UInt(Rt);
AccType acctype = AccType_NORMAL;
MemOp memop;
boolean signed;
integer regsize;

if opc<1> == '0' then
    // store or zero-extending load
    memop = if opc<0> == '1' then MemOp_LOAD else MemOp_STORE;
    regsize = if size == '11' then 64 else 32;
    signed = FALSE;
else
    if size == '11' then
        memop = MemOp_PREFETCH;
        if opc<0> == '1' then UNDEFINED;
    else
        // sign-extending load
        memop = if opc<0> == '1' then UnallocatedEncoding();
        else
            // sign-extending load
            memop = MemOp_LOAD;
            if size == '10' && opc<0> == '1' then UnallocatedEncoding();
            if size == '10' && opc<0> == '1' then UNDEFINED;
        regsize = if opc<0> == '1' then 32 else 64;
        signed = TRUE;

integer datasize = 8 << scale;
if bits(64) address;
bits(datasize) data;
boolean wb_unknown = FALSE;
boolean rt_unknown = FALSE;

if memop == HaveMTEExt() then
    boolean is_load_store = memop IN {MemOp STORE, MemOp LOAD};
    SetNotTagCheckedInstruction(is_load_store && n == 31 && !wback);

bits(64) address;
bits(datasize) data;
boolean wb_unknown = FALSE;
boolean rt_unknown = FALSE;

if memop == MemOp LOAD && wback && n == 31 then
    boolean is_load_store = memop IN {MemOp STORE, MemOp LOAD};
    SetNotTagCheckedInstruction(is_load_store && n == 31 && !wback);

bits(64) address;
bits(datasize) data;
boolean wb_unknown = FALSE;
boolean rt_unknown = FALSE;

if memop == MemOp STORE && wback && n == 31 then
    boolean is_load_store = memop IN {MemOp STORE, MemOp LOAD};
    SetNotTagCheckedInstruction(is_load_store && n == 31 && !wback);

bits(64) address;
bits(datasize) data;
boolean wb_unknown = FALSE;
boolean rt_unknown = FALSE;

if n == 31 then
    if memop != MemOp_PREFETCH then CheckSPAlignment();
    address = SP[];
else
    address = X[n];

if ! postindex then
    address = address + offset;

case memop of
    when MemOp STORE
        if rt_unknown then
            data = bits(datasize) UNKNOWN;
        else
            data = X[t];
        Mem[address, datasize DIV 8, acctype] = data;
    when MemOp LOAD
        data = Mem[address, datasize DIV 8, acctype];
        if signed then
            X[t] = SignExtend(data, regsize);
        else
            X[t] = ZeroExtend(data, regsize);
        when MemOp_PREFETCHPrefetch(address, t<4:0>);

if wback then
    if wb_unknown then
        address = bits(64) UNKNOWN;
    elsif postindex then
        address = address + offset;
    if n == 31 then
        SP[] = address;
else
	X[n] = address;

Operational information

If PSTATE.DIT is 1, the timing of this instruction is insensitive to the value of the data being loaded or stored.
STURB

Store Register Byte (unscaled) calculates an address from a base register value and an immediate offset, and stores a byte to the calculated address, from a 32-bit register. For information about memory accesses, see Load/Store addressing modes.

### Unscaled offset

\[
\text{STURB} <Wt>, [<Xn|SP>], #<\text{simm}>]
\]

boolean wback = FALSE;
boolean postindex = FALSE;
integer scale = UInt(size);
bits(64) offset = SignExtend(imm9, 64);

### Assembler Symbols

- `<Wt>`: Is the 32-bit name of the general-purpose register to be transferred, encoded in the "Rt" field.
- `<Xn|SP>`: Is the 64-bit name of the general-purpose base register or stack pointer, encoded in the "Rn" field.
- `<\text{simm}>`: Is the optional signed immediate byte offset, in the range -256 to 255, defaulting to 0 and encoded in the "imm9" field.

### Shared Decode

```plaintext
integer n = UInt(Rn);
integer t = UInt(Rt);
AccType acctype = AccType_NORMAL;
MemOp memop;
boolean signed;
integer regsize;
if opc<1> == '0' then
    // store or zero-extending load
    memop = if opc<0> == '1' then MemOp_LOAD else MemOp_STORE;
    regsize = if size == '11' then 64 else 32;
    signed = FALSE;
else
    if size == '11' then
        memop = MemOp_PREFETCH;
        if opc<0> == '1' then UNDEFINED;
    else
        // sign-extending load
        memop = if opc<0> == '1' then UnallocatedEncoding() else
        else
            // sign-extending load
            memop = if opc<0> == '1' then UnallocatedEncoding() else
            else
                // sign-extending load
                memop = if opc<0> == '1' then UnallocatedEncoding() else
                else
                    // sign-extending load
                    memop = if size == '10' && opc<0> == '1' then UnallocatedEncoding() else
                    else
                        // sign-extending load
                        memop = if size == '10' && opc<0> == '1' then UnallocatedEncoding() else
                        else
                            // sign-extending load
                            memop = if opc<0> == '1' then 32 else 64;
                            signed = TRUE;

integer datasize = 8 << scale;
```
if bits(64) address;
binary datasize) data;
boolean wb_unknown = FALSE;
boolean rt_unknown = FALSE;

if memop == MemOp_STORE then
    is_load_store = memop IN {MemOp STORE, MemOp LOAD};
    SetNotTagCheckedInstruction(is_load_store & n == 31 & wback);

bits(64) address;
bits(datasize) data;
boolean wb_unknown = FALSE;
boolean rt_unknown = FALSE;

if memop == MemOp_LOAD & wback & n == 31 then
    c = ConstrainUnpredictable(Unpredictable_WBOVERLAPLD);
    assert c IN {Constraint_WBSUPPRESS, Constraint_UNKNOWN, Constraint_UNDEF, Constraint_NOP};
    case c of
        when Constraint_WBSUPPRESS wback = FALSE; // writeback is suppressed
        when Constraint_UNKNOWN wb_unknown = TRUE; // writeback is UNKNOWN
        when Constraint_UNDEF rt_unknown = TRUE; // value stored is UNKNOWN
        when UnallocatedEncoding() EndOfInstruction();
        when Constraint_NOP EndOfInstruction();

if memop == MemOp_PREFETCH then
    MemPreFetch(address, t<4:0>);
    if wback then
        if wb_unknown then
            address = bits(64) UNKNOWN;
        elsif postindex then
            address = address + offset;
        if n == 31 then
            SP[] = address;
else

X[n] = address;

Operational information

If PSTATE.DIT is 1, the timing of this instruction is insensitive to the value of the data being loaded or stored.
STURH

Store Register Halfword (unscaled) calculates an address from a base register value and an immediate offset, and stores a halfword to the calculated address, from a 32-bit register. For information about memory accesses, see Load/Store addressing modes.

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9  | 8  | 7  | 6  | 5  | 4  | 3  | 2  | 1  | 0  |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0  | 1  | 1  | 1  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | imm9 | 0  | 0  | Rn  | Rt  |

**Unscaled offset**

STURH `<Wt>`, `[<Xn|SP>{, #<simm>}]`

```java
boolean wback = FALSE;
boolean postindex = FALSE;
integer scale = UInt(size);
bits(64) offset = SignExtend(imm9, 64);
```

**Assembler Symbols**

`<Wt>`  
Is the 32-bit name of the general-purpose register to be transferred, encoded in the "Rt" field.

`<Xn|SP>`  
Is the 64-bit name of the general-purpose base register or stack pointer, encoded in the "Rn" field.

`<simm>`  
Is the optional signed immediate byte offset, in the range -256 to 255, defaulting to 0 and encoded in the "imm9" field.

**Shared Decode**

```java
integer n = UInt(Rn);
integer t = UInt(Rt);
AccType acctype = AccType_NORMAL;
MemOp memop;
boolean signed;
integer regsize;

if opc<1> == '0' then
  // store or zero-extending load
  memop = if opc<0> == '1' then MemOp_LOAD else MemOp_STORE;
  regsize = if size == '11' then 64 else 32;
  signed = FALSE;
else
  if size == '11' then
    memop = MemOp_PREFETCH;
  else
    if opc<0> == '1' then UNDEFINED;
    else
      // sign-extending load
      memop = if opc<0> == '1' then UnallocatedEncoding();
    else
      // sign-extending load
      memop = MemOp_LOAD;
      if size == '10' && opc<0> == '1' then UnallocatedEncoding();
      if size == '10' && opc<0> == '1' then UNDEFINED;
      regsize = if opc<0> == '1' then 32 else 64;
      signed = TRUE;

integer datasize = 8 << scale;
```

STURH
if memop == MemOp_PREFETCH then
    CheckSPLocation();
    address = SP[];
else
    address = X[n];
if ! postindex then
    address = address + offset;

    case memop of
        when MemOp_STORE
            if rt_unknown then
                data = bits(datasize) UNKNOWN;
            else
                data = X[t];
            Mem[address, datasize DIV 8, acctype] = data;
        when MemOp_LOAD
            data = Mem[address, datasize DIV 8, acctype];
            if signed then
                X[t] = SignExtend(data, regsize);
            else
                X[t] = ZeroExtend(data, regsize);
        when MemOp_PREFETCH
            Prefetch(address, t<4:0>);
if wback then
    if wb_unknown then
        address = bits(64) UNKNOWN;
    elsif postindex then
        address = address + offset;
    if n == 31 then
        SP[] = address;
else
    \( X[n] = \text{address}; \)

Operational information

If PSTATE.DIT is 1, the timing of this instruction is insensitive to the value of the data being loaded or stored.

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STXP

Store Exclusive Pair of registers stores two 32-bit words or two 64-bit doublewords from two registers to a memory location if the PE has exclusive access to the memory address, and returns a status value of 0 if the store was successful, or of 1 if no store was performed. See Synchronization and semaphores. A 32-bit pair requires the address to be doubleword aligned and is single-copy atomic at doubleword granularity. A 64-bit pair requires the address to be quadword aligned and, if the Store-Exclusive succeeds, it causes a single-copy atomic update of the 128-bit memory location being updated. For information about memory accesses see Load/Store addressing modes.

32-bit (sz == 0)

STXP <Ws>, <Wt1>, <Wt2>, [<Xn|SP>{,0}]

64-bit (sz == 1)

STXP <Ws>, <Xt1>, <Xt2>, [<Xn|SP>{,0}]

integer n = UInt(Rn);
integer t = UInt(Rt);
integer t2 = UInt(Rt2); // ignored by load/store single register
integer s = UInt(Rs);   // ignored by all loads and store-release
AccType accctype = if o0 == 'l' then AccType_ORDERED_ATOMIC else AccType_ATOMIC;
boolean pair = TRUE;
MemOp memop = if L == 'l' then MemOp_LOAD else MemOp_STORE;
integer elsize = 32 << UInt(sz);
integer datasize = if pair then elsize * 2 else elsize;

For information about the CONSTRAINED UNPREDICTABLE behavior of this instruction, see Architectural Constraints on UNPREDICTABLE behaviors, and particularly STXP.

Assembler Symbols

<Ws> Is the 32-bit name of the general-purpose register into which the status result of the store exclusive is written, encoded in the "Rs" field. The value returned is:

0 If the operation updates memory.

1 If the operation fails to update memory.

<Xt1> Is the 64-bit name of the first general-purpose register to be transferred, encoded in the "Rt" field.

<Xt2> Is the 64-bit name of the second general-purpose register to be transferred, encoded in the "Rt2" field.

<Wt1> Is the 32-bit name of the first general-purpose register to be transferred, encoded in the "Rt" field.

<Wt2> Is the 32-bit name of the second general-purpose register to be transferred, encoded in the "Rt2" field.

<Xn|SP> Is the 64-bit name of the general-purpose base register or stack pointer, encoded in the "Rt" field.

Aborts and alignment

If a synchronous Data Abort exception is generated by the execution of this instruction:

- Memory is not updated.
- <Ws> is not updated.

Accessing an address that is not aligned to the size of the data being accessed causes an Alignment fault Data Abort exception to be generated, subject to the following rules:

- If AArch64.ExclusiveMonitorsPass() returns TRUE, the exception is generated.
- Otherwise, it is IMPLEMENTATION DEFINED whether the exception is generated.
If AArch64.ExclusiveMonitorsPass() returns FALSE and the memory address, if accessed, would generate a synchronous Data Abort exception, it is IMPLEMENTATION DEFINED whether the exception is generated.
bits(64) address;
bits(datasize) data;
constant integer dbytes = datasize DIV 8;
boolean rt_unknown = FALSE;
boolean rn_unknown = FALSE;

if memop == MemOp_STORE then
    boolean is_load_store = memop IN {MemOp STORE, MemOp LOAD};
    SetNotTagCheckedInstruction(is_load_store && n == 31);
if memop == MemOp LOAD && pair && t == t2 then
    Constraint c = ConstrainUnpredictable(Unpredictable_LDPOVERLAP);
    assert c IN {Constraint_UNKNOWN, Constraint_UNDEF, Constraint_NOP};
    case c of
        when Constraint_UNKNOWN rt_unknown = TRUE;  // result is UNKNOWN
        when Constraint_UNDEF UNDEFINED;
        when Constraint_NOP EndOfInstruction();
if memop == MemOp_STORE then
    if s == t || (pair && s == t2) then
        Constraint c = ConstrainUnpredictable(Unpredictable_DATAOVERLAP);
        assert c IN {Constraint_UNKNOWN, Constraint_NONE, Constraint_UNDEF, Constraint_NOP};
        case c of
            when Constraint_UNKNOWN rt_unknown = TRUE;  // store UNKNOWN value
            when Constraint_UNDEF rt_unknown = FALSE;  // store original value
            when Constraint_NOP UNDEFINED;
        end;
        when Constraint_NOP EndOfInstruction();
    if s == n && n != 31 then
        Constraint c = ConstrainUnpredictable(Unpredictable_BASEOVERLAP);
        assert c IN {Constraint_UNKNOWN, Constraint_NONE, Constraint_UNDEF, Constraint_NOP};
        case c of
            when Constraint_UNKNOWN rn_unknown = TRUE;  // address is UNKNOWN
            when Constraint_UNDEF rn_unknown = FALSE;  // address is original base
            when Constraint_UNDEF unallocatedencoding UNDEFINED;
        end;
        when Constraint_NOP EndOfInstruction();
if n == 31 then
    CheckSPAlignment();
    address = SP[];
elsif rn_unknown then
    address = bits(64) UNKNOWN;
else
    address = X[n];
case memop of
    when MemOp_STORE
        if rt_unknown then
            data = bits(datasize) UNKNOWN;
        elsif pair then
            bits(datasize DIV 2) el1 = X[t];
            bits(datasize DIV 2) el2 = X[t2];
            data = if BigEndian() then el1 : el2 else el2 : el1;
        else
            data = X[t];
        bit status = '1';
        // Check whether the Exclusives monitors are set to include the
        // physical memory locations corresponding to virtual address
        // range [address, address+dbytes-1].
        if AArch64.ExclusiveMonitorsPass(address, dbytes) then
            // This atomic write will be rejected if it does not refer
            // to the same physical locations after address translation.
            Mem[address, dbytes, acctype] = data;
            status = ExclusiveMonitorsStatus();
            X[s] = ZeroExtend(status, 32);
    when MemOp LOAD
Tell the Exclusives monitors to record a sequence of one or more atomic memory reads from virtual address range [address, address+dbytes-1]. The Exclusives monitor will only be set if all the reads are from the same dbytes-aligned physical address, to allow for the possibility of an atomicity break if the translation is changed between reads.

```
AArch64.SetExclusiveMonitors(address, dbytes);
```

if pair then
  
  if rt_unknown then
    // ConstrainedUNPREDICTABLE case
    \[t\] = bits(datasize) UNKNOWN;
  elsif elsize == 32 then
    // 32-bit load exclusive pair (atomic)
    data = Mem[address, dbytes, acctype];
    if BigEndian() then
      \[t\] = data<datasize-1:elsize>;
      \[t2\] = data<elsize-1:0>;
    else
      \[t\] = data<elsize-1:0>;
      \[t2\] = data<datasize-1:elsize>;
    end
  else // elsize == 64
    // 64-bit load exclusive pair (not atomic), but must be 128-bit aligned
    if address != Align(address, dbytes) then
      iswrite = FALSE;
      secondstage = FALSE;
      AArch64.Abort(address, AArch64.AlignmentFault(acctype, iswrite, secondstage));
      \[t\] = Mem[address + 0, 8, acctype];
      \[t2\] = Mem[address + 8, 8, acctype];
    else
      data = Mem[address, dbytes, acctype];
      \[t\] = ZeroExtend(data, regsize);
  end

Operational information

If PSTATE.DIT is 1, the timing of this instruction is insensitive to the value of the data being loaded or stored.

### Operational information

If PSTATE.DIT is 1, the timing of this instruction is insensitive to the value of the data being loaded or stored.

---

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STXR

Store Exclusive Register stores a 32-bit word or a 64-bit doubleword from a register to memory if the PE has exclusive access to the memory address, and returns a status value of 0 if the store was successful, or of 1 if no store was performed. See Synchronization and semaphores. For information about memory accesses see Load/Store addressing modes.

32-bit (size == 10)

\[
\text{STXR } <Ws>, <Wt>, [<Xn|SP>{,#0}]
\]

64-bit (size == 11)

\[
\text{STXR } <Ws>, <Xt>, [<Xn|SP>{,#0}]
\]

integer n = UInt(Rn);
integer t = UInt(Rt);
integer t2 = UInt(Rt2); // ignored by load/store single register
integer s = UInt(Rs);   // ignored by all loads and store-release

AccType axtype = if o0 == '1' then AccType ORDERED_ATOMIC else AccType_ATOMIC;
boolean pair = FALSE;
MemOp memop = if L == '1' then MemOp_LOAD else MemOp_STORE;
integer elsize = 8 << UInt(size);
integer datasize = if pair then elsize * 2 else elsize;

For information about the CONSTRAINED UNPREDICTABLE behavior of this instruction, see Architectural Constraints on UNPREDICTABLE behaviors, and particularly STXR.

Assembler Symbols

\(<Ws>\)
Is the 32-bit name of the general-purpose register into which the status result of the store exclusive is written, encoded in the "Rs" field. The value returned is:

0     If the operation updates memory.

1     If the operation fails to update memory.

\(<Xt>\)
Is the 64-bit name of the general-purpose register to be transferred, encoded in the "Rt" field.

\(<Wt>\)
Is the 32-bit name of the general-purpose register to be transferred, encoded in the "Rt" field.

\(<Xn|SP>\)
Is the 64-bit name of the general-purpose base register or stack pointer, encoded in the "Rn" field.

Aborts and alignment
If a synchronous Data Abort exception is generated by the execution of this instruction:

• Memory is not updated.
• <Ws> is not updated.

Accessing an address that is not aligned to the size of the data being accessed causes an Alignment fault Data Abort exception to be generated, subject to the following rules:

• If AArch64.ExclusiveMonitorsPass() returns TRUE, the exception is generated.
• Otherwise, it is IMPLEMENTATION DEFINED whether the exception is generated.

If AArch64.ExclusiveMonitorsPass() returns FALSE and the memory address, if accessed, would generate a synchronous Data Abort exception, it is IMPLEMENTATION DEFINED whether the exception is generated.
bits(64) address;
bits(datasize) data;
constant integer dbytes = datasize DIV 8;
boolean rt_unknown = FALSE;
boolean rn_unknown = FALSE;

if memop == HaveMTEExt() then
  boolean is_load_store = memop IN {MemOp STORE, MemOp LOAD};
  SetNotTagCheckedInstruction(is_load_store && n == 31);

if memop == MemOp LOAD && pair && t == t2 then
  Constraint c = ConstrainUnpredictable(Unpredictable_LDPOVERLAP);
  assert c IN {Constraint_UNKNOWN, Constraint_UNDEF, Constraint_NOP};
  case c of
    when Constraint_UNKNOWN rt_unknown = TRUE; // result is UNKNOWN
    when Constraint_UNDEF UNDEFINED;
    when Constraint_NOP EndOfInstruction();
  end;

if memop == MemOp STORE then
  if s == t || (pair && s == t2) then
    Constraint c = ConstrainUnpredictable(Unpredictable_DATAOVERLAP);
    assert c IN {Constraint_UNKNOWN, Constraint_NONE, Constraint_UNDEF, Constraint_NOP};
    case c of
      when Constraint_UNKNOWN rt_unknown = TRUE; // store UNKNOWN value
      when Constraint_NONE rt_unknown = FALSE; // store original value
      when Constraint_UNDEF UNDEFINED;
      when Constraint_NOP EndOfInstruction();
    end;
    if s == n && n != 31 then
      Constraint c = ConstrainUnpredictable(Unpredictable_BASEOVERLAP);
      assert c IN {Constraint_UNKNOWN, Constraint_NONE, Constraint_UNDEF, Constraint_NOP};
      case c of
        when Constraint_UNKNOWN rn_unknown = TRUE; // address is UNKNOWN
        when Constraint_NONE rn_unknown = FALSE; // address is original base
        when Constraint_UNDEF UnallocatedEncoding();
        when Constraint_NOP EndOfInstruction();
      end;
    end;

if n == 31 then
  CheckSPAlignment();
  address = SP[];
elsif rn_unknown then
  address = bits(64) UNKNOWN;
else
  address = X[n];

  case memop of
    when MemOp STORE
      if rt_unknown then
        data = bits(datasize) UNKNOWN;
      elsif pair then
        bits(datasize DIV 2) el1 = X[t];
        bits(datasize DIV 2) el2 = X[t2];
        data = if BigEndian() then el1 : el2 else el2 : el1;
      else
        data = X[t];

      bit status = '1';
      // Check whether the Exclusives monitors are set to include the
      // physical memory locations corresponding to virtual address
      // range [address, address+dbytes-1].
      if AArch64.ExclusiveMonitorsPass(address, dbytes) then
        // This atomic write will be rejected if it does not refer
        // to the same physical locations after address translation.
        Mem[address, dbytes, acctype] = data;
        status = ExclusiveMonitorsStatus();
        X[s] = ZeroExtend(status, 32);
      end;
    when MemOp LOAD

// Tell the Exclusives monitors to record a sequence of one or more atomic
// memory reads from virtual address range [address, address+dbytes-1].
// The Exclusives monitor will only be set if all the reads are from the
// same dbytes-aligned physical address, to allow for the possibility of
// an atomicity break if the translation is changed between reads.
AArch64.SetExclusiveMonitors(address, dbytes);

if pair then
  if rt_unknown then
    // ConstrainedUNPREDICTABLE case
    X[t]  = bits(datasize) UNKNOWN;
  elsif elsize == 32 then
    // 32-bit load exclusive pair (atomic)
    data = Mem[address, dbytes, acctype];
    if BigEndian() then
      X[t]  = data<datasize-1:elsize>;
      X[t2] = data<elsize-1:0>;
    else
      X[t]  = data<elsize-1:0>;
      X[t2] = data<datasize-1:elsize>;
  else // elsize == 64
    // 64-bit load exclusive pair (not atomic),
    // but must be 128-bit aligned
    if address != Align(address, dbytes) then
      iswrite = FALSE;
      secondstage = FALSE;
      AArch64.Abort(address, AArch64.AlignmentFault(acctype, iswrite, secondstage));
    else
      data = Mem[address, dbytes, acctype];
      X[t]  = Mem[address + 0, 8, acctype];
      X[t2] = Mem[address + 8, 8, acctype];
  end
end

X[t]  = ZeroExtend(data, regsize);

Operational information

If PSTATE.DIT is 1, the timing of this instruction is insensitive to the value of the data being loaded or stored.
STXRB

Store Exclusive Register Byte stores a byte from a register to memory if the PE has exclusive access to the memory address, and returns a status value of 0 if the store was successful, or of 1 if no store was performed. See Synchronization and semaphores. The memory access is atomic.

For information about memory accesses see Load/Store addressing modes.

No offset

```plaintext
STXRB <Ws>, <Wt>, [<Xn|SP>{,#0}]
```

```plaintext
integer n = UInt(Rn);
integer t = UInt(Rt);
integer t2 = UInt(Rt2); // ignored by load/store single register
integer s = UInt(Rs);   // ignored by all loads and store-release

AccType acctype = if o0 == '1' then AccType_ORDERED_ATOMIC else AccType_ATOMIC;
boolean pair = FALSE;
MemOp memop = if L == '1' then MemOp_LOAD else MemOp_STORE;
integer elsize = 8 << UInt(size);
integer regsize = if elsize == 64 then 64 else 32;
integer datasize = if pair then elsize * 2 else elsize;
```

For information about the CONSTRAINED UNPREDICTABLE behavior of this instruction, see Architectural Constraints on UNPREDICTABLE behaviors, and particularly STXRB.

Assembler Symbols

```plaintext
<Ws>          Is the 32-bit name of the general-purpose register into which the status result of the store exclusive is written, encoded in the "Rs" field. The value returned is:
0            If the operation updates memory.
1            If the operation fails to update memory.

<Wt>          Is the 32-bit name of the general-purpose register to be transferred, encoded in the "Rt" field.

<Xn|SP>       Is the 64-bit name of the general-purpose base register or stack pointer, encoded in the "Rn" field.
```

Aborts

If a synchronous Data Abort exception is generated by the execution of this instruction:

- Memory is not updated.
- <Ws> is not updated.

If AArch64.ExclusiveMonitorsPass() returns FALSE and the memory address, if accessed, would generate a synchronous Data Abort exception, it is IMPLEMENTATION DEFINED whether the exception is generated.
bits(64) address;
bits(datasize) data;
constant integer dbytes = datasize DIV 8;
boolean rt_unknown = FALSE;
boolean rn_unknown = FALSE;

if memop == HaveMTEExt() then
    boolean is_load_store = memop IN {MemOp STORE, MemOp LOAD};
    SetNotTagCheckedInstruction(is_load_store & n == 31);

if memop == MemOp LOAD & pair & t == t2 then
    Constraint c = ConstrainUnpredictable(Unpredictable_LDPOVERLAP);
    assert c IN {Constraint_UNKNOWN, Constraint_UNDEF, Constraint_NOP};
    when Constraint_UNKNOWN rt_unknown = TRUE;
    when Constraint_UNDEF UNDEFINED;
    when UnallocatedEncoding();
    when Constraint_NOP EndOfInstruction();

if memop == MemOp STORE then
    if s == t || (pair & & s == t2) then
        Constraint c = ConstrainUnpredictable(Unpredictable_DATAOVERLAP);
        assert c IN {Constraint_UNKNOWN, Constraint_NONE, Constraint_UNDEF, Constraint_NOP};
        when Constraint_UNKNOWN rt_unknown = TRUE;
        when Constraint_NONE rt_unknown = FALSE;
        when Constraint_UNDEF UNDEFINED;
        when UnallocatedEncoding();
        when Constraint_NOP EndOfInstruction();
    if s == n & n != 31 then
        Constraint c = ConstrainUnpredictable(Unpredictable_BASEOVERLAP);
        assert c IN {Constraint_UNKNOWN, Constraint_NONE, Constraint_UNDEF, Constraint_NOP};
        when Constraint_UNKNOWN rn_unknown = TRUE;
        when Constraint_NONE rn_unknown = FALSE;
        when Constraint_UNDEF UNDEFINED;
    else
        when Constraint_NOP EndOfInstruction();

if n == 31 then
    CheckSPAlignment();
    address = SP[];
elsif rn_unknown then
    address = bits(64) UNKNOWN;
else
    address = X[n];

case memop of
    when MemOp STORE
        if rt_unknown then
            data = bits(datasize) UNKNOWN;
        elsif pair then
            bits(datasize DIV 2) el1 = X[t];
            bits(datasize DIV 2) el2 = X[t2];
            data = if BigEndian() then el1 : el2 else el2 : el1;
        else
            data = X[t];
        bit status = '1';
        // Check whether the Exclusives monitors are set to include the
        // physical memory locations corresponding to virtual address
        // range [address, address+dbytes-1].
        if AArch64.ExclusiveMonitorsPass(address, dbytes) then
            // This atomic write will be rejected if it does not refer
            // to the same physical locations after address translation.
            Mem[address, dbytes, acctype] = data;
            status = ExclusiveMonitorsStatus();
            X[s] = ZeroExtend(status, 32);
        when MemOp LOAD
// Tell the Exclusives monitors to record a sequence of one or more atomic
// memory reads from virtual address range [address, address+dbytes-1].
// The Exclusives monitor will only be set if all the reads are from the
// same dbytes-aligned physical address, to allow for the possibility of
// an atomicity break if the translation is changed between reads.
AArch64.SetExclusive Monitors(address, dbytes);

if pair then
  if rt_unknown then
    // ConstrainedUNPREDICTABLE case
    X[t] = bits(datasize) UNKNOWN;
  elsif elsize == 32 then
    // 32-bit load exclusive pair (atomic)
    data = Mem[address, dbytes, acctype];
    if BigEndian() then
      X[t] = data<datasize-1:elsize>;
      X[t2] = data<elsize-1:0>;
    else
      X[t] = data<elsize-1:0>;
      X[t2] = data<datasize-1:elsize>;
    else // elsize == 64
      // 64-bit load exclusive pair (not atomic),
      // but must be 128-bit aligned
      if address != Align(address, dbytes) then
        iswrite = FALSE;
        secondstage = FALSE;
        AArch64.Abort(address, AArch64.AlignmentFault(acctype, iswrite, secondstage));
      X[t] = Mem[address + 0, 8, acctype];
      X[t2] = Mem[address + 8, 8, acctype];
    else
      data = Mem[address, dbytes, acctype];
      X[t] = ZeroExtend(data, regsize);
  end

Operational information

If PSTATE.DIT is 1, the timing of this instruction is insensitive to the value of the data being loaded or stored.

Operational information

If PSTATE.DIT is 1, the timing of this instruction is insensitive to the value of the data being loaded or stored.
STXRH

Store Exclusive Register Halfword stores a halfword from a register to memory if the PE has exclusive access to the memory address, and returns a status value of 0 if the store was successful, or of 1 if no store was performed. See Synchronization and semaphores. The memory access is atomic.

For information about memory accesses see Load/Store addressing modes.

No offset

```
STXRH <Ws>, <Wt>, [<Xn|SP>{,#0}]
```

integer n = UInt(Rn);
integer t = UInt(Rt);
integer t2 = UInt(Rt2); // ignored by load/store single register
integer s = UInt(Rs);   // ignored by all loads and store-release

```
AccType acctype = if o0 == '1' then AccType_ORDEREDATOMIC else AccType_ATOMIC;
boolean pair = FALSE;
MemOp memop = if L == '1' then MemOp_LOAD else MemOp_STORE;
integer elsize = 8 << UInt(size);
integer regsize = if elsize == 64 then 64 else 32;
integer datasize = if pair then elsize * 2 else elsize;
```

Assembler Symbols

<Ws> Is the 32-bit name of the general-purpose register into which the status result of the store exclusive is written, encoded in the "Rs" field. The value returned is:

0 If the operation updates memory.

1 If the operation fails to update memory.

<Wt> Is the 32-bit name of the general-purpose register to be transferred, encoded in the "Rt" field.

<Xn|SP> Is the 64-bit name of the general-purpose base register or stack pointer, encoded in the "Rn" field.

Aborts and alignment

If a synchronous Data Abort exception is generated by the execution of this instruction:

- Memory is not updated.
- <Ws> is not updated.

A non halfword-aligned memory address causes an Alignment fault Data Abort exception to be generated, subject to the following rules:

- If AArch64.ExclusiveMonitorsPass() returns TRUE, the exception is generated.
- Otherwise, it is IMPLEMENTATION DEFINED whether the exception is generated.

If AArch64.ExclusiveMonitorsPass() returns FALSE and the memory address, if accessed, would generate a synchronous Data Abort exception, it is IMPLEMENTATION DEFINED whether the exception is generated.
bits(64) address;
bits(datasize) data;
constant integer dbytes = datasize DIV 8;
boolean rt_unknown = FALSE;
boolean rn_unknown = FALSE;

if memop == HaveMTEExt() then
    boolean is_load_store = memop IN {MemOp STORE, MemOp LOAD};
    SetNotTagCheckedInstruction(is_load_store && n == 31);

if memop == MemOp LOAD && pair && t == t2 then
    Constraint c = ConstrainUnpredictable(Unpredictable LDPOVERLAP);
    assert c IN {Constraint UNKNOWN, Constraint_UNDEF, Constraint_NOP};
    case c of
        when Constraint UNKNOWN     rt_unknown = TRUE;    // result is UNKNOWN
        when Constraint_UNDEF        rt_unknown = FALSE;  // store original value
        when Constraint_NOP          rt_unknown = TRUE;    // result is UNKNOWN
    EndOfInstruction();

if memop == MemOp STORE then
    if s == t || (pair && s == t2) then
        Constraint c = ConstrainUnpredictable(Unpredictable DATAOVERLAP);
        assert c IN {Constraint UNKNOWN, Constraint_NONE, Constraint_UNDEF, Constraint_NOP};
        case c of
            when Constraint UNKNOWN     rt_unknown = TRUE;    // store UNKNOWN value
            when Constraint_UNDEF        rt_unknown = FALSE;  // store original value
            when Constraint_NOP          rt_unknown = TRUE;    // store UNKNOWN value
            when Constraint_NONE         rt_unknown = FALSE;  // store original value
        EndOfInstruction();

if n == 31 then
    CheckSPAlignment();
    address = SP[];
elsif rn_unknown then
    address = bits(64) UNKNOWN;
else
    address = X[n];

case memop of
    when MemOp STORE
        if rt_unknown then
            data = bits(datasize) UNKNOWN;
        elsif pair then
            bits(datasize DIV 2) e1l = X[t];
            bits(datasize DIV 2) e12 = X[t2];
            data = if BigEndian() then e1l : e12 else e2 : e12;
        else
            data = X[t];
    end case

    bit status = '1';
    // Check whether the Exclusives monitors are set to include the
    // physical memory locations corresponding to virtual address
    // range [address, address+dbytes-1].
    if AArch64.ExclusiveMonitorsPass(address, dbytes) then
        // This atomic write will be rejected if it does not refer
        // to the same physical locations after address translation.
        Mem[address, dbytes, acctype] = data;
        status = ExclusiveMonitorsStatus();
        X[s] = ZeroExtend(status, 32);
    end case

when MemOp LOAD
// Tell the Exclusives monitors to record a sequence of one or more atomic
// memory reads from virtual address range [address, address+dbytes-1].
// The Exclusives monitor will only be set if all the reads are from the
// same dbytes-aligned physical address, to allow for the possibility of
// an atomicity break if the translation is changed between reads.
AArch64.SetExclusiveMonitors(address, dbytes);

if pair then
  if rt_unknown then
    // ConstrainedUNPREDICTABLE case
    X[t] = bits(datasize) UNKNOWN;
  elsif elsize == 32 then
    // 32-bit load exclusive pair (atomic)
    data = Mem[address, dbytes, acctype];
    if BigEndian() then
      X[t] = data<datasize-1:elsize>;
      X[t2] = data<elsize-1:0>;
    else
      X[t] = data<elsize-1:0>;
      X[t2] = data<datasize-1:elsize>;
    end
  else // elsize == 64
    // 64-bit load exclusive pair (not atomic),
    // but must be 128-bit aligned
    if address != Align(address, dbytes) then
      iswrite = FALSE;
      secondstage = FALSE;
      AArch64.Abort(address, AArch64.AlignmentFault(acctype, iswrite, secondstage));
    end
    X[t] = Mem[address + 0, 8, acctype];
    X[t2] = Mem[address + 8, 8, acctype];
  end // elsize == 64
end // pair

Operational information

If PSTATE.DIT is 1, the timing of this instruction is insensitive to the value of the data being loaded or stored.
STZ2G

Store Allocation Tags, Zeroing stores an Allocation Tag to two Tag granules of memory, zeroing the associated data locations. The address used for the store is calculated from the source register and an immediate signed offset scaled by the Tag granule. The Allocation Tag is calculated from the Logical Address Tag in the source register. This instruction generates an Unchecked access.

It has encodings from 3 classes: Post-index, Pre-index and Signed offset.

**Post-index**

(ARMv8.5)

| 31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0 |
| 1 1 0 1 1 0 0 1 1 1 1 | imm9 | 0 1 | Xn | (1) (1) (1) (1) |
| (1)(1)(1)(1)(1) |

**Post-index**

STZ2G [<Xn|SP>], #<simm>

```java
integer n = UInt(Xn);
bits(64) offset = LSL(SignExtend(imm9, 64), LOG2_TAG_GRANULE);
boolean writeback = TRUE;
boolean postindex = TRUE;
boolean zero_data = TRUE;
```

**Pre-index**

(ARMv8.5)

| 31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0 |
| 1 1 0 1 1 0 0 1 1 1 1 | imm9 | 1 1 | Xn | (1) (1) (1) (1) |
| (1)(1)(1)(1)(1) |

**Pre-index**

STZ2G [<Xn|SP>], #<simm>!

```java
integer n = UInt(Xn);
bits(64) offset = LSL(SignExtend(imm9, 64), LOG2_TAG_GRANULE);
boolean writeback = TRUE;
boolean postindex = FALSE;
boolean zero_data = TRUE;
```

**Signed offset**

(ARMv8.5)

| 31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0 |
| 1 1 0 1 1 0 0 1 1 1 1 | imm9 | 1 0 | Xn | (1) (1) (1) (1) |
| (1)(1)(1)(1)(1) |

**Signed offset**

STZ2G [<Xn|SP>], #<simm>]

```java
integer n = UInt(Xn);
bits(64) offset = LSL(SignExtend(imm9, 64), LOG2_TAG_GRANULE);
boolean writeback = FALSE;
boolean postindex = FALSE;
boolean zero_data = TRUE;
```
Assembler Symbols

<Xn|SP> Is the 64-bit name of the general-purpose base register or stack pointer, encoded in the "Xn" field.

<simm> Is the optional signed immediate offset, a multiple of 16 in the range -4096 to 4080, defaulting to 0 and encoded in the "imm9" field.

Operation

```c
bits(64) address;
bites(4) tag;

SetNotTagCheckedInstruction(TRUE);

if n == 31 then
  CheckSPAlignment();
  address = SP[];
else
  address = X[n];

if !postindex then
  address = address + offset;

if zero_data then
  Mem[address, TAG_GRANULE, AccType_NORMAL] = Zeros(8*TAG_GRANULE);
  Mem[address+TAG_GRANULE, TAG_GRANULE, AccType_NORMAL] = Zeros(8*TAG_GRANULE);

tag = AllocationTagFromAddress(address);
MemTag[address] = tag;
MemTag[address+TAG_GRANULE] = tag;

if writeback then
  if postindex then
    address = address + offset;

  if n == 31 then
    SP[] = address;
  else
    X[n] = address;
```

Internal version only: isa v30.25, AdvSIMD v27.01, pseudocode v85-xml-00bet8_rc3; Build timestamp: 2018-09-13T13:04

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STZG

Store Allocation Tag, Zeroing stores an Allocation Tag to memory, zeroing the associated data location. The address used for the store is calculated from the source register and an immediate signed offset scaled by the Tag granule. The Allocation Tag is calculated from the Logical Address Tag in the source register.

This instruction generates an Unchecked access.

It has encodings from 3 classes: Post-index, Pre-index and Signed offset

Post-index

(ARMv8.5)

```
31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
1 1 0 1 1 0 0 1 0 1 1 imm9 0 1 Xn 1 1 1 (1) (1) (1) (1) (1)
```

Post-index

```
STZG [<Xn|SP>], #<simm>
```

```
integer n =.UInt(Xn);
bits(64) offset = LSL(SignExtend(imm9, 64), LOG2_TAG_GRANULE);
boolean writeback = TRUE;
boolean postindex = TRUE;
boolean zero_data = TRUE;
```

Pre-index

(ARMv8.5)

```
31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
1 1 0 1 1 0 0 1 0 1 1 imm9 1 1 Xn 1 (1) (1) (1) (1) (1)
```

Pre-index

```
STZG [<Xn|SP>, #<simm>]
```

```
integer n =.UInt(Xn);
bits(64) offset = LSL(SignExtend(imm9, 64), LOG2_TAG_GRANULE);
boolean writeback = TRUE;
boolean postindex = FALSE;
boolean zero_data = TRUE;
```

Signed offset

(ARMv8.5)

```
31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
1 1 0 1 1 0 0 1 0 1 1 imm9 1 0 Xn 1 (1) (1) (1) (1) (1)
```

Signed offset

```
STZG [<Xn|SP>], #<simm>]
```

```
integer n =.UInt(Xn);
bits(64) offset = LSL(SignExtend(imm9, 64), LOG2_TAG_GRANULE);
boolean writeback = FALSE;
boolean postindex = FALSE;
boolean zero_data = TRUE;
```
Assembler Symbols

<Xn|SP>  Is the 64-bit name of the general-purpose base register or stack pointer, encoded in the "Xn" field.

<simm>  Is the optional signed immediate offset, a multiple of 16 in the range -4096 to 4080, defaulting to 0 and encoded in the "imm9" field.

Operation

bits(64) address;

SetNotTagCheckedInstruction(TRUE);

if n == 31 then
    CheckSPAlignment();
    address = SP[];
else
    address = X[n];

if !postindex then
    address = address + offset;

if zero_data then
    Mem[address, TAG_GRANULE, AccType_NORMAL] = Zeros(TAG_GRANULE * 8);
    MemTag[address] = AllocationTagFromAddress(address);

if writeback then
    if postindex then
        address = address + offset;
    if n == 31 then
        SP[] = address;
    else
        X[n] = address;
**SUB (extended register)**

Subtract (extended register) subtracts a sign or zero-extended register value, followed by an optional left shift amount, from a register value, and writes the result to the destination register. The argument that is extended from the <Rm> register can be a byte, halfword, word, or doubleword.

### 32-bit (sf == 0)

\[ \text{SUB } <Wd|WSP>, <Wn|WSP>, <Wm>, (\langle \text{extend} \rangle (\#<\text{amount}>)) \]

### 64-bit (sf == 1)

\[ \text{SUB } <Xd|SP>, <Xn|SP>, <R><m>, (\langle \text{extend} \rangle (\#<\text{amount}>)) \]

- **integer d = UInt(Rd);**
- **integer n = UInt(Rn);**
- **integer m = UInt(Rm);**
- **integer datasize = if sf == '1' then 64 else 32;**
- **boolean sub_op = (op == '1');**
- **boolean setflags = (S == '1');**
- **ExtendType extend_type = DecodeRegExtend(option);**
- **integer shift = UInt(imm3);**
- **if shift > 4 then UNDEFINED; if shift > 4 then ReservedValue();**

### Assembler Symbols

- **<Wd|WSP>** is the 32-bit name of the destination general-purpose register or stack pointer, encoded in the "Rd" field.
- **<Wn|WSP>** is the 32-bit name of the first source general-purpose register or stack pointer, encoded in the "Rn" field.
- **<Wm>** is the 32-bit name of the second general-purpose source register, encoded in the "Rm" field.
- **<Xd|SP>** is the 64-bit name of the destination general-purpose register or stack pointer, encoded in the "Rd" field.
- **<Xn|SP>** is the 64-bit name of the first source general-purpose register or stack pointer, encoded in the "Rn" field.
- **<R>** is a width specifier, encoded in "option":

<table>
<thead>
<tr>
<th>option</th>
<th>&lt;R&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>000x</td>
<td>W</td>
</tr>
<tr>
<td>010</td>
<td>W</td>
</tr>
<tr>
<td>x11</td>
<td>X</td>
</tr>
<tr>
<td>10x</td>
<td>W</td>
</tr>
<tr>
<td>110</td>
<td>W</td>
</tr>
</tbody>
</table>

- **<m>** is the number [0-30] of the second general-purpose source register or the name ZR (31), encoded in the "Rm" field.
- **<extend>** For the 32-bit variant: is the extension to be applied to the second source operand, encoded in "option":

<table>
<thead>
<tr>
<th>option</th>
<th>&lt;extend&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>000</td>
<td>UXTB</td>
</tr>
<tr>
<td>001</td>
<td>UXTH</td>
</tr>
<tr>
<td>010</td>
<td>LSL</td>
</tr>
<tr>
<td>011</td>
<td>UXTX</td>
</tr>
<tr>
<td>100</td>
<td>SXTB</td>
</tr>
<tr>
<td>101</td>
<td>SXTH</td>
</tr>
<tr>
<td>110</td>
<td>SXTW</td>
</tr>
<tr>
<td>111</td>
<td>SXTX</td>
</tr>
</tbody>
</table>

If "Rd" or "Rn" is '11111' (WSP) and "option" is '010' then LSL is preferred, but may be omitted when "imm3" is '000'. In all other cases <extend> is required and must be UXTW when "option" is '010'.

For the 64-bit variant: is the extension to be applied to the second source operand, encoded in "option":

---

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If "Rd" or "Rn" is '11111' (SP) and "option" is '011' then LSL is preferred, but may be omitted when "imm3" is '000'. In all other cases <extend> is required and must be UXTX when "option" is '011'.

<amount>

Is the left shift amount to be applied after extension in the range 0 to 4, defaulting to 0, encoded in the "imm3" field. It must be absent when <extend> is absent, is required when <extend> is LSL, and is optional when <extend> is present but not LSL.

Operation

```plaintext
bits(datasize) result;
bits(datasize) operand1 = if n == 31 then SP[] else X[n];
bits(datasize) operand2 = ExtendReg(m, extend_type, shift);
bits(4) nzcv;
bit carry_in;
if sub_op then
    operand2 = NOT(operand2);
    carry_in = '1';
else
    carry_in = '0';
(result, nzcv) = AddWithCarry(operand1, operand2, carry_in);
if setflags then
    PSTATE.<N,Z,C,V> = nzcv;
if d == 31 && !setflags then
    SP[] = result;
else
    X[d] = result;
```

Operational information

If PSTATE.DIT is 1:
- The execution time of this instruction is independent of:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
- The response of this instruction to asynchronous exceptions does not vary based on:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
**SUB (immediate)**

Subtract (immediate) subtracts an optionally-shifted immediate value from a register value, and writes the result to the destination register.

<table>
<thead>
<tr>
<th>sf</th>
<th>1</th>
<th>0</th>
<th>1</th>
<th>0</th>
<th>0</th>
<th>0</th>
<th>1</th>
<th>imm12</th>
<th>Rn</th>
<th>Rd</th>
</tr>
</thead>
<tbody>
<tr>
<td>op</td>
<td>S</td>
<td>shift</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

32-bit (sf == 0)

`SUB <Wd|WSP>, <Wn|WSP>, #<imm>{, <shift>}`

64-bit (sf == 1)

`SUB <Xd|SP>, <Xn|SP>, #<imm>{, <shift>}`

```plaintext
ingter d = UInt(Rd);
ingter n = UInt(Rn);
ingter datasize = if sf == '1' then 64 else 32;
boolean sub_op = (op == '1');
boolean setflags = (S == '1');
bits(datasize) imm;

case shift of
  when '00' imm = ZeroExtend(imm12, datasize);
  when '01' imm = ZeroExtend(imm12 : Zeros(12), datasize);
  when '10' SEE "ADDG, SUBG";
  when '1x' ReservedValue();
```

**Assembler Symbols**

- `<Wd|WSP>` Is the 32-bit name of the destination general-purpose register or stack pointer, encoded in the "Rd" field.
- `<Wn|WSP>` Is the 32-bit name of the source general-purpose register or stack pointer, encoded in the "Rn" field.
- `<Xd|SP>` Is the 64-bit name of the destination general-purpose register or stack pointer, encoded in the "Rd" field.
- `<Xn|SP>` Is the 64-bit name of the source general-purpose register or stack pointer, encoded in the "Rn" field.
- `<imm>` Is an unsigned immediate, in the range 0 to 4095, encoded in the "imm12" field.
- `<shift>` Is the optional left shift to apply to the immediate, defaulting to LSL #0 and encoded in "shift<0>":

<table>
<thead>
<tr>
<th>shift&lt;0&gt;</th>
<th>&lt;shift&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0x0</td>
<td>LSL #0</td>
</tr>
<tr>
<td>101</td>
<td>LSL #12</td>
</tr>
<tr>
<td>11x</td>
<td>Reserved</td>
</tr>
</tbody>
</table>
Operation

```c
bits(datasize) result;
bits(datasize) operand1 = if n == 31 then SP[] else X[n];
bits(datasize) operand2 = imm;
bits(4) nzcv;
bit carry_in;
if sub_op then
    operand2 = NOT(operand2);
carry_in = '1';
else
    carry_in = '0';
(result, nzcv) = AddWithCarry(operand1, operand2, carry_in);
if setflags then
    PSTATE.<N,Z,C,V> = nzcv;
if d == 31 && !setflags then
    SP[] = result;
else
    X[d] = result;
```

Operational information

If PSTATE.DIT is 1:

- The execution time of this instruction is independent of:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
- The response of this instruction to asynchronous exceptions does not vary based on:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
**SUB (shifted register)**

Subtract (shifted register) subtracts an optionally-shifted register value from a register value, and writes the result to the destination register.

This instruction is used by the alias **NEG (shifted register)**.

<table>
<thead>
<tr>
<th>sf</th>
<th>1</th>
<th>0</th>
<th>0</th>
<th>1</th>
<th>0</th>
<th>1</th>
<th>shift</th>
<th>0</th>
<th>Rm</th>
<th>imm6</th>
<th>Rn</th>
<th>Rd</th>
</tr>
</thead>
<tbody>
<tr>
<td>op</td>
<td>S</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**32-bit (sf == 0)**

```plaintext
SUB <Wd>, <Wn>, <Wm>{, <shift> #<amount>}
```

**64-bit (sf == 1)**

```plaintext
SUB <Xd>, <Xn>, <Xm>{, <shift> #<amount>}
```

```plaintext
integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rm);
integer datasize = if sf == '1' then 64 else 32;
boolean sub_op = (op == '1');
boolean setflags = (S == '1');

```plaintext
if shift == '11' then UNDEFINED;
if sf == '0' && imm6<5> == '1' then UNDEFINED;
if shift == '11' then
   ReservedValue();
if sf == '0' && imm6<5> == '1' then ReservedValue();
```

```plaintext
ShiftType shift_type = DecodeShift(shift);
integer shift_amount = UInt(imm6);
```

**Assembler Symbols**

- `<Wd>`: Is the 32-bit name of the general-purpose destination register, encoded in the "Rd" field.
- `<Wn>`: Is the 32-bit name of the first general-purpose source register, encoded in the "Rn" field.
- `<Wm>`: Is the 32-bit name of the second general-purpose source register, encoded in the "Rm" field.
- `<Xd>`: Is the 64-bit name of the general-purpose destination register, encoded in the "Rd" field.
- `<Xn>`: Is the 64-bit name of the first general-purpose source register, encoded in the "Rn" field.
- `<Xm>`: Is the 64-bit name of the second general-purpose source register, encoded in the "Rm" field.
- `<shift>`: Is the optional shift type to be applied to the second source operand, defaulting to LSL and encoded in “shift”:

<table>
<thead>
<tr>
<th>shift</th>
<th>&lt;shift&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>LSL</td>
</tr>
<tr>
<td>01</td>
<td>LSR</td>
</tr>
<tr>
<td>10</td>
<td>ASR</td>
</tr>
<tr>
<td>11</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

- `<amount>`: For the 32-bit variant: is the shift amount, in the range 0 to 31, defaulting to 0 and encoded in the "imm6" field.
  For the 64-bit variant: is the shift amount, in the range 0 to 63, defaulting to 0 and encoded in the "imm6" field.

**Alias Conditions**

<table>
<thead>
<tr>
<th>Alias</th>
<th>Is preferred when</th>
</tr>
</thead>
<tbody>
<tr>
<td>NEG (shifted register)</td>
<td>Rn == '11111'</td>
</tr>
</tbody>
</table>
Operation

```plaintext
bits(datasize) result;
bits(datasize) operand1 = X[n];
bits(datasize) operand2 = ShiftReg(m, shift_type, shift_amount);
bits(4) nzcv;
bit carry_in;

if sub_op then
    operand2 = NOT(operand2);
    carry_in = '1';
else
    carry_in = '0';

(result, nzcv) = AddWithCarry(operand1, operand2, carry_in);
if setflags then
    PSTATE.<N,Z,C,V> = nzcv;
X[d] = result;
```

Operational information

If PSTATE.DIT is 1:

- The execution time of this instruction is independent of:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
- The response of this instruction to asynchronous exceptions does not vary based on:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
SUB (vector)

Subtract (vector). This instruction subtracts each vector element in the second source SIMD&FP register from the corresponding vector element in the first source SIMD&FP register, places the result into a vector, and writes the vector to the destination SIMD&FP register.

Depending on the settings in the `CPACR_EL1`, `CPTR_EL2`, and `CPTR_EL3` registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

It has encodings from 2 classes: `Scalar` and `Vector`

### Scalar

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
|    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| 0  | 1  | 1  | 1  | 1  | 1  | 0  | size | 1  | Rm  | 1  | 0  | 0  | 0  | 0  | 1  | Rn  | Rd  |

U

### Vector

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
|    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| 0  | Q | 1  | 0  | 1  | 1  | 0  | size | 1  | Rm  | 1  | 0  | 0  | 0  | 0  | 1  | Rn  | Rd  |

U

### Assembler Symbols

- `<V>` is a width specifier, encoded in "size":
  - | Size | `<V>` |
  - | 0x   | RESERVED |
  - | 10   | RESERVED |
  - | 11   | D |

- `<d>` is the number of the SIMD&FP destination register, in the "Rd" field.
- `<n>` is the number of the first SIMD&FP source register, encoded in the "Rn" field.
Is the number of the second SIMD&FP source register, encoded in the "Rm" field.

Is the name of the SIMD&FP destination register, encoded in the "Rd" field.

Is an arrangement specifier, encoded in "size:Q":

<table>
<thead>
<tr>
<th>size</th>
<th>Q</th>
<th>T</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>0</td>
<td>8B</td>
</tr>
<tr>
<td>00</td>
<td>1</td>
<td>16B</td>
</tr>
<tr>
<td>01</td>
<td>0</td>
<td>4H</td>
</tr>
<tr>
<td>01</td>
<td>1</td>
<td>8H</td>
</tr>
<tr>
<td>10</td>
<td>0</td>
<td>2S</td>
</tr>
<tr>
<td>10</td>
<td>1</td>
<td>4S</td>
</tr>
<tr>
<td>11</td>
<td>0</td>
<td>RESERVED</td>
</tr>
<tr>
<td>11</td>
<td>1</td>
<td>2D</td>
</tr>
</tbody>
</table>

Is the name of the first SIMD&FP source register, encoded in the "Rn" field.

Is the name of the second SIMD&FP source register, encoded in the "Rm" field.

**Operation**

```c
CheckFPAdvSIMDEnabled64();
bits(datasize) operand1 = V[n];
bits(datasize) operand2 = V[m];
bits(datasize) result;
bits(esize) element1;
bits(esize) element2;
for e = 0 to elements-1
    element1 = Elem[operand1, e, esize];
    element2 = Elem[operand2, e, esize];
    if sub_op then
        Elem[result, e, esize] = element1 - element2;
    else
        Elem[result, e, esize] = element1 + element2;
V[d] = result;
```

**Operational information**

If PSTATE.DIT is 1:
- The execution time of this instruction is independent of:
  - The values of the data supplied in any of its registers.
  - The values of theNZCV flags.
- The response of this instruction to asynchronous exceptions does not vary based on:
  - The values of the data supplied in any of its registers.
  - The values of theNZCV flags.
SUBG

Subtract with Tag subtracts an immediate value scaled by the Tag granule from the address in the source register, modifies the Logical Address Tag of the address using an immediate value, and writes the result to the destination register. Tags specified in GCR_EL1.Exclude are excluded from the possible outputs when modifying the Logical Address Tag.

Integer

(ARMv8.5)

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 1  | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 0 | uimm6 | (0) | (0) | uimm4 | Xn | Xd |

Integer

SUBG <Xd|SP>, <Xn|SP>, #<uimm6>, #<uimm4>

```
integer d = UInt(Xd);
integer n = UInt(Xn);
bits(4) tag_offset = uimm4;
bits(64) offset = LSL(ZeroExtend(uimm6, 64), LOG2_TAG_GRANULE);
boolean ADD = FALSE;
```

Assembler Symbols

<Xd|SP> Is the 64-bit name of the destination general-purpose register or stack pointer, encoded in the "Xd" field.

<Xn|SP> Is the 64-bit name of the source general-purpose register or stack pointer, encoded in the "Xn" field.

<uimm6> Is an unsigned immediate, a multiple of 16 in the range 0 to 1008, encoded in the "uimm6" field.

<uimm4> Is an unsigned immediate, in the range 0 to 15, encoded in the "uimm4" field.

Operation

```
bits(64) operand1 = if n == 31 then SP[] else X[n];
bits(4) start_tag = AllocationTagFromAddress(operand1);
bits(16) exclude = GCR_EL1.Exclude;
bits(64) result;
bits(4) rtag;

if AllocationTagAccessIsEnabled() then
    rtag = ChooseNonExcludedTag(start_tag, tag_offset, exclude);
else
    rtag = '0000';

if ADD then
    (result, -) = AddWithCarry(operand1, offset, '0');
else
    (result, -) = AddWithCarry(operand1, NOT(offset), '1');

result = AddressWithAllocationTag(result, rtag);

if d == 31 then
    SP[] = result;
else
    X[d] = result;
```
**SUBHN, SUBHN2**

Subtract returning High Narrow. This instruction subtracts each vector element in the second source SIMD&FP register from the corresponding vector element in the first source SIMD&FP register, places the most significant half of the result into a vector, and writes the vector to the lower or upper half of the destination SIMD&FP register. All the values in this instruction are signed integer values.

The results are truncated. For rounded results, see **RSUBHN**.

The **SUBHN** instruction writes the vector to the lower half of the destination register and clears the upper half, while the **SUBHN2** instruction writes the vector to the upper half of the destination register without affecting the other bits of the register.

Depending on the settings in the **CP14CR_EL1, CPTR_EL2, and CPTR_EL3** registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9  | 8  | 7  | 6  | 5  | 4  | 3  | 2  | 1  | 0  |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0  | Q  | 0  | 1  | 1  | 1  | 1  | 0  | size | 1  | Rm | 0  | 1  | 1  | 0  | 0  | Rd |
| U  | 0  |    |    |    |    |    |    |      |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |

Three registers, not all the same type

**SUBHN[2]** `<Vd>`, `<Tb>`, `<Vn>`, `<Ta>`, `<Vm>`, `<Ta>`

```
integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rm);

if size == '11' then UNDEFINED;
integer esize = 8 << if size == '11' then ReservedValue();
integer elsize = 0 << UInt(size);
integer datasize = 64;
integer part = UInt(Q);
integer elements = datasize DIV esize;

boolean sub_op = (o1 == '1');
boolean round = (U == '1');
```

**Assembler Symbols**

2

Is the second and upper half specifier. If present it causes the operation to be performed on the upper 64 bits of the registers holding the narrower elements, and is encoded in “Q”:

```
<table>
<thead>
<tr>
<th>Q</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>[absent]</td>
</tr>
<tr>
<td>1</td>
<td>[present]</td>
</tr>
</tbody>
</table>
```

`<Vd>`

Is the name of the SIMD&FP destination register, encoded in the "Rd" field.

`<Tb>`

Is an arrangement specifier, encoded in “size:Q”:

```
size | Q    | `<Tb>`
-----|------|-------
00   | 0    | 8B    
00   | 1    | 16B   
01   | 0    | 4H    
01   | 1    | 8H    
10   | 0    | 2S    
10   | 1    | 4S    
11   | x    | RESERVED 
```

`<Vn>`

Is the name of the first SIMD&FP source register, encoded in the "Rn" field.

`<Ta>`

Is an arrangement specifier, encoded in “size”:

```
size | `<Ta>`
-----|-------
00   | 8H    
01   | 4S    
10   | 2D    
11   | RESERVED 
```
<Vm> Is the name of the second SIMD&FP source register, encoded in the "Rm" field.

### Operation

```c
CheckFPAdvSIMDEnabled64();
bits(2*datasize) operand1 = V[n];
bits(2*datasize) operand2 = V[m];
bits(datasize) result;
integer round_const = if round then 1 << (esize - 1) else 0;
bits(2*esize) element1;
bits(2*esize) element2;
bits(2*esize) sum;

for e = 0 to elements-1
    element1 = Elem[operand1, e, 2*esize];
    element2 = Elem[operand2, e, 2*esize];
    if sub_op then
        sum = element1 - element2;
    else
        sum = element1 + element2;
    sum = sum + round_const;
    Elem[result, e, esize] = sum<2*esize-1:esize>;
Vpart[d, part] = result;
```

### Operational information

If PSTATE.DIT is 1:
- The execution time of this instruction is independent of:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
- The response of this instruction to asynchronous exceptions does not vary based on:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
SUBP

Subtract Pointer subtracts the 56-bit address held in the second source register from the 56-bit address held in the first source register, sign-extends the result to 64-bits, and writes the result to the destination register.

Integer
(ARMv8.5)

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
|   1| 0  | 0  | 1  | 1  | 0  | 1  | 1  | 0  | 1  | 0  | 1  | 0  | 1  | 1  | 0  | Xm |   0 | 0  | 0  | 0  | 0  | Xn |   Xd |

Integer

SUBP <Xd>, <Xn|SP>, <Xm|SP>

integer d = UInt(Xd);
integer n = UInt(Xn);
integer m = UInt(Xm);
boolean setflags = FALSE;

Assembler Symbols

<Xd> Is the 64-bit name of the general-purpose destination register, encoded in the "Xd" field.
<Xn|SP> Is the 64-bit name of the first source general-purpose register or stack pointer, encoded in the "Xn" field.
<Xm|SP> Is the 64-bit name of the second general-purpose source register or stack pointer, encoded in the "Xm" field.

Operation

bits(64) operand1 = if n == 31 then SP[] else X[n];
bits(64) operand2 = if m == 31 then SP[] else X[m];
operand1 = SignExtend(operand1<55:0>, 64);
operand2 = SignExtend(operand2<55:0>, 64);

bits(64) result;
bits(4) nzcv;

operand2 = NOT(operand2);
(result, nzcv) = AddWithCarry(operand1, operand2, '1');
if setflags then
  PSTATE.<N,Z,C,V> = nzcv;
  X[d] = result;

---

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SUBPS

Subtract Pointer, setting Flags subtracts the 56-bit address held in the second source register from the 56-bit address held in the first source register, sign-extends the result to 64-bits, and writes the result to the destination register. It updates the condition flags based on the result of the subtraction.

This instruction is used by the alias CMPP.

**Integer (ARMv8.5)**

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 1  | 0  | 1  | 1  | 1  | 0  | 1  | 1  | 0  |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |

**Integer**

```
SUBPS <Xd>, <Xn|SP>, <Xm|SP>
```

```
integer d = UInt(Xd);
integer n = UInt(Xn);
integer m = UInt(Xm);
boolean setflags = TRUE;
```

**Assembler Symbols**

- `<Xd>`: Is the 64-bit name of the general-purpose destination register, encoded in the "Xd" field.
- `<Xn|SP>`: Is the 64-bit name of the first source general-purpose register or stack pointer, encoded in the "Xn" field.
- `<Xm|SP>`: Is the 64-bit name of the second general-purpose source register or stack pointer, encoded in the "Xm" field.

**Alias Conditions**

<table>
<thead>
<tr>
<th>Alias</th>
<th>Is preferred when</th>
</tr>
</thead>
<tbody>
<tr>
<td>CMPP</td>
<td><code>S == '1' &amp;&amp; Xd == '11111'</code></td>
</tr>
</tbody>
</table>

**Operation**

```
bits(64) operand1 = if n == 31 then SP[] else X[n];
bits(64) operand2 = if m == 31 then SP[] else X[m];
operand1 = SignExtend(operand1<55:0>, 64);
operand2 = SignExtend(operand2<55:0>, 64);

bits(64) result;
bits(4) nzcv;
operand2 = NOT(operand2);
(result, nzcv) = AddWithCarry(operand1, operand2, '1');
if setflags then
    PSTATE.<N,Z,C,V> = nzcv;
X[d] = result;
```
SUBS (extended register)

Subtract (extended register), setting flags, subtracts a sign or zero-extended register value, followed by an optional left shift amount, from a register value, and writes the result to the destination register. The argument that is extended from the <Rm> register can be a byte, halfword, word, or doubleword. It updates the condition flags based on the result.

This instruction is used by the alias **CMP (extended register)**.

32-bit (sf == 0)

SUBS <Wd>, <Wn|WSP>, <Wm>{, <extend> {#<amount>}}

64-bit (sf == 1)

SUBS <Xd>, <Xn|SP>, <R><m>{, <extend> {#<amount>}}

integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rm);
integer datasize = if sf == '1' then 64 else 32;
boolean sub_op = (op == '1');
boolean setflags = (S == '1');
ExtendType extend_type = DecodeRegExtend(option);
integer shift = UInt(imm3);
if shift > 4 then UNDEFINED;
if shift > 4 then ReservedValue();

Assembler Symbols

<Wd> Is the 32-bit name of the general-purpose destination register, encoded in the "Rd" field.
<Wn|WSP> Is the 32-bit name of the first source general-purpose register or stack pointer, encoded in the "Rn" field.
<Wm> Is the 32-bit name of the second general-purpose source register, encoded in the "Rm" field.
<Xd> Is the 64-bit name of the general-purpose destination register, encoded in the "Rd" field.
<Xn|SP> Is the 64-bit name of the first source general-purpose register or stack pointer, encoded in the "Rn" field.
<R> Is a width specifier, encoded in "option":

<table>
<thead>
<tr>
<th>option</th>
<th>&lt;R&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00x</td>
<td>W</td>
</tr>
<tr>
<td>010</td>
<td>W</td>
</tr>
<tr>
<td>x11</td>
<td>X</td>
</tr>
<tr>
<td>10x</td>
<td>W</td>
</tr>
<tr>
<td>110</td>
<td>W</td>
</tr>
</tbody>
</table>

<m> Is the number [0-30] of the second general-purpose source register or the name ZR (31), encoded in the "Rm" field.
<br> For the 32-bit variant: is the extension to be applied to the second source operand, encoded in "option":

<table>
<thead>
<tr>
<th>option</th>
<th>&lt;extend&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>000</td>
<td>UXTB</td>
</tr>
<tr>
<td>001</td>
<td>UXTH</td>
</tr>
<tr>
<td>010</td>
<td>LSL</td>
</tr>
<tr>
<td>011</td>
<td>UTX</td>
</tr>
<tr>
<td>100</td>
<td>SXTB</td>
</tr>
<tr>
<td>101</td>
<td>SXTH</td>
</tr>
<tr>
<td>110</td>
<td>SXTW</td>
</tr>
<tr>
<td>111</td>
<td>SXTX</td>
</tr>
</tbody>
</table>
If "Rn" is '11111' (WSP) and "option" is '010' then LSL is preferred, but may be omitted when "imm3" is '000'. In all other cases <extend> is required and must be UXTW when "option" is '010'.

For the 64-bit variant: is the extension to be applied to the second source operand, encoded in "option":

<table>
<thead>
<tr>
<th>option</th>
<th>&lt;extend&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>000</td>
<td>UXTB</td>
</tr>
<tr>
<td>001</td>
<td>UXTH</td>
</tr>
<tr>
<td>010</td>
<td>UXTW</td>
</tr>
<tr>
<td>011</td>
<td>LSL</td>
</tr>
<tr>
<td>100</td>
<td>SXTB</td>
</tr>
<tr>
<td>101</td>
<td>SXTH</td>
</tr>
<tr>
<td>110</td>
<td>SXTW</td>
</tr>
<tr>
<td>111</td>
<td>SXTX</td>
</tr>
</tbody>
</table>

If "Rn" is '11111' (SP) and "option" is '011' then LSL is preferred, but may be omitted when "imm3" is '000'. In all other cases <extend> is required and must be UXTX when "option" is '011'.

<amount>

Is the left shift amount to be applied after extension in the range 0 to 4, defaulting to 0, encoded in the "imm3" field. It must be absent when <extend> is absent, is required when <extend> is LSL, and is optional when <extend> is present but not LSL.

**Alias Conditions**

<table>
<thead>
<tr>
<th>Alias</th>
<th>Is preferred when</th>
</tr>
</thead>
<tbody>
<tr>
<td>CMP (extended register)</td>
<td>Rd == '11111'</td>
</tr>
</tbody>
</table>

**Operation**

```plaintext
bits(datasize) result;
bits(datasize) operand1 = if n == 31 then SP[] else X[n];
bits(datasize) operand2 = ExtendReg(m, extend_type, shift);
bits(4) nzcv;
bit carry_in;
if sub_op then
    operand2 = NOT(operand2);
    carry_in = '1';
else
    carry_in = '0';
(result, nzcv) = AddWithCarry(operand1, operand2, carry_in);
if setflags then
    PSTATE.<N,Z,C,V> = nzcv;
if d == 31 && !setflags then
    SP[] = result;
else
    X[d] = result;
```

**Operational information**

If PSTATE.DIT is 1:

- The execution time of this instruction is independent of:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
- The response of this instruction to asynchronous exceptions does not vary based on:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
SUBS (immediate)

Subtract (immediate), setting flags, subtracts an optionally-shifted immediate value from a register value, and writes the result to the destination register. It updates the condition flags based on the result.

This instruction is used by the alias CMP (immediate).

### 32-bit (sf == 0)

\[
\text{SUBS} <Wd>, <Wn|WSP>, #\langle imm \rangle, \langle shift \rangle
\]

### 64-bit (sf == 1)

\[
\text{SUBS} <Xd>, <Xn|SP>, #\langle imm \rangle, \langle shift \rangle
\]

Assembler Symbols

- `<Wd>` Is the 32-bit name of the general-purpose destination register, encoded in the "Rd" field.
- `<Wn|WSP>` Is the 32-bit name of the source general-purpose register or stack pointer, encoded in the "Rn" field.
- `<Xd>` Is the 64-bit name of the general-purpose destination register, encoded in the "Rd" field.
- `<Xn|SP>` Is the 64-bit name of the source general-purpose register or stack pointer, encoded in the "Rn" field.
- `<imm>` Is an unsigned immediate, in the range 0 to 4095, encoded in the "imm12" field.
- `<shift>` Is the optional left shift to apply to the immediate, defaulting to LSL 0 and encoded in “shift=0”:

<table>
<thead>
<tr>
<th>shift&lt;0&gt;</th>
<th>shift&lt;1&gt;</th>
<th>shift&lt;2&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>LSL #0</td>
<td></td>
</tr>
<tr>
<td>01</td>
<td>LSL #12</td>
<td></td>
</tr>
<tr>
<td>1x</td>
<td>RESERVED</td>
<td></td>
</tr>
</tbody>
</table>

### Alias Conditions

<table>
<thead>
<tr>
<th>Alias</th>
<th>Is preferred when</th>
</tr>
</thead>
<tbody>
<tr>
<td>CMP (immediate)</td>
<td>Rd == '11111'</td>
</tr>
</tbody>
</table>

integer \(d\) = \(\text{UInt}(Rd)\);
integer \(n\) = \(\text{UInt}(Rn)\);
integer \(\text{datasize}\) = if \(sf == '1'\) then 64 else 32;
boolean \(\text{sub}_\text{op}\) = (op == '1');
boolean \(\text{setflags}\) = (S == '1');
bits(\(\text{datasize}\)) \(\langle \text{imm} \rangle\);

\[
\text{case shift of}
\]

- when '00' \(\langle \text{imm} \rangle\) = \(\text{ZeroExtend}(\text{imm12}, \text{datasize})\);
- when '01' \(\langle \text{imm} \rangle\) = \(\text{ZeroExtend}(\text{imm12}, \text{Zeros}(12), \text{datasize})\);
- when '10' SEE "ADDG, SUBG";
- when '11' (when '1x') \(\text{ReservedValue()}\);
Operation

```c
bits(datasize) result;
bits(datasize) operand1 = if n == 31 then SP[] else X[n];
bits(datasize) operand2 = imm;
bits(4) nzcv;
bit carry_in;
if sub_op then
  operand2 = NOT(operand2);
  carry_in = '1';
else
  carry_in = '0';
(result, nzcv) = AddWithCarry(operand1, operand2, carry_in);
if setflags then
  PSTATE.<N,Z,C,V> = nzcv;
if d == 31 && !setflags then
  SP[] = result;
else
  X[d] = result;
```

Operational information

If PSTATE.DIT is 1:

- The execution time of this instruction is independent of:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
- The response of this instruction to asynchronous exceptions does not vary based on:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
SUBS (shifted register)

Subtract (shifted register), setting flags, subtracts an optionally-shifted register value from a register value, and writes the result to the destination register. It updates the condition flags based on the result.

This instruction is used by the aliases CMP (shifted register) and NEGS.

<table>
<thead>
<tr>
<th>sf</th>
<th>1</th>
<th>1</th>
<th>0</th>
<th>0</th>
<th>1</th>
<th>1</th>
<th>shift</th>
<th>0</th>
<th>Rm</th>
<th>imm6</th>
<th>Rn</th>
<th>Rd</th>
</tr>
</thead>
<tbody>
<tr>
<td>op</td>
<td>S</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

32-bit (sf == 0)

SUBS <Wd>, <Wn>, <Wm>, (<shift> #<amount>)

64-bit (sf == 1)

SUBS <Xd>, <Xn>, <Xm>, (<shift> #<amount>)

integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rm);
integer datasize = if sf == '1' then 64 else 32;
boolean sub_op = (op == '1');
boolean setflags = (S == '1');
if shift == '11' then UNDEFINED;
if sf == '0' && imm6<5> == '1' then UNDEFINED; if shift == '11' then RESERVED();
ShiftType shift_type = DecodeShift(shift);
integer shift_amount = UInt(imm6);

Assembler Symbols

- <Wd> Is the 32-bit name of the general-purpose destination register, encoded in the "Rd" field.
- <Wn> Is the 32-bit name of the first general-purpose source register, encoded in the "Rn" field.
- <Wm> Is the 32-bit name of the second general-purpose source register, encoded in the "Rm" field.
- <Xd> Is the 64-bit name of the general-purpose destination register, encoded in the "Rd" field.
- <Xn> Is the 64-bit name of the first general-purpose source register, encoded in the "Rn" field.
- <Xm> Is the 64-bit name of the second general-purpose source register, encoded in the "Rm" field.
- <shift> Is the optional shift type to be applied to the second source operand, defaulting to LSL and encoded in "shift":

<table>
<thead>
<tr>
<th>shift</th>
<th>&lt;shift&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>LSL</td>
</tr>
<tr>
<td>01</td>
<td>LSR</td>
</tr>
<tr>
<td>10</td>
<td>ASR</td>
</tr>
<tr>
<td>11</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

- <amount> For the 32-bit variant: is the shift amount, in the range 0 to 31, defaulting to 0 and encoded in the "imm6" field.
  For the 64-bit variant: is the shift amount, in the range 0 to 63, defaulting to 0 and encoded in the "imm6" field.
**Alias Conditions**

<table>
<thead>
<tr>
<th>Alias</th>
<th>Is preferred when</th>
</tr>
</thead>
<tbody>
<tr>
<td>CMP (shifted register)</td>
<td>Rd == '11111'</td>
</tr>
<tr>
<td>NEGS</td>
<td>Rn == '11111'</td>
</tr>
</tbody>
</table>

**Operation**

```plaintext
bits(datasize) result;
bits(datasize) operand1 = X[n];
bits(datasize) operand2 = ShiftReg(m, shift_type, shift_amount);
bits(4) nzcv;
bit carry_in;

if sub_op then
    operand2 = NOT(operand2);
    carry_in = '1';
else
    carry_in = '0';

(result, nzcv) = AddWithCarry(operand1, operand2, carry_in);

if setflags then
    PSTATE.<N,Z,C,V> = nzcv;
X[d] = result;
```

**Operational information**

If PSTATE.DIT is 1:

- The execution time of this instruction is independent of:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
- The response of this instruction to asynchronous exceptions does not vary based on:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
SUQADD

Signed saturating Accumulate of Unsigned value. This instruction adds the unsigned integer values of the vector elements in the source SIMD&FP register to corresponding signed integer values of the vector elements in the destination SIMD&FP register, and writes the resulting signed integer values to the destination SIMD&FP register.

If overflow occurs with any of the results, those results are saturated. If saturation occurs, the cumulative saturation bit $FPSR.QC$ is set.

Depending on the settings in the $CPACR_EL1$, $CPTR_EL2$, and $CPTR_EL3$ registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

It has encodings from 2 classes: Scalar and Vector

Scalar

SUQADD $<V><d>$, $<V><n>$

```plaintext
integer d = UInt(Rd);
integer n = UInt(Rn);

integer esize = 8 << UInt(size);
integer datasize = esize;
integer elements = 1;

boolean unsigned = (U == '1');
```

Vector

SUQADD $<Vd>.,<T>$, $<Vn>.,<T>$

```plaintext
integer d = UInt(Rd);
integer n = UInt(Rn);

if size:Q == '110' then UNDEFINED;
integer esize = 8 << UInt(size);
integer datasize = esize;
integer elements = datasize DIV esize;

boolean unsigned = (U == '1');
```

Assembler Symbols

$<V>$ Is a width specifier, encoded in "size":

<table>
<thead>
<tr>
<th>size</th>
<th>$&lt;V&gt;$</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>B</td>
</tr>
<tr>
<td>01</td>
<td>H</td>
</tr>
<tr>
<td>10</td>
<td>S</td>
</tr>
<tr>
<td>11</td>
<td>D</td>
</tr>
</tbody>
</table>

SUQADD
Is the number of the SIMD&FP destination register, encoded in the "Rd" field.

Is the number of the SIMD&FP source register, encoded in the "Rn" field.

Is the name of the SIMD&FP destination register, encoded in the "Rd" field.

Is an arrangement specifier, encoded in “size:Q”:

<table>
<thead>
<tr>
<th>size</th>
<th>Q</th>
<th>&lt;T&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>0</td>
<td>8B</td>
</tr>
<tr>
<td>00</td>
<td>1</td>
<td>16B</td>
</tr>
<tr>
<td>01</td>
<td>0</td>
<td>4H</td>
</tr>
<tr>
<td>01</td>
<td>1</td>
<td>8H</td>
</tr>
<tr>
<td>10</td>
<td>0</td>
<td>2S</td>
</tr>
<tr>
<td>10</td>
<td>1</td>
<td>4S</td>
</tr>
<tr>
<td>11</td>
<td>0</td>
<td>RESERVED</td>
</tr>
<tr>
<td>11</td>
<td>1</td>
<td>2D</td>
</tr>
</tbody>
</table>

Is the name of the SIMD&FP source register, encoded in the "Rn" field.

**Operation**

```c
CheckFPAdvSIMDEnabled64();

bits(datasize) operand = V[n];
bits(datasize) result;

bits(datasize) operand2 = V[d];
integer op1;
integer op2;
boolean sat;

for e = 0 to elements-1
  op1 = Int(Elem[operand, e, esize], !unsigned);
  op2 = Int(Elem[operand2, e, esize], unsigned);
  (Elem[result, e, esize], sat) = SatQ(op1 + op2, esize, unsigned);
  if sat then FPSR.QC = '1';
V[d] = result;
```


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SWP, SWPA, SWPAL, SWPL

Swap word or doubleword in memory atomically loads a 32-bit word or 64-bit doubleword from a memory location, and stores the value held in
a register back to the same memory location. The value initially loaded from memory is returned in the destination register.

- If the destination register is not one of WZR or XZR, SWPA and SWPAL load from memory with acquire semantics.
- SWPL and SWPAL store to memory with release semantics.
- SWP has no memory ordering requirements.

For more information about memory ordering semantics see Load-Acquire, Store-Release.
For information about memory accesses see Load/Store addressing modes.

Integer
(ARMv8.1)

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9  | 8  | 7  | 6  | 5  | 4  | 3  | 2  | 1  | 0  |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 1  | x  | 1  | 1  | 1  | 0  | 0  | A  | R  | 1  | Rs | 1  | 0  | 0  | 0  | 0  | Rn | 1  | 0  | 0  | 0  | 0  | Rn | 1  | 0  | 0  | 0  | 0  | Rt |

size
32-bit SWP (size == 10 && A == 0 && R == 0)

    SWP <Ws>, <Wt>, [<Xn|SP>]

32-bit SWPA (size == 10 && A == 1 && R == 0)

    SWPA <Ws>, <Wt>, [<Xn|SP>]

32-bit SWPAL (size == 10 && A == 1 && R == 1)

    SWPAL <Ws>, <Wt>, [<Xn|SP>]

32-bit SWPL (size == 10 && A == 0 && R == 1)

    SWPL <Ws>, <Wt>, [<Xn|SP>]

64-bit SWP (size == 11 && A == 0 && R == 0)

    SWP <Xs>, <Xt>, [<Xn|SP>]

64-bit SWPA (size == 11 && A == 1 && R == 0)

    SWPA <Xs>, <Xt>, [<Xn|SP>]

64-bit SWPAL (size == 11 && A == 1 && R == 1)

    SWPAL <Xs>, <Xt>, [<Xn|SP>]

64-bit SWPL (size == 11 && A == 0 && R == 1)

    SWPL <Xs>, <Xt>, [<Xn|SP>]

if !HaveAtomicExt() then UNDEFINED;
integer t = UnallocatedEncoding();
integer n = UInt(Rn);
integer s = UInt(Rs);
integer datasize = 8 << UInt(size);
integer regsize = if datasize == 64 then 64 else 32;
AccType ldacctype = if A == '1' && Rt != '11111' then AccType_ORDEREDATOMICRW else AccType_ATOMICRW;
AccType stacctype = if R == '1' then AccType_ORDEREDATOMICRW else AccType_ATOMICRW;

Assembler Symbols

<Ws> Is the 32-bit name of the general-purpose register to be stored, encoded in the "Rs" field.
<Wt> Is the 32-bit name of the general-purpose register to be loaded, encoded in the "Rt" field.
<Xs> Is the 64-bit name of the general-purpose register to be stored, encoded in the "Rs" field.
<Xt> Is the 64-bit name of the general-purpose register to be loaded, encoded in the "Rt" field.
<Xn|SP> Is the 64-bit name of the general-purpose base register or stack pointer, encoded in the "Rn" field.
Operation

```c
bits(64) address;
bits(datasize) data;

if n == 31 then
    HaveMTEExt() then
        SetNotTagCheckedInstruction(n == 31);
    CheckSPAAlignment();
    address = SP[];
else
    address = X[n];

// All observers in the shareability domain observe the
// following load and store atomically.
data = Mem[address, datasize DIV 8, ldacctype];
Mem[address, datasize DIV 8, stacctype] = X[s];

X[t] = ZeroExtend(data, regsize);
```

Internal version only: isa v30.25,v29.05, AdvSIMD v27.01,v26.0, pseudocode v85-xml-00bet8_rc3v35s; Build timestamp: 2018-09-13T13:2018-06-16T02:04:45

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SWPB, SWPAB, SWPALB, SWPLB

Swap byte in memory atomically loads an 8-bit byte from a memory location, and stores the value held in a register back to the same memory location. The value initially loaded from memory is returned in the destination register.

- If the destination register is not WZR, SWPAB and SWPALB load from memory with acquire semantics.
- SWPLB and SWPALB store to memory with release semantics.
- SWPB has no memory ordering requirements.

For more information about memory ordering semantics see Load-Acquire, Store-Release.
For information about memory accesses see Load/Store addressing modes.

### Integer

**(ARMv8.1)**

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0  | 0  | 1  | 1  | 1  | 0  | 0  | 0  | A  | R  | 1  | 1  | 0  | 0  | 0  | 0  | R  | n  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  |

**size**

### SWPB (A == 1 & R == 0)

```
SWPB <Ws>, <Wt>, [<Xn|SP>]  
```

### SWPAB (A == 1 & R == 1)

```
SWPAB <Ws>, <Wt>, [<Xn|SP>]  
```

### SWPB (A == 0 & R == 0)

```
SWPB <Ws>, <Wt>, [<Xn|SP>]  
```

### SWPLB (A == 0 & R == 1)

```
SWPLB <Ws>, <Wt>, [<Xn|SP>]  
```

```java
if !HaveAtomicExt() then UNDEFINED;
int t = 1;
int n = Uint(Rn);
int s = Uint(Rs);
int datasize = 8 << Uint(size);
int regsize = if datasize == 64 then 64 else 32;

AccType ldacctype = if A == '1' && Rt != '11111' then AccType_ORDEREDATOMICRW else AccType_ATOMICRW;
AccType stacctype = if R == '1' then AccType_ORDEREDATOMICRW else AccType_ATOMICRW;
```

### Assembler Symbols

- `<Ws>`: Is the 32-bit name of the general-purpose register to be stored, encoded in the "Rs" field.
- `<Wt>`: Is the 32-bit name of the general-purpose register to be loaded, encoded in the "Rt" field.
- `<Xn|SP>`: Is the 64-bit name of the general-purpose base register or stack pointer, encoded in the "Rn" field.
Operation

bits(64) address;
b.ids(\text{datasize}) data;

\textbf{if} n == 31 \textbf{then} \texttt{HaveMTEExt()} \textbf{then}
\quad \texttt{SetNotTagCheckedInstruction(n == 31)};

\textbf{if} n == 31 \textbf{then}
\quad \texttt{CheckSPA}ignment();
\qquad \texttt{address = SP[]};
\textbf{else}
\quad \texttt{address = X[n]};

// All observers in the shareability domain observe the
// following load and store atomically.
data = \texttt{Mem}[\text{address, datasize DIV 8, ldacctype}];
\texttt{Mem}[\text{address, datasize DIV 8, stacctype}] = \texttt{X}[s];

\texttt{X}[t] = \texttt{ZeroExtend}(data, regsize);
SWPH, SWPAH, SWPALH, SWPLH

Swap halfword in memory atomically loads a 16-bit halfword from a memory location, and stores the value held in a register back to the same memory location. The value initially loaded from memory is returned in the destination register.

- If the destination register is not WZR, SWPAH and SWPALH load from memory with acquire semantics.
- SWPLH and SWPALH store to memory with release semantics.
- SWPH has no memory ordering requirements.

For more information about memory ordering semantics see Load-Acquire, Store-Release. For information about memory accesses see Load/Store addressing modes.

### Integer (ARMv8.1)

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9  | 8  | 7  | 6  | 5  | 4  | 3  | 2  | 1  | 0  |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0  | 0  | 1  | 1  | 1  | 1  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 1  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  |

**SWPAH (A == 1 && R == 0)**

SWPAH <Ws>, <Wt>, [<Xn|SP>]

**SWPALH (A == 1 && R == 1)**

SWPALH <Ws>, <Wt>, [<Xn|SP>]

**SWPH (A == 0 && R == 0)**

SWPH <Ws>, <Wt>, [<Xn|SP>]

**SWPLH (A == 0 && R == 1)**

SWPLH <Ws>, <Wt>, [<Xn|SP>]

```assembly
if !HaveAtomicExt() then UNDEFINED;

integer t = 0 then UnallocatedEncoding();
integer t = UInt(Rt);
integer n = UInt(Rn);
integer s = UInt(Rs);

integer datasize = 8 << UInt(size);
integer regsize = if datasize == 64 then 64 else 32;
AccType ldacctype = if A == '1' && Rt != '11111' then AccType_ORDEREDATOMICRW else AccType_ATOMICRW;
AccType stacctype = if R == '1' then AccType_ORDEREDATOMICRW else AccType_ATOMICRW;
```

**Assembler Symbols**

- <Ws> Is the 32-bit name of the general-purpose register to be stored, encoded in the "Rs" field.
- <Wt> Is the 32-bit name of the general-purpose register to be loaded, encoded in the "Rt" field.
- <Xn|SP> Is the 64-bit name of the general-purpose base register or stack pointer, encoded in the "Rn" field.
bits(64) address;
bits(datasize) data;

if n == 31 then 
  HaveMTEExt() then
    SetNotTagCheckedInstruction(n == 31);
endif

if n == 31 then
  CheckSPAlignment();
  address = SP[];
else
  address = X[n];
endif

// All observers in the shareability domain observe the
// following load and store atomically.
data = Mem[address, datasize DIV 8, ldacctype];
Mem[address, datasize DIV 8, stacctype] = X[s];

X[t] = ZeroExtend(data, regsize);

Internal version only: isa v30.35 v29.05, AdvSIMD v27.01 v26.0, pseudocode v85-xml-008ec8_rc3c353 ; Build timestamp: 2018-09-13T13:2018-06-16T09:04:45

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SYS

System instruction. For more information, see Op0 equals 0b01, cache maintenance, TLB maintenance, and address translation instructions for the encodings of System instructions.

This instruction is used by the aliases AT, FFP, CPP, DC, DVP, IC, and TLBI.

Assembler Symbols

<op1> Is a 3-bit unsigned immediate, in the range 0 to 7, encoded in the "op1" field.
<Cn> Is a name 'Cn', with 'n' in the range 0 to 15, encoded in the "CRn" field.
<Cr> Is a name 'Cm', with 'm' in the range 0 to 15, encoded in the "CRm" field.
<op2> Is a 3-bit unsigned immediate, in the range 0 to 7, encoded in the "op2" field.
<Xt> Is the 64-bit name of the optional general-purpose source register, defaulting to '11111', encoded in the "Rt" field.

Alias Conditions

<table>
<thead>
<tr>
<th>Alias</th>
<th>Is preferred when</th>
</tr>
</thead>
<tbody>
<tr>
<td>AT</td>
<td>CRn == '0111' &amp;&amp; CRm == '100x' &amp;&amp; SysOp(op1,'0111',CRm,op2) == Sys_AT</td>
</tr>
<tr>
<td>CFP</td>
<td>op1 == '011' &amp;&amp; CRn == '0111' &amp;&amp; CRm == '0011' &amp;&amp; op2 == '100' &amp;&amp; SysOp(op1,'0111',CRm,op2) == Sys_CFP</td>
</tr>
<tr>
<td>CPP</td>
<td>op1 == '011' &amp;&amp; CRn == '0111' &amp;&amp; CRm == '0011' &amp;&amp; op2 == '111' &amp;&amp; SysOp(op1,'0111',CRm,op2) == Sys_CPP</td>
</tr>
<tr>
<td>DC</td>
<td>CRn == '01111000' &amp;&amp; SysOp(op1,'01111000',CRm,op2) == Sys_DC</td>
</tr>
<tr>
<td>DVP</td>
<td>op1 == '011' &amp;&amp; CRn == '0111' &amp;&amp; CRm == '0011' &amp;&amp; op2 == '101'</td>
</tr>
<tr>
<td>IC</td>
<td>CRn == '0111' &amp;&amp; SysOp(op1,'0111',CRm,op2) == Sys_IC</td>
</tr>
<tr>
<td>TLBI</td>
<td>CRn == '1000' &amp;&amp; SysOp(op1,'1000',CRm,op2) == Sys_TLBI</td>
</tr>
</tbody>
</table>

Operation

if has_result then
    \[X[t]\] = AArch64.SysInstrWithResult(sys_op0, sys_op1, sys_crn, sys_crm, sys_op2);
else
    AArch64.SysInstr(sys_op0, sys_op1, sys_crn, sys_crm, sys_op2, X[t]);
TBL

Table vector Lookup. This instruction reads each value from the vector elements in the index source SIMD&FP register, uses each result as an index to perform a lookup in a table of bytes that is described by one to four source table SIMD&FP registers, places the lookup result in a vector, and writes the vector to the destination SIMD&FP register. If an index is out of range for the table, the result for that lookup is 0. If more than one source register is used to describe the table, the first source register describes the lowest bytes of the table.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

<table>
<thead>
<tr>
<th>31</th>
<th>30</th>
<th>29</th>
<th>28</th>
<th>27</th>
<th>26</th>
<th>25</th>
<th>24</th>
<th>23</th>
<th>22</th>
<th>21</th>
<th>20</th>
<th>19</th>
<th>18</th>
<th>17</th>
<th>16</th>
<th>15</th>
<th>14</th>
<th>13</th>
<th>12</th>
<th>11</th>
<th>10</th>
<th>9</th>
<th>8</th>
<th>7</th>
<th>6</th>
<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Q</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
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<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Two register table (len == 01)

TBL <Vd>.<Ta>, { <Vn>.16B, <Vn+1>.16B }, <Vm>.<Ta>

Three register table (len == 10)

TBL <Vd>.<Ta>, { <Vn>.16B, <Vn+1>.16B, <Vn+2>.16B }, <Vm>.<Ta>

Four register table (len == 11)

TBL <Vd>.<Ta>, { <Vn>.16B, <Vn+1>.16B, <Vn+2>.16B, <Vn+3>.16B }, <Vm>.<Ta>

Single register table (len == 00)

TBL <Vd>.<Ta>, { <Vn>.16B }, <Vm>.<Ta>

- integer d = UInt(Rd);
- integer n = UInt(Rn);
- integer m = UInt(Rm);
- integer datasize = if Q == '1' then 128 else 64;
- integer elements = datasize DIV 8;
- integer regs = UInt(len) + 1;
- boolean is_tbl = (op == '0');

Assembler Symbols

- <Vd> Is the name of the SIMD&FP destination register, encoded in the "Rd" field.
- <Ta> Is an arrangement specifier, encoded in “Q”:

<table>
<thead>
<tr>
<th>Q</th>
<th>Ta</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>8B</td>
</tr>
<tr>
<td>1</td>
<td>16B</td>
</tr>
</tbody>
</table>

- <Vn> For the four register table, three register table and two register table variant: is the name of the first SIMD&FP table register, encoded in the "Rn" field.
  For the single register table variant: is the name of the SIMD&FP table register, encoded in the "Rn" field.
- <Vn+1> Is the name of the second SIMD&FP table register, encoded as "Rn" plus 1 modulo 32.
- <Vn+2> Is the name of the third SIMD&FP table register, encoded as "Rn" plus 2 modulo 32.
- <Vn+3> Is the name of the fourth SIMD&FP table register, encoded as "Rn" plus 3 modulo 32.
- <Vm> Is the name of the SIMD&FP index register, encoded in the "Rm" field.
Operation

```c
CheckFPAdvSIMDEnabled64();
bits(datasize) indices = V[m];
bits(128*regs) table = Zeros();
bits(datasize) result;
integer index;

// Create table from registers
for i = 0 to regs - 1
    table<128*i+127:128*i> = V[n];
    n = (n + 1) MOD 32;

result = if is_tbl then Zeros() else V[d];
for i = 0 to elements - 1
    index = Uint(Elem[indices, i, 8]);
    if index < 16 * regs then
        Elem[result, i, 8] = Elem[table, index, 8];

V[d] = result;
```

Operational information

If PSTATE.DIT is 1:

- The execution time of this instruction is independent of:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
- The response of this instruction to asynchronous exceptions does not vary based on:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
TBNZ

Test bit and Branch if Nonzero compares the value of a bit in a general-purpose register with zero, and conditionally branches to a label at a PC-relative offset if the comparison is not equal. It provides a hint that this is not a subroutine call or return. This instruction does not affect condition flags.

<table>
<thead>
<tr>
<th>op</th>
<th>imm14</th>
<th>Rt</th>
</tr>
</thead>
<tbody>
<tr>
<td>b5</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>b40</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

14-bit signed PC-relative branch offset

TBNZ <R><t>, #<imm>, <label>

integer t = UInt(Rt);
integer datasize = if b5 == '1' then 64 else 32;
integer bit_pos = UInt(b5:b40);
bit bit_val = op;
bits(64) offset = SignExtend(imm14:'00', 64);

Assembler Symbols

<R> Is a width specifier, encoded in "b5":

<table>
<thead>
<tr>
<th>b5</th>
<th>&lt;R&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>W</td>
</tr>
<tr>
<td>1</td>
<td>X</td>
</tr>
</tbody>
</table>

In assembler source code an 'X' specifier is always permitted, but a 'W' specifier is only permitted when the bit number is less than 32.

<t> Is the number [0-30] of the general-purpose register to be tested or the name ZR (31), encoded in the "Rt" field.

<imm> Is the bit number to be tested, in the range 0 to 63, encoded in "b5:b40".

<label> Is the program label to be conditionally branched to. Its offset from the address of this instruction, in the range +/-32KB, is encoded as "imm14" times 4.

Operation

bits(datasize) operand = X[t];
if operand<bit_pos> == bit_val then
   BranchTo(PC[] + offset, BranchType_DIRBranchType_JMP);

Internal version only: isa v30.25 v29.05 v27.01 v26.0, AdvSIMD v85-xml-008ec8 rc3a55 ; Build timestamp: 2018-09-13T13:2045 2018-06-16T09:45:04

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TBX

Table vector lookup extension. This instruction reads each value from the vector elements in the index source SIMD&FP register, uses each result as an index to perform a lookup in a table of bytes that is described by one to four source table SIMD&FP registers, places the lookup result in a vector, and writes the vector to the destination SIMD&FP register. If an index is out of range for the table, the existing value in the vector element of the destination register is left unchanged. If more than one source register is used to describe the table, the first source register describes the lowest bytes of the table.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

\[
\begin{array}{cccccccccccc}
0 & Q & 0 & 0 & 1 & 1 & 0 & 0 & 0 & 0 & Rm & 0 \\
\end{array}
\]

Two register table (len == 01)

TBX <Vd>.<Ta>, { <Vn>.16B, <Vn+1>.16B }, <Vm>.<Ta>

Three register table (len == 10)

TBX <Vd>.<Ta>, { <Vn>.16B, <Vn+1>.16B, <Vn+2>.16B }, <Vm>.<Ta>

Four register table (len == 11)

TBX <Vd>.<Ta>, { <Vn>.16B, <Vn+1>.16B, <Vn+2>.16B, <Vn+3>.16B }, <Vm>.<Ta>

Single register table (len == 00)

TBX <Vd>.<Ta>, { <Vn>.16B }, <Vm>.<Ta>

integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rm);

integer datasize = if Q == '1' then 128 else 64;
integer elements = datasize DIV 8;
integer regs = UInt(len) + 1;
boolean is_tbl = (op == '0');

Assembler Symbols

<Vd> Is the name of the SIMD&FP destination register, encoded in the "Rd" field.
<Ta> Is an arrangement specifier, encoded in “Q”:

<table>
<thead>
<tr>
<th>Q</th>
<th>&lt;Ta&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>8B</td>
</tr>
<tr>
<td>1</td>
<td>16B</td>
</tr>
</tbody>
</table>

<Vn> For the four register table, three register table and two register table variant: is the name of the first SIMD&FP table register, encoded in the "Rn" field.

For the single register table variant: is the name of the SIMD&FP table register, encoded in the "Rn" field.

<Vn+1> Is the name of the second SIMD&FP table register, encoded as "Rn" plus 1 modulo 32.

<Vn+2> Is the name of the third SIMD&FP table register, encoded as "Rn" plus 2 modulo 32.

<Vn+3> Is the name of the fourth SIMD&FP table register, encoded as "Rn" plus 3 modulo 32.

<Vm> Is the name of the SIMD&FP index register, encoded in the "Rm" field.
Operation

```c
CheckFPAdvSIMDEnabled64();
bits(datasize) indices = V[m];
bits(128*regs) table = Zeros();
bits(datasize) result;
integer index;

// Create table from registers
for i = 0 to regs - 1
  table<128*i+127:128*i> = V[n];
  n = (n + 1) MOD 32;
result = if is_tbl then Zeros() else V[d];
for i = 0 to elements - 1
  index = UInt(Elem[indices, i, 8]);
  if index < 16 * regs then
    Elem[result, i, 8] = Elem[table, index, 8];
V[d] = result;
```

Operational information

If PSTATE.DIT is 1:

- The execution time of this instruction is independent of:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
- The response of this instruction to asynchronous exceptions does not vary based on:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
Test bit and Branch if Zero compares the value of a test bit with zero, and conditionally branches to a label at a PC-relative offset if the comparison is equal. It provides a hint that this is not a subroutine call or return. This instruction does not affect condition flags.

<table>
<thead>
<tr>
<th>31</th>
<th>30</th>
<th>29</th>
<th>28</th>
<th>27</th>
<th>26</th>
<th>25</th>
<th>24</th>
<th>23</th>
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<th>19</th>
<th>18</th>
<th>17</th>
<th>16</th>
<th>15</th>
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<th>13</th>
<th>12</th>
<th>11</th>
<th>10</th>
<th>9</th>
<th>8</th>
<th>7</th>
<th>6</th>
<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td>b5</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>b40</td>
<td>imm14</td>
<td>Rt</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

14-bit signed PC-relative branch offset

TBZ `<R>`<t>, #<imm>, <label>

integer t = UInt(Rt);

integer datasize = if b5 == '1' then 64 else 32;
integer bit_pos = UInt(b5:b40);
bit bit_val = op;
bits(64) offset = SignExtend(imm14:'00', 64);

Assembler Symbols

< R > Is a width specifier, encoded in “b5”:

<table>
<thead>
<tr>
<th>&lt;R&gt;</th>
<th>b5</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>W</td>
</tr>
<tr>
<td>1</td>
<td>X</td>
</tr>
</tbody>
</table>

In assembler source code an 'X' specifier is always permitted, but a 'W' specifier is only permitted when the bit number is less than 32.

< t > Is the number [0-30] of the general-purpose register to be tested or the name ZR (31), encoded in the "Rt" field.

<imm> Is the bit number to be tested, in the range 0 to 63, encoded in "b5:b40".

<label> Is the program label to be conditionally branched to. Its offset from the address of this instruction, in the range +/-32KB, is encoded as "imm14" times 4.

Operation

bits(datasize) operand = X[t];

if operand<bit_pos> == bit_val then
    BranchTo(PC[] + offset, BranchType_DIR, BranchType_JMP);


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**TRN1**

Transpose vectors (primary). This instruction reads corresponding even-numbered vector elements from the two source SIMD&FP registers, starting at zero, places each result into consecutive elements of a vector, and writes the vector to the destination SIMD&FP register. Vector elements from the first source register are placed into even-numbered elements of the destination vector, starting at zero, while vector elements from the second source register are placed into odd-numbered elements of the destination vector.

By using this instruction with TRN2, a 2 x 2 matrix can be transposed.

The following figure shows an example of the operation of TRN1 and TRN2 halfword operations where Q = 0.

![Example of TRN1 and TRN2 operations](image)

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

```
31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
0 | Q | 0 | 0 | 1 | 1 | 1 | 0 | size | 0 | Rm | 0 | 0 | 1 | 0 | 1 | 0 | Rn | Rd
```

### Advanced SIMD

**TRN1** `<Vd>`. `<T>`, `<Vn>`. `<T>`, `<Vm>`. `<T>`

```
integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rm);

if size:Q == '110' then UNDEFINED;
integer esize = 8 << if size:Q == '110' then ReservedValue[4];
integer esize = 8 << UInt(size);
integer datasize = if Q == '1' then 128 else 64;
integer elements = datasize DIV esize;
integer part = UInt(op);
integer pairs = elements DIV 2;
```

### Assembler Symbols

- `<Vd>` Is the name of the SIMD&FP destination register, encoded in the "Rd" field.
- `<T>` Is an arrangement specifier, encoded in “size:Q”:

<table>
<thead>
<tr>
<th>Q</th>
<th><code>&lt;T&gt;</code></th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>8B</td>
</tr>
<tr>
<td>00</td>
<td>16B</td>
</tr>
<tr>
<td>01</td>
<td>4H</td>
</tr>
<tr>
<td>01</td>
<td>8H</td>
</tr>
<tr>
<td>10</td>
<td>2S</td>
</tr>
<tr>
<td>10</td>
<td>4S</td>
</tr>
<tr>
<td>11</td>
<td>RESERVED</td>
</tr>
<tr>
<td>11</td>
<td>2D</td>
</tr>
</tbody>
</table>

- `<Vn>` Is the name of the first SIMD&FP source register, encoded in the "Rn" field.
- `<Vm>` Is the name of the second SIMD&FP source register, encoded in the "Rm" field.
Operation

```c
void CheckFPAdvSIMDEnabled64()
{
    bits(datasize) operand1 = V[n];
    bits(datasize) operand2 = V[m];
    bits(datasize) result;
    integer p;
    for p = 0 to pairs-1
        Elem[result, 2*p+0, esize] = Elem[operand1, 2*p+part, esize];
        Elem[result, 2*p+1, esize] = Elem[operand2, 2*p+part, esize];
    V[d] = result;
}
```

Operational information

If PSTATE.DIT is 1:

- The execution time of this instruction is independent of:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
- The response of this instruction to asynchronous exceptions does not vary based on:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
TRN2

Transpose vectors (secondary). This instruction reads corresponding odd-numbered vector elements from the two source SIMD&FP registers, places each result into consecutive elements of a vector, and writes the vector to the destination SIMD&FP register. Vector elements from the first source register are placed into even-numbered elements of the destination vector, starting at zero, while vector elements from the second source register are placed into odd-numbered elements of the destination vector.

By using this instruction with TRN1, a 2 x 2 matrix can be transposed.

The following figure shows an example of the operation of TRN1 and TRN2 halfword operations where Q = 0.

![Figure showing the operation of TRN1 and TRN2 halfword operations with Q = 0.]

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

```
31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
|   Q   |   0   |   1   |   1   |   0   | size |   0   |   0   |   1   |   1   |   0   | Rm |   0   |   1   |   1   |   0   |   0   | Rd |
|-------|-------|-------|-------|-------|------|-------|-------|-------|-------|-------|----|-------|-------|-------|-------|----|

op
```

Advanced SIMD

```
integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rm);

if size:Q == '110' then UNDEFINED;
integer esize = 8 << (if size:Q == '110' then ReservedValue(4);
integer esize = 8 << UInt(size);
integer datasize = if Q == '1' then 128 else 64;
integer elements = datasize DIV esize;
integer part = UInt(op);
integer pairs = elements DIV 2;
```

Assembler Symbols

- `<Vd>` is the name of the SIMD&FP destination register, encoded in the "Rd" field.
- `<T>` is an arrangement specifier, encoded in “size:Q”:
  ```
<table>
<thead>
<tr>
<th>size</th>
<th>Q</th>
<th>&lt;T&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>0</td>
<td>8B</td>
</tr>
<tr>
<td>00</td>
<td>1</td>
<td>16B</td>
</tr>
<tr>
<td>01</td>
<td>0</td>
<td>4H</td>
</tr>
<tr>
<td>01</td>
<td>1</td>
<td>8H</td>
</tr>
<tr>
<td>10</td>
<td>0</td>
<td>2S</td>
</tr>
<tr>
<td>10</td>
<td>1</td>
<td>4S</td>
</tr>
<tr>
<td>11</td>
<td>0</td>
<td>RESERVED</td>
</tr>
<tr>
<td>11</td>
<td>1</td>
<td>2D</td>
</tr>
</tbody>
</table>
  ```
- `<Vn>` is the name of the first SIMD&FP source register, encoded in the "Rn" field.
- `<Vm>` is the name of the second SIMD&FP source register, encoded in the "Rm" field.
Operation

```c
CheckFPAdvSIMEnabled64();
bits(datasize) operand1 = V[n];
bits(datasize) operand2 = V[m];
bits(datasize) result;

for p = 0 to pairs-1
    Elem[result, 2*p+0, esize] = Elem[operand1, 2*p+part, esize];
    Elem[result, 2*p+1, esize] = Elem[operand2, 2*p+part, esize];

V[d] = result;
```

Operational information

If PSTATE.DIT is 1:

- The execution time of this instruction is independent of:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.

- The response of this instruction to asynchronous exceptions does not vary based on:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
TSB CSYNC

Trace Synchronization Barrier. This instruction is a barrier that synchronizes the trace operations of instructions. If the Self-Hosted Trace Extension is not implemented, this instruction executes as a NOP.

System
(ARMv8.4)

<table>
<thead>
<tr>
<th>CRm</th>
<th>op2</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
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<td>0</td>
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<td>0</td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
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<tr>
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<td>0</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

System

TSB CSYNC

```c
SystemHintOp op;

case CRm:op2 of
  when '0000 000' op = SystemHintOp_NOP;
  when '0000 001' op = SystemHintOp_YIELD;
  when '0000 010' op = SystemHintOp_WFE;
  when '0000 011' op = SystemHintOp_WFI;
  when '0000 100' op = SystemHintOp_SEV;
  when '0000 101' op = SystemHintOp_SEVL;
  when '0000 111' SEA "XPACLRI";
  when '0001 xxx' SEA "PACIA1716, PACIB1716, AUTIA1716, AUTIB1716";
  when '0010 000' if !HaveRAExt() then EndOfInstruction(); // Instruction executes as NOP
    op = SystemHintOp_ESB;
  when '0010 001' if !HaveStatisticalProfiling() then EndOfInstruction(); // Instruction executes as NOP
    op = SystemHintOp_PSB;
  when '0010 010' if !HaveSelfHostedTrace() then EndOfInstruction(); // Instruction executes as NOP
    op = SystemHintOp_TSB;
  when '0010 100' op = SystemHintOp_CSDB;
  when '0011 xxx' SEA "PACIAZ, PACIASP, PACIBZ, PACIBSP, AUTIAZ, AUTIASP, AUTIBZ, AUTIBSP";
  when '0100 xx0' op = SystemHintOp_BTI;
  BTypeCompatible = BTypeCompatible_BTI(op2<2:1>);
  otherwise EndOfInstruction(); // Instruction executes as NOP
```

TSB CSYNC  Page 1392
case op of
  when SystemHintOp_YIELDHint_Yield();

  when SystemHintOp_WFE
    if IsEventRegisterSet() then
      ClearEventRegister();
    else
      if PSTATE.EL == EL0 then
        // Check for traps described by the OS which may be EL1 or EL2.
        AArch64.CheckForWFxTrap(EL1, TRUE);
      if EL2Enabled() && PSTATE.EL IN {EL0, EL1} && !IsInHost() then
        // Check for traps described by the Hypervisor.
        AArch64.CheckForWFxTrap(EL2, TRUE);
      if HaveEL(EL3) && PSTATE.EL != EL3 then
        // Check for traps described by the Secure Monitor.
        AArch64.CheckForWFxTrap(EL3, TRUE);
      WaitForEvent();
    end
  when SystemHintOp_WFI
    if !InterruptPending() then
      if PSTATE.EL == EL0 then
        // Check for traps described by the OS which may be EL1 or EL2.
        AArch64.CheckForWFxTrap(EL1, FALSE);
      if EL2Enabled() && PSTATE.EL IN {EL0, EL1} && !IsInHost() then
        // Check for traps described by the Hypervisor.
        AArch64.CheckForWFxTrap(EL2, FALSE);
      if HaveEL(EL3) && PSTATE.EL != EL3 then
        // Check for traps described by the Secure Monitor.
        AArch64.CheckForWFxTrap(EL3, FALSE);
      WaitForInterrupt();
    end
  when SystemHintOp_SEVSEndEvent();

  when SystemHintOp_SEVLSendEventLocal();

  when SystemHintOp_ESBSynchronizeErrors();
    AArch64.ESBSOperation();
    if EL2Enabled() && PSTATE.EL IN {EL0, EL1} then
      AArch64.vESBOperation();
      TakeUnmaskedSErrorInterrupts();
  when SystemHintOp_PSBProfilingSynchronizationBarrier();

  when SystemHintOp_TSB
    TraceSynchronizationBarrier();

  when SystemHintOp_CSDBConsumptionOfSpeculativeDataBarrier();
    when otherwise // do nothing SystemHintOp_BTI
      BTypeNext = '00';
    when otherwise // do nothing

UABA

Unsigned Absolute difference and Accumulate. This instruction subtracts the elements of the second source SIMD&FP register from the corresponding elements of the first source SIMD&FP register, and accumulates the absolute values of the results into the elements of the vector of the destination SIMD&FP register.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

<table>
<thead>
<tr>
<th>31</th>
<th>30</th>
<th>29</th>
<th>28</th>
<th>27</th>
<th>26</th>
<th>25</th>
<th>24</th>
<th>23</th>
<th>22</th>
<th>21</th>
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<th>16</th>
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<th>6</th>
<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>size</td>
<td>1</td>
<td>Rm</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>Rd</td>
<td>ac</td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

Three registers of the same type

UABA <Vd>, <T>, <Vn>, <T>, <Vm>, <T>

```plaintext
integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rm);
if size == '11' then UNDEFINED;
integer esize = 8 << if size == '11' then ReservedValue() else UInt(size);
integer datasize = if Q == '1' then 128 else 64;
integer elements = datasize DIV esize;
boolean unsigned = (U == '1');
boolean accumulate = (ac == '1');
```

Assembler Symbols

- **<Vd>** is the name of the SIMD&FP destination register, encoded in the "Rd" field.
- **<T>** is an arrangement specifier, encoded in “size:Q”:

<table>
<thead>
<tr>
<th>size</th>
<th>Q</th>
<th>&lt;T&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>0</td>
<td>8B</td>
</tr>
<tr>
<td>00</td>
<td>1</td>
<td>16B</td>
</tr>
<tr>
<td>01</td>
<td>0</td>
<td>4H</td>
</tr>
<tr>
<td>01</td>
<td>1</td>
<td>8H</td>
</tr>
<tr>
<td>10</td>
<td>0</td>
<td>2S</td>
</tr>
<tr>
<td>10</td>
<td>1</td>
<td>4S</td>
</tr>
<tr>
<td>11</td>
<td>x</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

- **<Vn>** is the name of the first SIMD&FP source register, encoded in the "Rn" field.
- **<Vm>** is the name of the second SIMD&FP source register, encoded in the "Rm" field.

Operation

```plaintext
CheckFPAdvSIMDEnabled64();
bits(datasize) operand1 = V[n];
bits(datasize) operand2 = V[m];
bits(datasize) result;
integer element1;
integer element2;
bits(esize) absdiff;
result = if accumulate then V[d] else Zeros();
for e = 0 to elements-1
    element1 = Int(Elem[operand1, e, esize], unsigned);
    element2 = Int(Elem[operand2, e, esize], unsigned);
    absdiff = Abs(element1 - element2)<esize-1:0>;
    Elem[result, e, esize] = Elem[result, e, esize] + absdiff;
V[d] = result;
```

UABA
Operational information

If PSTATE.DIT is 1:

• The execution time of this instruction is independent of:
  ◦ The values of the data supplied in any of its registers.
  ◦ The values of the NZCV flags.

• The response of this instruction to asynchronous exceptions does not vary based on:
  ◦ The values of the data supplied in any of its registers.
  ◦ The values of the NZCV flags.
UABAL, UABAL2

Unsigned Absolute difference and Accumulate Long. This instruction subtracts the vector elements in the lower or upper half of the second source SIMD&FP register from the corresponding vector elements of the first source SIMD&FP register, and accumulates the absolute values of the results into the vector elements of the destination SIMD&FP register. The destination vector elements are twice as long as the source vector elements. All the values in this instruction are unsigned integer values.

The UABAL instruction extracts each source vector from the lower half of each source register, while the UABAL2 instruction extracts each source vector from the upper half of each source register.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

### Three registers, not all the same type

UABAL(2) <Vd>.<Ta>, <Vn>.<Tb>, <Vm>.<Tb>

```plaintext
integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rm);

if size == '11' then UNDEFINED;
integer esize = 8 <<if size == '11' then ReservedValue();
integer datashize = 64;
integer part = UInt(Q);
integer elements = datashize DIV esize;

boolean accumulate = (op == '0');
boolean unsigned = (U == '1');
```

### Assembler Symbols

2  
Is the second and upper half specifier. If present it causes the operation to be performed on the upper 64 bits of the registers holding the narrower elements, and is encoded in "Q":

<table>
<thead>
<tr>
<th>Q</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>[absent]</td>
</tr>
<tr>
<td>1</td>
<td>[present]</td>
</tr>
</tbody>
</table>

<Vd>  
Is the name of the SIMD&FP destination register, encoded in the "Rd" field.

<Ta>  
Is an arrangement specifier, encoded in “size”:

<table>
<thead>
<tr>
<th>size</th>
<th>&lt;Ta&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>8H</td>
</tr>
<tr>
<td>01</td>
<td>4S</td>
</tr>
<tr>
<td>10</td>
<td>2D</td>
</tr>
<tr>
<td>11</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

<Vn>  
Is the name of the first SIMD&FP source register, encoded in the "Rn" field.

<Tb>  
Is an arrangement specifier, encoded in “size:Q”:

<table>
<thead>
<tr>
<th>size</th>
<th>Q</th>
<th>&lt;Tb&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>0</td>
<td>8B</td>
</tr>
<tr>
<td>00</td>
<td>1</td>
<td>16B</td>
</tr>
<tr>
<td>01</td>
<td>0</td>
<td>4H</td>
</tr>
<tr>
<td>01</td>
<td>1</td>
<td>8H</td>
</tr>
<tr>
<td>10</td>
<td>0</td>
<td>2S</td>
</tr>
<tr>
<td>10</td>
<td>1</td>
<td>4S</td>
</tr>
<tr>
<td>11</td>
<td>x</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>
<Vm>Is the name of the second SIMD&FP source register, encoded in the "Rm" field.

Operation

```c
CheckFPAdvSIMDEnabled64();
bits(datasize) operand1 = Vpart[n, part];
bits(datasize) operand2 = Vpart[m, part];
integer element1;
integer element2;
better(2*datasize) absdiff;

result = if accumulate then V[d] else Zeros();
for e = 0 to elements-1
    element1 = Int(Elem[operand1, e, esize], unsigned);
    element2 = Int(Elem[operand2, e, esize], unsigned);
    absdiff = Abs(element1 - element2)<<2*esize-1:0>;</n
V[d] = result;
```

Operational information

If PSTATE.DIT is 1:

- The execution time of this instruction is independent of:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.

- The response of this instruction to asynchronous exceptions does not vary based on:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.

Internal version only: isa v30.25 ... ; Build timestamp: 2018-09-13T13:2018-06-16T09:45:04

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UABD

Unsigned Absolute Difference (vector). This instruction subtracts the elements of the vector of the second source SIMD&FP register from the corresponding elements of the first source SIMD&FP register, places the absolute values of the results into a vector, and writes the vector to the destination SIMD&FP register.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

Three registers of the same type

UABD <Vd>, <T>, <Vn>, <T>, <Vm>.<T>

<table>
<thead>
<tr>
<th>size</th>
<th>Q</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
</tr>
</tbody>
</table>

integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rm);

if size == '11' then UNDEFINED;
integer esize = 8 << if size == '11' then ReservedValue();
integer esize = 8 << UInt(size);
integer datasize = if Q == '1' then 128 else 64;
integer elements = datasize DIV esize;

boolean unsigned = (U == '1');
boolean accumulate = (ac == '1');

Assembler Symbols

<AssembledCode>

Operation

CheckFPAdvSIMDEnabled64();
bits(datasize) operand1 = V[n];
bits(datasize) operand2 = V[m];
bits(datasize) result;
integer element1;
integer element2;
bits(esize) absdiff;
result = if accumulate then V[d] else Zeros();
for e = 0 to elements-1
  element1 = Int(Elem[operand1, e, esize], unsigned);
  element2 = Int(Elem[operand2, e, esize], unsigned);
  absdiff = Abs(element1 - element2)<esize-1:0>;
  Elem[result, e, esize] = Elem[result, e, esize] + absdiff;
V[d] = result;
Operational information

If PSTATE.DIT is 1:

- The execution time of this instruction is independent of:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.

- The response of this instruction to asynchronous exceptions does not vary based on:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
UABDL, UABDL2

Unsigned Absolute Difference Long. This instruction subtracts the vector elements in the lower or upper half of the second source SIMD&FP register from the corresponding vector elements of the first source SIMD&FP register, places the absolute value of the result into a vector, and writes the vector to the destination SIMD&FP register. The destination vector elements are twice as long as the source vector elements. All the values in this instruction are unsigned integer values.

The UABDL instruction extracts each source vector from the lower half of each source register, while the UABDL2 instruction extracts each source vector from the upper half of each source register.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

Three registers, not all the same type

UABDL(2) <Vd>..<Ta>, <Vn>.<Tb>, <Vm>.<Tb>

<table>
<thead>
<tr>
<th>Q</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>[absent]</td>
</tr>
<tr>
<td>1</td>
<td>[present]</td>
</tr>
</tbody>
</table>

<Vd> Is the name of the SIMD&FP destination register, encoded in the "Rd" field.

<Ta> Is an arrangement specifier, encoded in “size”:

<table>
<thead>
<tr>
<th>size</th>
<th>&lt;Ta&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>8H</td>
</tr>
<tr>
<td>01</td>
<td>4S</td>
</tr>
<tr>
<td>10</td>
<td>2D</td>
</tr>
<tr>
<td>11</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

<Vn> Is the name of the first SIMD&FP source register, encoded in the "Rn" field.

<Tb> Is an arrangement specifier, encoded in “size-Q”:

<table>
<thead>
<tr>
<th>size</th>
<th>Q</th>
<th>&lt;Tb&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>0</td>
<td>8B</td>
</tr>
<tr>
<td>00</td>
<td>1</td>
<td>16B</td>
</tr>
<tr>
<td>01</td>
<td>0</td>
<td>4H</td>
</tr>
<tr>
<td>01</td>
<td>1</td>
<td>8H</td>
</tr>
<tr>
<td>10</td>
<td>0</td>
<td>2S</td>
</tr>
<tr>
<td>10</td>
<td>1</td>
<td>4S</td>
</tr>
<tr>
<td>11</td>
<td>x</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

Assembler Symbols

2 Is the second and upper half specifier. If present it causes the operation to be performed on the upper 64 bits of the registers holding the narrower elements, and is encoded in "Q":

2

boolean accumulate = (op == '0');
boolean unsigned = (U == '1');
Operation

```c
CheckFPAdvSIMDEnabled64();
bv<datasize> operand1 = Vpart[n, part];
bv<datasize> operand2 = Vpart[m, part];
bv<2*datasize> result;
integer element1;
integer element2;
bv<2*esize> absdiff;

result = if accumulate then V[d] else Zeros();
for e = 0 to elements-1
    element1 = Int(Elem[operand1, e, esize], unsigned);
    element2 = Int(Elem[operand2, e, esize], unsigned);
    absdiff = Abs(element1 - element2)<2*esize-1:0>;
    Elem[result, e, 2*esize] = Elem[result, e, 2*esize] + absdiff;
V[d] = result;
```

Operational information

If PSTATE.DIT is 1:
- The execution time of this instruction is independent of:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
- The response of this instruction to asynchronous exceptions does not vary based on:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
UADALP

Unsigned Add and Accumulate Long Pairwise. This instruction adds pairs of adjacent unsigned integer values from the vector in the source SIMD&FP register and accumulates the results with the vector elements of the destination SIMD&FP register. The destination vector elements are twice as long as the source vector elements.

Depending on the settings in the \texttt{CPACR\_EL1}, \texttt{CPTR\_EL2}, and \texttt{CPTR\_EL3} registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

\begin{verbatim}
            31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
U  Q 1 0 1 1 | size | 1 0 0 0 0 0 | 1 | 1 | 1 | 0 | 0 1 0 1 0
Rn | Rd
op
\end{verbatim}

Vector

\texttt{UADALP} <\texttt{Vd}>, <\texttt{Ta}>, <\texttt{Vn}>, <\texttt{Tb}>

\begin{verbatim}
integer d = UInt(Rd);
integer n = UInt(Rn);

if size == '11' then UNDEFINED;
integer esize = 8 <<<if size == '11' then ReservedValue() ;
integer esize = 8 << UInt(size);
integer datasize = if Q == '1' then 128 else 64;
integer elements = datasize DIV (2*esize);
boolean acc = (op == '1');
boolean unsigned = (U == '1');
\end{verbatim}

Assembler Symbols

\texttt{<Vd>} Is the name of the SIMD&FP destination register, encoded in the "Rd" field.

\texttt{<Ta>} Is an arrangement specifier, encoded in “size:Q”:

\begin{verbatim}
size Q <Ta>
00 0 4H
00 1 8H
01 0 2S
01 1 4S
10 0 1D
10 1 2D
11 x RESERVED
\end{verbatim}

\texttt{<Vn>} Is the name of the SIMD&FP source register, encoded in the "Rn" field.

\texttt{<Tb>} Is an arrangement specifier, encoded in “size:Q”:

\begin{verbatim}
size Q <Tb>
00 0 8B
00 1 16B
01 0 4H
01 1 8H
10 0 2S
10 1 4S
11 x RESERVED
\end{verbatim}
Operation

```c
CheckFPAdvSIMDEnabled64();
bits(datasize) operand = V[n];
bits(datasize) result;

bits(2*esize) sum;
integer op1;
integer op2;

result = if acc then V[d] else Zeros();
for e = 0 to elements-1
    op1 = Int(Elem[operand, 2*e+0, esize], unsigned);
    op2 = Int(Elem[operand, 2*e+1, esize], unsigned);
    sum = (op1 + op2)<2*esize-1:0>;
    Elem[result, e, 2*esize] = Elem[result, e, 2*esize] + sum;
V[d] = result;
```

Operational information

If PSTATE.DIT is 1:

- The execution time of this instruction is independent of:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
- The response of this instruction to asynchronous exceptions does not vary based on:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.

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UADDL, UADDL2

Unsigned Add Long (vector). This instruction adds each vector element in the lower or upper half of the first source SIMD&FP register to the corresponding vector element of the second source SIMD&FP register, places the result into a vector, and writes the vector to the destination SIMD&FP register. The destination vector elements are twice as long as the source vector elements. All the values in this instruction are unsigned integer values.

The UADDL instruction extracts each source vector from the lower half of each source register, while the UADDL2 instruction extracts each source vector from the upper half of each source register.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

<table>
<thead>
<tr>
<th>Size</th>
<th>Rd</th>
<th>Rm</th>
<th>Rn</th>
<th>S</th>
<th>Tm</th>
<th>Tn</th>
<th>Tm</th>
<th>Tn</th>
<th>Q</th>
<th>U</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>size</td>
<td>1</td>
<td>Rm</td>
<td>0</td>
</tr>
</tbody>
</table>

Three registers, not all the same type

UADDL(2) <Vd>,<Ta>, <Vn>,<Tb>, <Vm>,<Tb>

```
integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rm);
if size == '11' then UNDEFINED;
integer esize = 8 << if size == '11' then ReservedValue();
integer esize = 8 << Int(size);
integer datasize = 64;
integer part = UInt(Q);
integer elements = datasize DIV esize;
boolean sub_op = (o1 == '1');
boolean unsigned = (U == '1');
```

Assembler Symbols

2 Is the second and upper half specifier. If present it causes the operation to be performed on the upper 64 bits of the registers holding the narrower elements, and is encoded in “Q”:

<table>
<thead>
<tr>
<th>Q</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>[absent]</td>
</tr>
<tr>
<td>1</td>
<td>[present]</td>
</tr>
</tbody>
</table>

<Vd> Is the name of the SIMD&FP destination register, encoded in the "Rd" field.
<Ta> Is an arrangement specifier, encoded in “size”:

<table>
<thead>
<tr>
<th>size</th>
<th>&lt;Ta&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>8H</td>
</tr>
<tr>
<td>01</td>
<td>4S</td>
</tr>
<tr>
<td>10</td>
<td>2D</td>
</tr>
<tr>
<td>11</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

<Vn> Is the name of the first SIMD&FP source register, encoded in the "Rn" field.
<Tb> Is an arrangement specifier, encoded in “size:Q”:

<table>
<thead>
<tr>
<th>size</th>
<th>Q</th>
<th>&lt;Tb&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>0</td>
<td>8B</td>
</tr>
<tr>
<td>00</td>
<td>1</td>
<td>16B</td>
</tr>
<tr>
<td>01</td>
<td>0</td>
<td>4H</td>
</tr>
<tr>
<td>01</td>
<td>1</td>
<td>8H</td>
</tr>
<tr>
<td>10</td>
<td>0</td>
<td>2S</td>
</tr>
<tr>
<td>10</td>
<td>1</td>
<td>4S</td>
</tr>
<tr>
<td>11</td>
<td>x</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>
<Vm>
Is the name of the second SIMD&FP source register, encoded in the "Rm" field.

**Operation**

```c
CheckFPAdvSIMDEnabled64();

bits(datasize) operand1 = Vpart[n, part];
bits(datasize) operand2 = Vpart[m, part];

bits(2*datasize) result;
integer element1;
integer element2;
integer sum;

for e = 0 to elements-1
   element1 = Int(Elem[operand1, e, esize], unsigned);
   element2 = Int(Elem[operand2, e, esize], unsigned);
   if sub_op then
      sum = element1 - element2;
   else
      sum = element1 + element2;

   Elem[result, e, 2*esize] = sum<2*esize-1:0>;

V[d] = result;
```

**Operational information**

If PSTATE.DIT is 1:
- The execution time of this instruction is independent of:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
- The response of this instruction to asynchronous exceptions does not vary based on:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.

Internal version only: isa v30.25, AdvSIMD v27.01, pseudocode v85-xml-00bet8_rc3atts ; Build timestamp: 2018-09-13T13:2018-06-16T09:04:45

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UADDLP

Unsigned Add Long Pairwise. This instruction adds pairs of adjacent unsigned integer values from the vector in the source SIMD&FP register, places the result into a vector, and writes the vector to the destination SIMD&FP register. The destination vector elements are twice as long as the source vector elements.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

<table>
<thead>
<tr>
<th>31</th>
<th>30</th>
<th>29</th>
<th>28</th>
<th>27</th>
<th>26</th>
<th>25</th>
<th>24</th>
<th>23</th>
<th>22</th>
<th>21</th>
<th>20</th>
<th>19</th>
<th>18</th>
<th>17</th>
<th>16</th>
<th>15</th>
<th>14</th>
<th>13</th>
<th>12</th>
<th>11</th>
<th>10</th>
<th>9</th>
<th>8</th>
<th>7</th>
<th>6</th>
<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Q</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>size</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>Rn</td>
<td>Rd</td>
<td>op</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Vector

UADDLP <Vd>,<Ta>,<Vn>.<Tb>

integer d = UInt(Rd);
integer n = UInt(Rn);

if size == '11' then UNDEFINED;
integer esize = 8 << if size == '11' then ReservedValue();
integer esize = 8 << UInt(size);
integer datasize = if Q == '1' then 128 else 64;
integer elements = datasize DIV (2*esize);
boolean acc = (op == '1');
boolean unsigned = (U == '1');

Assembler Symbols

<Vd> Is the name of the SIMD&FP destination register, encoded in the "Rd" field.
<Ta> Is an arrangement specifier, encoded in “size:Q”:
<table>
<thead>
<tr><th>size</th><th>Q</th><th><Ta></th></tr>
</thead>
<tbody>
<tr><td>00</td><td>0</td><td>4H</td></tr>
<tr><td>00</td><td>1</td><td>8H</td></tr>
<tr><td>01</td><td>0</td><td>2S</td></tr>
<tr><td>01</td><td>1</td><td>4S</td></tr>
<tr><td>10</td><td>0</td><td>1D</td></tr>
<tr><td>10</td><td>1</td><td>2D</td></tr>
<tr><td>11</td><td>x</td><td>RESERVED</td></tr>
</tbody>
</table>

<Vn> Is the name of the SIMD&FP source register, encoded in the "Rn" field.
<Tb> Is an arrangement specifier, encoded in “size:Q”:
<table>
<thead>
<tr><th>size</th><th>Q</th><th><Tb></th></tr>
</thead>
<tbody>
<tr><td>00</td><td>0</td><td>8B</td></tr>
<tr><td>00</td><td>1</td><td>16B</td></tr>
<tr><td>01</td><td>0</td><td>4H</td></tr>
<tr><td>01</td><td>1</td><td>8H</td></tr>
<tr><td>10</td><td>0</td><td>2S</td></tr>
<tr><td>10</td><td>1</td><td>4S</td></tr>
<tr><td>11</td><td>x</td><td>RESERVED</td></tr>
</tbody>
</table>
Operation

```c
CheckFPAdvSIMDEnabled64();
bits(datasize) operand = V[n];
bits(datasize) result;

bits(2*esize) sum;
integer op1;
integer op2;

result = if acc then V[d] else Zeros();
for e = 0 to elements-1
    op1 = Int(Elem[operand, 2*e+0, esize], unsigned);
    op2 = Int(Elem[operand, 2*e+1, esize], unsigned);
    sum = (op1 + op2)<2*esize-1:0>;
    Elem[result, e, 2*esize] = Elem[result, e, 2*esize] + sum;
V[d] = result;
```

Operational information

If PSTATE.DIT is 1:

- The execution time of this instruction is independent of:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
- The response of this instruction to asynchronous exceptions does not vary based on:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
UADDLV

Unsigned sum Long across Vector. This instruction adds every vector element in the source SIMD&FP register together, and writes the scalar result to the destination SIMD&FP register. The destination scalar is twice as long as the source vector elements. All the values in this instruction are unsigned integer values.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

```
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9  | 8  | 7  | 6  | 5  | 4  | 3  | 2  | 1  | 0  |
|-----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0   | Q  | 1  | 0  | 1  | 1  | 0  | size| 1  | 1  | 0  | 0  | 0  | 0  | 1  | 1  | 0  | Rn | Rd |
| U   |
```

Advanced SIMD

UADDLV <V><d>, <Vn>.<T>

```
integer d = UInt(Rd);
integer n = UInt(Rn);
if size:Q == '100' then UNDEFINED;
if size == '11' then UNDEFINED;
integer esize = 8 << Int(size);
integer datasize = if Q == '1' then 128 else 64;
integer elements = datasize DIV esize;
boolean unsigned = (U == '1');
```

Assembler Symbols

- `<V>` Is the destination width specifier, encoded in “size”:
  - | size | <V> |
  - | 00  | H   |
  - | 01  | S   |
  - | 10  | D   |
  - | 11  | RESERVED |

- `<d>` Is the number of the SIMD&FP destination register, encoded in the "Rd" field.

- `<Vn>` Is the name of the SIMD&FP source register, encoded in the "Rn" field.

- `<T>` Is an arrangement specifier, encoded in “size:Q”:
  - | size | Q | <T> |
  - | 00   | 0 | 8B  |
  - | 00   | 1 | 16B |
  - | 01   | 0 | 4H  |
  - | 01   | 1 | 8H  |
  - | 10   | 0 | RESERVED |
  - | 10   | 1 | 4S  |
  - | 11   | x | RESERVED |
Operation

```c
CheckFPAdvSIMDEnabled64();
bits(datasize) operand = V[n];
integer sum;

sum = Int(Elem)(operand, 0, esize), unsigned);
for e = 1 to elements-1
    sum = sum + Int(Elem)(operand, e, esize), unsigned);

V[d] = sum<2*esize-1:0>;
```

Operational information

If PSTATE.DIT is 1:

- The execution time of this instruction is independent of:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.

- The response of this instruction to asynchronous exceptions does not vary based on:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
**UADDW, UADDW2**

Unsigned Add Wide. This instruction adds the vector elements of the first source SIMD&FP register to the corresponding vector elements in the lower or upper half of the second source SIMD&FP register, places the result in a vector, and writes the vector to the SIMD&FP destination register. The vector elements of the destination register and the first source register are twice as long as the vector elements of the second source register. All the values in this instruction are unsigned integer values.

The UADDW instruction extracts vector elements from the lower half of the second source register, while the UADDW2 instruction extracts vector elements from the upper half of the second source register.

Depending on the settings in the `CPACR_EL1`, `CPTR_EL2`, and `CPTR_EL3` registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

```
<table>
<thead>
<tr>
<th></th>
<th>Q</th>
<th>1</th>
<th>0</th>
<th>1</th>
<th>1</th>
<th>0</th>
<th>size</th>
<th>1</th>
<th>Rm</th>
<th>0</th>
<th>0</th>
<th>0</th>
<th>1</th>
<th>0</th>
<th>Rn</th>
<th>Rd</th>
</tr>
</thead>
<tbody>
<tr>
<td>U</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
```

**Three registers, not all the same type**

UADDW2(<Vd>,<Ta>, <Vn>,<Ta>, <Vm>,<Tb>)

integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rm);

if size == '11' then UNDEFINED;

integer esize = 8 << if size == '11' then ReservedValue() else UInt(size);
integer datasize = 64;
integer part = UInt(Q);
integer elements = datasize DIV esize;

boolean sub_op = (o1 == '1');
boolean unsigned = (U == '1');

**Assembler Symbols**

<table>
<thead>
<tr>
<th></th>
<th>Q</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0</td>
<td>[absent]</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>[present]</td>
</tr>
</tbody>
</table>

<Vd> Is the name of the SIMD&FP destination register, encoded in the "Rd" field.

<Ta> Is an arrangement specifier, encoded in “size”:

<table>
<thead>
<tr>
<th>size</th>
<th>&lt;Ta&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>8H</td>
</tr>
<tr>
<td>01</td>
<td>4S</td>
</tr>
<tr>
<td>10</td>
<td>2D</td>
</tr>
<tr>
<td>11</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

<Vn> Is the name of the first SIMD&FP source register, encoded in the "Rn" field.

<Vm> Is the name of the second SIMD&FP source register, encoded in the "Rm" field.

<Tb> Is an arrangement specifier, encoded in “size-Q”:
### Operation

```c
CheckFPAdvSIMDEnabled64();

bits(2*datasize) operand1 = V[n];
bits(datasize) operand2 = Vpart[m, part];
bits(2*datasize) result;
integer element1;
integer element2;
integer sum;
for e = 0 to elements-1
  element1 = Int(Elem[operand1, e, 2*esize], unsigned);
  element2 = Int(Elem[operand2, e, esize], unsigned);
  if sub_op then
    sum = element1 - element2;
  else
    sum = element1 + element2;
  Elem[result, e, 2*esize] = sum<2*esize-1:0>;
V[d] = result;
```

### Operational information

If PSTATE.DIT is 1:

- The execution time of this instruction is independent of:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
- The response of this instruction to asynchronous exceptions does not vary based on:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.

Internal version only: isa v30.25, AdvSIMD v27.01, pseudocode v85-xml-00bet8_rc3; Build timestamp: 2018-09-13T13:04:45

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UBFM

Unaligned Bitfield Move is usually accessed via one of its aliases, which are always preferred for disassembly.
If <imms> is greater than or equal to <immr>, this copies a bitfield of (<imms>-<immr>+1) bits starting from bit position <immr> in the source
register to the least significant bits of the destination register.
If <imms> is less than <immr>, this copies a bitfield of (<imms>+1) bits from the least significant bits of the source register to bit position
(regsize-<immr>) of the destination register, where regsize is the destination register size of 32 or 64 bits.
In both cases the destination bits below and above the bitfield are set to zero.

This instruction is used by the aliases LSL (immediate), LSR (immediate), UBFIZ, UBFX, UXTB, and UXTH.

31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0

<table>
<thead>
<tr>
<th>sf</th>
<th>1</th>
<th>0</th>
<th>1</th>
<th>1</th>
<th>0</th>
<th>1</th>
<th>0</th>
<th>1</th>
<th>N</th>
<th>immr</th>
<th>imms</th>
<th>Rd</th>
</tr>
</thead>
<tbody>
<tr>
<td>opc</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

32-bit (sf == 0 && N == 0)

UBFM <Wd>, <Wn>, #<immr>, #<imms>

64-bit (sf == 1 && N == 1)

UBFM <Xd>, <Xn>, #<immr>, #<imms>

integer d = UInt(Rd);
integer n = UInt(Rn);
integer datasize = if sf == '1' then 64 else 32;

boolean inzero;
boolean extend;
integer R;
integer S;
bits(datasize) wmask;
bits(datasize) tmask;

case opc of
  when '00' inzero = TRUE;  extend = TRUE;    // SBFM
  when '01' inzero = FALSE; extend = FALSE;   // BPM
  when '10' inzero = TRUE;  extend = FALSE;   // UBFM
  when '11' UNDEFINED;

  if sf == '1' && N != '1' then UNDEFINED;
  if sf == '0' && (N != '0' || immr<5> != '0' || imms<5> != '0') then UNDEFINED;

R = when '11' UnallocatedEncoding();

if sf == '1' && N != '1' then ReservedValue();
if sf == '0' && (N != '0' || immr<5> != '0' || imms<5> != '0') then ReservedValue();

R = UInt(immr);
S = UInt(imms);
(wmask, tmask) = DecodeBitMasks(N, imms, immr, FALSE);

Assembler Symbols

<Wd> Is the 32-bit name of the general-purpose destination register, encoded in the "Rd" field.

<Wn> Is the 32-bit name of the general-purpose source register, encoded in the "Rn" field.

<Xd> Is the 64-bit name of the general-purpose destination register, encoded in the "Rd" field.

<Xn> Is the 64-bit name of the general-purpose source register, encoded in the "Rn" field.

<immr> For the 32-bit variant: is the right rotate amount, in the range 0 to 31, encoded in the "immr" field.
For the 64-bit variant: is the right rotate amount, in the range 0 to 63, encoded in the "immr" field.

For the 32-bit variant: is the leftmost bit number to be moved from the source, in the range 0 to 31, encoded in the "imms" field.

For the 64-bit variant: is the leftmost bit number to be moved from the source, in the range 0 to 63, encoded in the "imms" field.

### Alias Conditions

<table>
<thead>
<tr>
<th>Alias</th>
<th>Of variant</th>
<th>Is preferred when</th>
</tr>
</thead>
<tbody>
<tr>
<td>LSL (immediate)</td>
<td>32-bit</td>
<td>imms != '011111' &amp;&amp; imms + 1 == immr</td>
</tr>
<tr>
<td>LSL (immediate)</td>
<td>64-bit</td>
<td>imms != '111111' &amp;&amp; imms + 1 == immr</td>
</tr>
<tr>
<td>LSR (immediate)</td>
<td>32-bit</td>
<td>imms == '011111'</td>
</tr>
<tr>
<td>LSR (immediate)</td>
<td>64-bit</td>
<td>imms == '111111'</td>
</tr>
<tr>
<td>UBFIZ</td>
<td></td>
<td>UInt(imms) &lt; UInt(immr)</td>
</tr>
<tr>
<td>UBFX</td>
<td></td>
<td>BFXPreferred(sf, opc&lt;1&gt;, imms, immr)</td>
</tr>
<tr>
<td>UXTB</td>
<td></td>
<td>immr == '000000' &amp;&amp; imms == '000111'</td>
</tr>
<tr>
<td>UXTH</td>
<td></td>
<td>immr == '000000' &amp;&amp; imms == '001111'</td>
</tr>
</tbody>
</table>

### Operation

```plaintext
bits(datasize) dst = if inzero then Zeros() else X[d];
bits(datasize) src = X[n];

// perform bitfield move on low bits
bits(datasize) bot = (dst AND NOT(wmask)) OR (ROR(src, R) AND wmask);

// determine extension bits (sign, zero or dest register)
bits(datasize) top = if extend then Replicate(src<S>) else dst;

// combine extension bits and result bits
X[d] = (top AND NOT(tmask)) OR (bot AND tmask);
```

### Operational information

If PSTATE.DIT is 1:

- The execution time of this instruction is independent of:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
- The response of this instruction to asynchronous exceptions does not vary based on:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
UBFX

Unsigned Bitfield Extract copies a bitfield of `<width>` bits starting from bit position `<lsb>` in the source register to the least significant bits of the destination register, and sets destination bits above the bitfield to zero.

This is an alias of UBFM. This means:

- The encodings in this description are named to match the encodings of UBFM.
- The description of UBFM gives the operational pseudocode for this instruction.

| 31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0 | sf | 0 | 1 | 0 | 0 | 1 | 1 | 0 | N | immr | imms | Rn | Rd |
| 32-bit (sf == 0 && N == 0) |

UBFX `<Wd>`, `<Wn>`, #<lsb>, #<width>

is equivalent to

UBFM `<Wd>`, `<Wn>`, #<lsb>, #(<lsb>+<width>-1)

and is the preferred disassembly when BFXPreferred(sf, opc<1>, imms, immr).

64-bit (sf == 1 && N == 1)

UBFX `<Xd>`, `<Xn>`, #<lsb>, #<width>

is equivalent to

UBFM `<Xd>`, `<Xn>`, #<lsb>, #(<lsb>+<width>-1)

and is the preferred disassembly when BFXPreferred(sf, opc<1>, imms, immr).

Assembler Symbols

- `<Wd>` Is the 32-bit name of the general-purpose destination register, encoded in the "Rd" field.
- `<Wn>` Is the 32-bit name of the general-purpose source register, encoded in the "Rn" field.
- `<Xd>` Is the 64-bit name of the general-purpose destination register, encoded in the "Rd" field.
- `<Xn>` Is the 64-bit name of the general-purpose source register, encoded in the "Rn" field.
- `<lsb>` For the 32-bit variant: is the bit number of the lsb of the source bitfield, in the range 0 to 31.
  For the 64-bit variant: is the bit number of the lsb of the source bitfield, in the range 0 to 63.
- `<width>` For the 32-bit variant: is the width of the bitfield, in the range 1 to 32-<lsb>.
  For the 64-bit variant: is the width of the bitfield, in the range 1 to 64-<lsb>.

Operation

The description of UBFM gives the operational pseudocode for this instruction.

Operational information

If PSTATE.DIT is 1:
- The execution time of this instruction is independent of:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
- The response of this instruction to asynchronous exceptions does not vary based on:
  - The values of the data supplied in any of its registers.
The values of the NZCV flags.

Internal version only: isa v30.25, AdvSIMD v27.01, pseudocode v85-xml-00eer_rc355 ; Build timestamp: 2018-09-13T13:2018-09-16T09:45

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UCVTF (vector, fixed-point)

Unsigned fixed-point Convert to Floating-point (vector). This instruction converts each element in a vector from fixed-point to floating-point using the rounding mode that is specified by the FPCR, and writes the result to the SIMD&FP destination register.

A floating-point exception can be generated by this instruction. Depending on the settings in FPCR, the exception results in either a flag being set in FPSR, or a synchronous exception being generated. For more information, see Floating-point exception traps.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the Security state and Exception level in which the instruction is executed, an attempt to execute the instruction might be trapped.

It has encodings from 2 classes: Scalar and Vector

Scalar

UCVTF <V><d>, <V><n>, #<fbits>

integer d = UInt(Rd);
integer n = UInt(Rn);

if immh == '000x' || (immh == '001x' && !HaveFP16Ext()) then UNDEFINED;
integer esize = if immh == '1xxx' then 64 else if immh == '01xx' then 32 else 16;
integer datasize = esize;
integer elements = 1;
integer fracbits = (esize * 2) -1;

boolean unsigned = (U == '1');
FPRounding rounding = FPRoundingMode(FPCR);

Vector

UCVTF (vector, fixed-point)
Vector

UCVTF $\langle Vd \rangle$, $\langle T \rangle$, $\langle Vn \rangle$. $\langle T \rangle$, $\langle fbits \rangle$

integer $d = \text{UInt}(Rd);$
integer $n = \text{UInt}(Rn);$

if $\text{immh} = '0000'$ then \text{SEE($\text{asimdimm}$)};
if $\text{immh} = '000x'$ || (immh == '001x' & & $\text{HaveFP16Ext()}$) then UNDEFINED;
if $\text{immh} > 3:$ $q = '10'$ then UNDEFINED;
integer $\text{esize} = 64$ else if $\text{immh} = '01xx'$ then 32 else 16;
integer $\text{datasize} = 128$ else if $Q = '1'$ then 128 else 64;
integer $\text{elements} = \text{datasize} \text{DIV esize}.$

integer $\text{fracbits} = (\text{esize} * 2) - 41$ then \text{ReservedValue}();
if $\text{immh} > 3:$ $q = '10'$ then \text{ReservedValue}();
integer $\text{esize} = 64$ else if $\text{immh} = '01xx'$ then 32 else 16;
integer $\text{datasize} = 128$ else if $Q = '1'$ then 128 else 64;
integer $\text{elements} = \text{datasize} \text{DIV esize}.$

integer $\text{fracbits} = (\text{esize} * 2) - \text{UInt}(\text{immh}:\text{immb});$
boolean $\text{unsigned} = (U == '1');$
$\text{FPRounding}$ $\text{rounding} = \text{FPRoundingMode}(\text{FPCR});$

### Assembler Symbols

$\langle V \rangle$ Is a width specifier, encoded in “immh”:

<table>
<thead>
<tr>
<th>immh</th>
<th>$\langle V \rangle$</th>
</tr>
</thead>
<tbody>
<tr>
<td>000x</td>
<td>RESERVED</td>
</tr>
<tr>
<td>001x</td>
<td>H</td>
</tr>
<tr>
<td>01xx</td>
<td>S</td>
</tr>
<tr>
<td>1xxx</td>
<td>D</td>
</tr>
</tbody>
</table>

$\langle d \rangle$ Is the number of the SIMD&FP destination register, in the “Rd” field.

$\langle n \rangle$ Is the number of the first SIMD&FP source register, encoded in the “Rn” field.

$\langle Vd \rangle$ Is the name of the SIMD&FP destination register, encoded in the “Rd” field.

$\langle T \rangle$ Is an arrangement specifier, encoded in “immh:Q”:

<table>
<thead>
<tr>
<th>immh</th>
<th>Q</th>
<th>$\langle T \rangle$</th>
</tr>
</thead>
<tbody>
<tr>
<td>0000</td>
<td>x</td>
<td>\text{SEE Advanced SIMD modified immediate}</td>
</tr>
<tr>
<td>0001</td>
<td>x</td>
<td>RESERVED</td>
</tr>
<tr>
<td>001x</td>
<td>0</td>
<td>4H</td>
</tr>
<tr>
<td>001x</td>
<td>1</td>
<td>8H</td>
</tr>
<tr>
<td>01xx</td>
<td>0</td>
<td>2S</td>
</tr>
<tr>
<td>01xx</td>
<td>1</td>
<td>4S</td>
</tr>
<tr>
<td>1xxx</td>
<td>0</td>
<td>RESERVED</td>
</tr>
<tr>
<td>1xxx</td>
<td>1</td>
<td>2D</td>
</tr>
</tbody>
</table>

$\langle Vn \rangle$ Is the name of the SIMD&FP source register, encoded in the “Rn” field.

$\langle fbits \rangle$ For the scalar variant: is the number of fractional bits, in the range 1 to the operand width, encoded in “immh:immb”:

<table>
<thead>
<tr>
<th>immh</th>
<th>$\langle fbits \rangle$</th>
</tr>
</thead>
<tbody>
<tr>
<td>000x</td>
<td>RESERVED</td>
</tr>
<tr>
<td>001x</td>
<td>(32-$\text{UInt}(\text{immh}:\text{immb})$)</td>
</tr>
<tr>
<td>01xx</td>
<td>(64-$\text{UInt}(\text{immh}:\text{immb})$)</td>
</tr>
<tr>
<td>1xxx</td>
<td>(128-$\text{UInt}(\text{immh}:\text{immb})$)</td>
</tr>
</tbody>
</table>

For the vector variant: is the number of fractional bits, in the range 1 to the element width, encoded in “immh:immb”:

<table>
<thead>
<tr>
<th>immh</th>
<th>$\langle fbits \rangle$</th>
</tr>
</thead>
<tbody>
<tr>
<td>0000</td>
<td>\text{SEE Advanced SIMD modified immediate}</td>
</tr>
<tr>
<td>0001</td>
<td>RESERVED</td>
</tr>
<tr>
<td>001x</td>
<td>(32-$\text{UInt}(\text{immh}:\text{immb})$)</td>
</tr>
<tr>
<td>01xx</td>
<td>(64-$\text{UInt}(\text{immh}:\text{immb})$)</td>
</tr>
<tr>
<td>1xxx</td>
<td>(128-$\text{UInt}(\text{immh}:\text{immb})$)</td>
</tr>
</tbody>
</table>
Operation

```c
CheckFPAdvSIMDEnabled64();

bits(datasize) operand = V[n];
bits(datasize) result;
bits(esize) element;

for e = 0 to elements-1
    element = Elem[operand, e, esize];
    Elem[result, e, esize] = FixedToFP(element, fracbits, unsigned, FPCR, rounding);

V[d] = result;
```


( old ) htmldiff from- ( new )
UCVTF (vector, integer)

Unsigned integer Convert to Floating-point (vector). This instruction converts each element in a vector from an unsigned integer value to a floating-point value using the rounding mode that is specified by the FPCR, and writes the result to the SIMD&FP destination register.

A floating-point exception can be generated by this instruction. Depending on the settings in FPCR, the exception results in either a flag being set in FPSR, or a synchronous exception being generated. For more information, see Floating-point exception traps.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the Security state and Exception level in which the instruction is executed, an attempt to execute the instruction might be trapped.

It has encodings from 4 classes: Scalar half precision, Scalar single-precision and double-precision, Vector half precision and Vector single-precision and double-precision

Scalar half precision (ARMv8.2)

<table>
<thead>
<tr>
<th>31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0</th>
<th>Rn</th>
<th>Rd</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 1 1 1 1 1 1 0 0</td>
<td>1 1 1 1 0 0</td>
<td>U</td>
</tr>
</tbody>
</table>

Scalar single-precision and double-precision

<table>
<thead>
<tr>
<th>31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0</th>
<th>Rn</th>
<th>Rd</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 1 1 1 1 1 0 0</td>
<td>sz 1 0 0 0 0</td>
<td>U</td>
</tr>
</tbody>
</table>

Scalar single-precision and double-precision

UCVTF <V<d>, <V<n>

<table>
<thead>
<tr>
<th>31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0</th>
<th>Rn</th>
<th>Rd</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 1 1 1 1 1 0 0</td>
<td>sz 1 0 0 0 0</td>
<td>U</td>
</tr>
</tbody>
</table>

Vector half precision (ARMv8.2)

<table>
<thead>
<tr>
<th>31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0</th>
<th>Rn</th>
<th>Rd</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 1 1 1 1 1 0 0</td>
<td>1 1 1 1 0 0</td>
<td>U</td>
</tr>
</tbody>
</table>

UCVTF (vector, integer)
Vector half precision

UCVT F $<V_d>., <T>., <V_n>., <T>

if !HaveFP16Ext() then UNDEFINED;

integer d = 4; then UnallocatedEncoding();
integer d = UInt (Rd);
integer n = UInt (Rn);

integer esize = 16;
integer datasize = if Q == '1' then 128 else 64;
integer elements = datasize DIV esize;
boolean unsigned = (U == '1');

Vector single-precision and double-precision

integer d = UInt (Rd);
integer n = UInt (Rn);

if sz:Q == '10' then UNDEFINED;
integer esize = 32 << if sz:Q == '10' then ReservedValue();
integer esize = 32 << UInt (sz);
integer datasize = if Q == '1' then 128 else 64;
integer elements = datasize DIV esize;
boolean unsigned = (U == '1');

Assembler Symbols

$<H_d>$ Is the 16-bit name of the SIMD&FP destination register, encoded in the "Rd" field.

$<H_n>$ Is the 16-bit name of the SIMD&FP source register, encoded in the "Rn" field.

$<V>$ Is a width specifier, encoded in "sz":

<table>
<thead>
<tr>
<th>sz</th>
<th>$&lt;V&gt;$</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>S</td>
</tr>
<tr>
<td>1</td>
<td>D</td>
</tr>
</tbody>
</table>

$<d>$ Is the number of the SIMD&FP destination register, encoded in the "Rd" field.

$<n>$ Is the number of the SIMD&FP source register, encoded in the "Rn" field.

$<V_d>$ Is the name of the SIMD&FP destination register, encoded in the "Rd" field.

$<T>$ For the vector half precision variant: is an arrangement specifier, encoded in “Q”:

<table>
<thead>
<tr>
<th>Q</th>
<th>$&lt;T&gt;$</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>4H</td>
</tr>
<tr>
<td>1</td>
<td>8H</td>
</tr>
</tbody>
</table>

For the vector single-precision and double-precision variant: is an arrangement specifier, encoded in “sz:Q”:

<table>
<thead>
<tr>
<th>sz</th>
<th>Q</th>
<th>$&lt;T&gt;$</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>2S</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>4S</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>RESERVED</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>2D</td>
</tr>
</tbody>
</table>

$<V_n>$ Is the name of the SIMD&FP source register, encoded in the "Rn" field.
Operation

```c
CheckFPAdvSIMDEnabled64();

bits(datasize) operand = V[n];
bits(datasize) result;
FPRounding rounding = FPRoundingMode(FPCR);
bits(esize) element;
for e = 0 to elements-1
    element = Elem[operand, e, esize];
    Elem[result, e, esize] = FixedToFP(element, 0, unsigned, FPCR, rounding);
V[d] = result;
```
UCVTF (scalar, fixed-point)

Unsigned fixed-point Convert to Floating-point (scalar). This instruction converts the unsigned value in the 32-bit or 64-bit general-purpose source register to a floating-point value using the rounding mode that is specified by the FPCR, and writes the result to the SIMD&FP destination register.

A floating-point exception can be generated by this instruction. Depending on the settings in FPCR, the exception results in either a flag being set in FPSR, or a synchronous exception being generated. For more information, see Floating-point exception traps.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the Security state and Exception level in which the instruction is executed, an attempt to execute the instruction might be trapped.

<table>
<thead>
<tr>
<th>sf</th>
<th>0</th>
<th>0</th>
<th>1</th>
<th>1</th>
<th>1</th>
<th>0</th>
<th>type</th>
<th>0</th>
<th>0</th>
<th>0</th>
<th>1</th>
<th>1</th>
<th>scale</th>
<th>Rn</th>
<th>Rd</th>
</tr>
</thead>
<tbody>
<tr>
<td>rmode</td>
<td>opcode</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
32-bit to half-precision (sf == 0 && type == 11)  
(ARMv8.2)

UCVTF <Hd>, <Wn>, #<fbits>

32-bit to single-precision (sf == 0 && type == 00)

UCVTF <Sd>, <Wn>, #<fbits>

32-bit to double-precision (sf == 0 && type == 01)

UCVTF <Dd>, <Wn>, #<fbits>

64-bit to half-precision (sf == 1 && type == 11)  
(ARMv8.2)

UCVTF <Hd>, <Xn>, #<fbits>

64-bit to single-precision (sf == 1 && type == 00)

UCVTF <Sd>, <Xn>, #<fbits>

64-bit to double-precision (sf == 1 && type == 01)

UCVTF <Dd>, <Xn>, #<fbits>
integer \( d = \text{UInt}(Rd) \);
integer \( n = \text{UInt}(Rn) \);

integer intsize = if sf == '1' then 64 else 32;
integer fltsize;
FPConvOp op;
FPRounding rounding;
boolean unsigned;

case type of
  when '00' fltsize = 32;
  when '01' fltsize = 64;
  when '10' UNDEFINED;
  when '11'
    if when '10' UNallocatedEncoding();
    when '11'
      if HaveFP16Ext() then
        fltsize = 16;
      else
        UNDEFINED;
  else
    UNDEFINED;

if sf == '0' \&\& scale<5> == '0' then UNDEFINED;
integer fracbits = 64 - \text{UInt}(scale);

if sf == '0' \&\& scale<5> == '0' then UNallocatedEncoding();
integer fracbits = 64 - \text{UInt}(scale);

case opcode<2:1>:rmode of
  when '00 11' // FCVTZ
    rounding = FPRounding ZERO;
    unsigned = (opcode<0> == '1');
    op = FPConvOp CVT_FtoI;
  when '01 00' // [US]CVTF
    rounding = FPRoundingMode(FPCR);
    unsigned = (opcode<0> == '1');
    op = FPConvOp CVT_ItoF;
  otherwise
    UNallocatedEncoding;
  otherwise
    UNDEFINED();

Assembler Symbols

<\text{Dd}> Is the 64-bit name of the SIMD&FP destination register, encoded in the "Rd" field.

<\text{Hd}> Is the 16-bit name of the SIMD&FP destination register, encoded in the "Rd" field.

<\text{Sd}> Is the 32-bit name of the SIMD&FP destination register, encoded in the "Rd" field.

<\text{Xn}> Is the 64-bit name of the general-purpose source register, encoded in the "Rn" field.

<\text{Wn}> Is the 32-bit name of the general-purpose source register, encoded in the "Rn" field.

<\text{fbits}> For the 32-bit to double-precision, 32-bit to half-precision and 32-bit to single-precision variant: is the number of bits after the binary point in the fixed-point source, in the range 1 to 32, encoded as 64 minus "scale".

For the 64-bit to double-precision, 64-bit to half-precision and 64-bit to single-precision variant: is the number of bits after the binary point in the fixed-point source, in the range 1 to 64, encoded as 64 minus "scale".
Operation

CheckFPAdvSIMEnabled64();

bits(fltsize) fltval;
bits(intsize) intval;

case op of
  when FPConvOp_CVT_FtoI
    fltval = V[n];
    intval = FPToFixed(fltval, fracbits, unsigned, FPCR, rounding);
    X[d] = intval;
  when FPConvOp_CVT_ItoF
    intval = X[n];
    fltval = FixedToFP(intval, fracbits, unsigned, FPCR, rounding);
    V[d] = fltval;

Internal version only: isa v30.25 v29.05, AdvSIMD v27.01 v26.0, pseudocode v85-xml-00bet8_rc3329; Build timestamp: 2018-09-13T13:2018-06-16T09:04:45

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UCVTF (scalar, integer)

Unsigned integer Convert to Floating-point (scalar). This instruction converts the unsigned integer value in the general-purpose source register to a floating-point value using the rounding mode that is specified by the FPCR, and writes the result to the SIMD&FP destination register.

A floating-point exception can be generated by this instruction. Depending on the settings in FPCR, the exception results in either a flag being set in FPSR, or a synchronous exception being generated. For more information, see Floating-point exception traps.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.
32-bit to half-precision (sf == 0 && type == 11)  
(ARMv8.2)  
UCVTФ <Hd>, <Wn>

32-bit to single-precision (sf == 0 && type == 00)  
UCVTФ <Sd>, <Wn>

32-bit to double-precision (sf == 0 && type == 01)  
UCVTФ <Dd>, <Wn>

64-bit to half-precision (sf == 1 && type == 11)  
(ARMv8.2)  
UCVTФ <Hd>, <Xn>

64-bit to single-precision (sf == 1 && type == 00)  
UCVTФ <Sd>, <Xn>

64-bit to double-precision (sf == 1 && type == 01)  
UCVTФ <Dd>, <Xn>
integer \(d\) = \textit{UInt}(Rd);
integer \(n\) = \textit{UInt}(Rn);

integer intsize = if \(sf\) == '1' then 64 else 32;
integer \(f\)ltsize;
\textbf{FPConvOp} \(\text{op}\);  
\textbf{FPRounding} \(\text{rounding}\);  
boolean unsigned;
integer \(p\)art;

\textbf{case} type of \textbf{case} \(\text{opcode}<2:1>:rmode\) of
  when '00'
    \(f\)ltsize = 32;
  when '01'
    \(f\)ltsize = 64;
  when '10'
    if \(\text{opcode}<2:1>:rmode\) != '11 01' then UNDEFINED;
    \(f\)ltsize = 128;
  when '11'
    if \(\text{opcode}<2:1>:rmode\) != '11 01' then \textit{UnallocatedEncoding}();
    \(f\)ltsize = 128;
  when '11'
    if \(\text{HaveFP16Ext}()\) then
      \(f\)ltsize = 16;
    else
      UNDEFINED;

\textbf{case} \(\text{opcode}<2:1>:rmode\) of
  when '00 \textit{xx}' // FCVT[\textit{NPMZ}][\textit{US}]
    \(r\)ounding = \textit{UnallocatedEncoding}();
  case \(\text{opcode}<2:1>:rmode\) of
    when '00 \textit{xx}' // FCVT[\textit{NPMZ}][\textit{US}]
      \(r\)ounding = \textbf{FPDecodeRounding}(\text{rmode});
      unsigned = (\(\text{opcode}<0>\) == '1');
      \(o\)p = \textbf{FPConvOp_CVT_FtoI};
    when '01 00' // [\textit{US}]CVTF
      \(r\)ounding = \textbf{FP.RoundingMode}(\text{FPCR});
      unsigned = (\(\text{opcode}<0>\) == '1');
      \(o\)p = \textbf{FPConvOp_CVT_ItoF};
    when '10 00' // FCVT[A][\textit{US}]
      \(r\)ounding = \textbf{FP.Rounding_TIEAWAY};
      unsigned = (\(\text{opcode}<0>\) == '1');
      \(o\)p = \textbf{FPConvOp_CVT_FtoI};
    when '11 00' // FMOV
      if \(f\)ltsize != 16 \&\& \(f\)ltsize != \(\)ntsize then UNDEFINED;
      \(o\)p = if \(\text{opcode}<0>\) == '1' then \textit{UnallocatedEncoding}();
      \(o\)p = if \(\text{opcode}<0>\) == '1' then \textbf{FPConvOp_MOV_ItoF} else \textbf{FPConvOp_MOV_FtoI};
      \(p\)art = 0;
    when '11 01' // FMOV D[1]
      if \(\)ntsize != 64 \&\& \(f\)ltsize != 128 then UNDEFINED;
      \(o\)p = if \(\text{opcode}<0>\) == '1' then \textit{UnallocatedEncoding}();
      \(o\)p = if \(\text{opcode}<0>\) == '1' then \textbf{FPConvOp_MOV_ItoF} else \textbf{FPConvOp_MOV_FtoI};
      \(p\)art = 1;
      \(f\)ltsize = 64; // size of D[1] is 64
    when '11 11' // FJCVTZS
      if \(\text{HaveFJCVTZSExt}()\) then UNDEFINED;
      \(r\)ounding = \textit{UnallocatedEncoding}();
      \(r\)ounding = \textbf{FPRounding_ZERO};
      unsigned = (\(\text{opcode}<0>\) == '1');
      \(o\)p = \textbf{FPConvOp_CVT_FtoI_JS};
  otherwise
    \textit{UnallocatedEncoding}();
  otherwise
    UNDEFINED();

\textbf{Assembler Symbols}

\texttt{<Dd>} Is the 64-bit name of the SIMD\&FP destination register, encoded in the "Rd" field.
Is the 16-bit name of the SIMD&FP destination register, encoded in the "Rd" field.
Is the 32-bit name of the SIMD&FP destination register, encoded in the "Rd" field.
Is the 64-bit name of the general-purpose source register, encoded in the "Rn" field.
Is the 32-bit name of the general-purpose source register, encoded in the "Rn" field.

Operation

```c
CheckFPAdvSIMDEnabled64();

bits(fltsize) fltval;
bits(intsize) intval;

case op of
    when FPConvOp_CVT_FtoI
        fltval = V[n];
        intval = FPTofixed(fltval, 0, unsigned, FPCR, rounding);
        X[d] = intval;
    when FPConvOp_CVT_ItoF
        intval = X[n];
        fltval = FixedToFP(intval, 0, unsigned, FPCR, rounding);
        V[d] = fltval;
    when FPConvOp_MOV_FtoI
        fltval = Vpart[n,part];
        intval = ZeroExtend(fltval, intsize);
        X[d] = intval;
    when FPConvOp_MOV_ItoF
        intval = X[n];
        fltval = intval<fltsize-1:0>;
        Vpart[d,part] = fltval;
    when FPConvOp_CVT_FtoI_JS
        fltval = V[n];
        intval = FPTofixedJS(fltval, FPCR, TRUE);
        X[d] = ZeroExtend(intval<31:0>, 64);
```


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UDF

Permanently Undefined generates an Undefined Instruction exception (ESR_ELx.EC = 0b0000000). The encodings for UDF used in this section are defined as permanently UNDEFINED in the ARMv8-A architecture.

```
   0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0

    imm16
```

Integer

```
UDF #<imm>

// The imm16 field is ignored by hardware.
UNDEFINED;
```

Assembler Symbols

```
<imm> is a 16-bit unsigned immediate, in the range 0 to 65535, encoded in the "imm16" field. The PE ignores the value of this constant.
```

Operation

```
// No operation.
```
UDOT (by element)

Dot Product unsigned arithmetic (vector, by element). This instruction performs the dot product of the four 8-bit elements in each 32-bit element of the first source register with the four 8-bit elements of an indexed 32-bit element in the second source register, accumulating the result into the corresponding 32-bit element of the destination register.

Depending on the settings in the `CPACR_EL1`, `CPTR_EL2`, and `CPTR_EL3` registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

In ARMv8.2 and ARMv8.3, this is an optional instruction. From ARMv8.4 it is mandatory for all implementations to support it. `ID_AA64ISAR0_EL1.DP` indicates whether this instruction is supported.

Vector (ARMv8.2)

```
0 Q 1 0 1 1 1 1 size L M Rm 1 1 1 0 H 0 Rn Rd U
```

Vector

```
if !HaveDOTPExt() then UNDEFINED;
if size != '10' then UNDEFINED;
boolean signed = (U=='0');
integer d = if size != '10' then ReservedValue() else UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(M:Rm);
integer index = UInt(H:L);
integer esize = 8 << UInt(size);
integer datasize = if Q == 'l' then 128 else 64;
integer elements = datasize DIV esize;
```

Assembler Symbols

- `<Vd>` Is the name of the SIMD&FP destination register, encoded in the "Rd" field.
- `<Ta>` Is an arrangement specifier, encoded in “Q”:
  - Q <Ta>
    - 0 2S
    - 1 4S
- `<Vn>` Is the name of the first SIMD&FP source register, encoded in the "Rn" field.
- `<Tb>` Is an arrangement specifier, encoded in “Q”:
  - Q <Tb>
    - 0 8B
    - 1 16B
- `<Vm>` Is the name of the second SIMD&FP source register, encoded in the "M:Rm" fields.
- `<index>` Is the element index, encoded in the "H:L" fields.
CheckFPAdvSIMDEnabled64();

bits(datasize) operand1 = V[n];
bits(128) operand2 = V[m];
bits(datasize) result = V[d];
for e = 0 to elements-1
    integer res = 0;
    integer element1, element2;
    for i = 0 to 3
        if signed then
            element1 = SInt(Elem[operand1, 4 * e + i, esize DIV 4]);
            element2 = SInt(Elem[operand2, 4 * index + i, esize DIV 4]);
        else
            element1 = UInt(Elem[operand1, 4 * e + i, esize DIV 4]);
            element2 = UInt(Elem[operand2, 4 * index + i, esize DIV 4]);
        res = res + element1 * element2;
        Elem[result, e, esize] = Elem[result, e, esize] + res;
    V[d] = result;
UDOT (vector)

Dot Product unsigned arithmetic (vector). This instruction performs the dot product of the four 8-bit elements in each 32-bit element of the first source register with the four 8-bit elements of the corresponding 32-bit element in the second source register, accumulating the result into the corresponding 32-bit element of the destination register.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

In ARMv8.2 and ARMv8.3, this is an optional instruction. From ARMv8.4 it is mandatory for all implementations to support it.

ID_AA64ISAR0_EL1.DP indicates whether this instruction is supported.

Three registers of the same type

<table>
<thead>
<tr>
<th>31</th>
<th>30</th>
<th>29</th>
<th>28</th>
<th>27</th>
<th>26</th>
<th>25</th>
<th>24</th>
<th>23</th>
<th>22</th>
<th>21</th>
<th>20</th>
<th>19</th>
<th>18</th>
<th>17</th>
<th>16</th>
<th>15</th>
<th>14</th>
<th>13</th>
<th>12</th>
<th>11</th>
<th>10</th>
<th>9</th>
<th>8</th>
<th>7</th>
<th>6</th>
<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>size</td>
<td>0</td>
<td>Rm</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>Rn</td>
<td>0</td>
<td>Rd</td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Three registers of the same type

UDOT <Vd>.<Ta>, <Vn>.<Tb>, <Vm>.<Tb>

<table>
<thead>
<tr>
<th>Q</th>
<th>&lt;Ta&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>2S</td>
</tr>
<tr>
<td>1</td>
<td>4S</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Q</th>
<th>&lt;Tb&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>8B</td>
</tr>
<tr>
<td>1</td>
<td>16B</td>
</tr>
</tbody>
</table>

Assembler Symbols

<Vd> Is the name of the SIMD&FP destination register, encoded in the "Rd" field.

<Ta> Is an arrangement specifier, encoded in “Q”:

<Vn> Is the name of the first SIMD&FP source register, encoded in the "Rn" field.

<Tb> Is an arrangement specifier, encoded in “Q”:

<Vm> Is the name of the second SIMD&FP source register, encoded in the "Rm" field.
Operation

```c
CheckFPAdvSIMEnabled64();
bits(datasize) operand1 = V[n];
bits(datasize) operand2 = V[m];
bits(datasize) result;

result = V[d];
for e = 0 to elements-1
    integer res = 0;
    integer element1, element2;
    for i = 0 to 3
        if signed then
            element1 = SInt(Elem[operand1, 4 * e + i, esize DIV 4]);
            element2 = SInt(Elem[operand2, 4 * e + i, esize DIV 4]);
        else
            element1 = UInt(Elem[operand1, 4 * e + i, esize DIV 4]);
            element2 = UInt(Elem[operand2, 4 * e + i, esize DIV 4]);
        res = res + element1 * element2;
        Elem[result, e, esize] = Elem[result, e, esize] + res;
    V[d] = result;
```
**UHADD**

Unsigned Halving Add. This instruction adds corresponding unsigned integer values from the two source SIMD&FP registers, shifts each result right one bit, places the results into a vector, and writes the vector to the destination SIMD&FP register.

The results are truncated. For rounded results, see **URHADD**.

Depending on the settings in the `CPACR_EL1`, `CPTR_EL2`, and `CPTR_EL3` registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

<table>
<thead>
<tr>
<th>31</th>
<th>30</th>
<th>29</th>
<th>28</th>
<th>27</th>
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<th>25</th>
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<th>7</th>
<th>6</th>
<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
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<td>0</td>
<td>0</td>
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<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>

### Three registers of the same type

UHADD `<Vd>`, `<Vn>`, `<Vm>`

#### Assembler Symbols

- `<Vd>`
  Is the name of the SIMD&FP destination register, encoded in the "Rd" field.
- `<Vn>`
  Is the name of the first SIMD&FP source register, encoded in the "Rn" field.
- `<Vm>`
  Is the name of the second SIMD&FP source register, encoded in the "Rm" field.

#### Operation

```plaintext
CheckFPAdySIMDEnabled64();
bits(datasize) operand1 = V[n];
bits(datasize) operand2 = V[m];
bits(datasize) result;
integer element1;
integer element2;
integer sum;
for e = 0 to elements-1
    element1 = Int(Elem[operand1, e, esize], unsigned);
    element2 = Int(Elem[operand2, e, esize], unsigned);
    sum = element1 + element2;
    Elem[result, e, esize] = sum<esize:1>;
V[d] = result;
```
Operational information

If PSTATE.DIT is 1:

- The execution time of this instruction is independent of:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.

- The response of this instruction to asynchronous exceptions does not vary based on:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
UHSUB

Unsigned Halving Subtract. This instruction subtracts the vector elements in the second source SIMD&FP register from the corresponding vector elements in the first source SIMD&FP register, shifts each result right one bit, places each result into a vector, and writes the vector to the destination SIMD&FP register.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

<table>
<thead>
<tr>
<th>Q</th>
<th>0</th>
<th>1</th>
<th>0</th>
<th>1</th>
<th>1</th>
<th>0</th>
<th>1</th>
<th>63</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rd</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
</tbody>
</table>

Three registers of the same type

\[ \text{UHSUB} <V_d>.<T>, <V_n>.<T>, <V_m>.<T> \]

integer d = \text{UInt}(Rd);
integer n = \text{UInt}(Rn);
integer m = \text{UInt}(Rm);

if size == '11' then UNDEFINED;
integer esize = 8 << if size == '11' then \text{ReservedValue}();
integer esize = 8 << \text{UInt}(size);
integer datasize = if Q == '1' then 128 else 64;
integer elements = datasize \text{DIV} esize;
boolean unsigned = (U == '1');

Assembler Symbols

\(<V_d>\) Is the name of the SIMD&FP destination register, encoded in the “Rd” field.
\(<T>\) Is an arrangement specifier, encoded in “size:Q”:

<table>
<thead>
<tr>
<th>size</th>
<th>Q</th>
<th>&lt;T&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>0</td>
<td>8B</td>
</tr>
<tr>
<td>00</td>
<td>1</td>
<td>16B</td>
</tr>
<tr>
<td>01</td>
<td>0</td>
<td>4H</td>
</tr>
<tr>
<td>01</td>
<td>1</td>
<td>8H</td>
</tr>
<tr>
<td>10</td>
<td>0</td>
<td>2S</td>
</tr>
<tr>
<td>10</td>
<td>1</td>
<td>4S</td>
</tr>
<tr>
<td>11</td>
<td>x</td>
<td>\text{RESERVED}</td>
</tr>
</tbody>
</table>

\(<V_n>\) Is the name of the first SIMD&FP source register, encoded in the “Rn” field.
\(<V_m>\) Is the name of the second SIMD&FP source register, encoded in the “Rm” field.

Operation

\text{CheckFPAdvSIMDEnabled64}();
bits(datasize) operand1 = V[n];
bits(datasize) operand2 = V[m];
bits(datasize) result;
integer element1;
integer element2;
integer diff;

for e = 0 to elements-1
    element1 = \text{Int}(\text{Elem}[operand1, e, esize], unsigned);
    element2 = \text{Int}(\text{Elem}[operand2, e, esize], unsigned);
    diff = element1 - element2;
    \text{Elem}[result, e, esize] = diff<esize:1>;
\text{V}[d] = result;
Operational information

If PSTATE.DIT is 1:

- The execution time of this instruction is independent of:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.

- The response of this instruction to asynchronous exceptions does not vary based on:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
UMAX

Unsigned Maximum (vector). This instruction compares corresponding elements in the vectors in the two source SIMD&FP registers, places the larger of each pair of unsigned integer values into a vector, and writes the vector to the destination SIMD&FP register.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

<table>
<thead>
<tr>
<th>31</th>
<th>30</th>
<th>29</th>
<th>28</th>
<th>27</th>
<th>26</th>
<th>25</th>
<th>24</th>
<th>23</th>
<th>22</th>
<th>21</th>
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<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Q</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
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<td></td>
<td></td>
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<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

Three registers of the same type

UMAX <Vd>.<T>, <Vn>.<T>, <Vm>.<T>

integer d =(UInt(Rd));
integer n = UInt(Rn);
integer m = UInt(Rm);
if size == '11' then UNDEFINED;
integer esize = 8 << if size == '11' then ReservedValue();
integer esize = 8 << UInt(size);
integer datasize = if Q == '1' then 128 else 64;
integer elements = datasize DIV esize;

boolean unsigned = (U == '1');
boolean minimum = (o1 == '1');

Assembler Symbols

<Vd> Is the name of the SIMD&FP destination register, encoded in the "Rd" field.
<T> Is an arrangement specifier, encoded in “size:Q”:

<Vn> Is the name of the first SIMD&FP source register, encoded in the "Rn" field.
<Vm> Is the name of the second SIMD&FP source register, encoded in the "Rm" field.

Operation

CheckFPAdvSIMDEnabled64();
bits(datasize) operand1 = V[n];
bits(datasize) operand2 = V[m];
bits(datasize) result;
integer element1;
integer element2;
integer maxmin;

for e = 0 to elements-1
  element1 = Int(Elem[operand1, e, esize], unsigned);
  element2 = Int(Elem[operand2, e, esize], unsigned);
  maxmin = if minimum then Min(element1, element2) else Max(element1, element2);
  Elem[result, e, esize] = maxmin<esize-1:0>;

V[d] = result;
Operational information

If PSTATE.DIT is 1:

• The execution time of this instruction is independent of:
  ◦ The values of the data supplied in any of its registers.
  ◦ The values of the NZCV flags.

• The response of this instruction to asynchronous exceptions does not vary based on:
  ◦ The values of the data supplied in any of its registers.
  ◦ The values of the NZCV flags.
Unsigned Maximum Pairwise. This instruction creates a vector by concatenating the vector elements of the first source SIMD&FP register after the vector elements of the second source SIMD&FP register, reads each pair of adjacent vector elements in the two source SIMD&FP registers, writes the largest of each pair of unsigned integer values into a vector, and writes the vector to the destination SIMD&FP register.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

**Assembler Symbols**

- `<Vd>` Is the name of the SIMD&FP destination register, encoded in the "Rd" field.
- `<Vn>` Is the name of the first SIMD&FP source register, encoded in the "Rn" field.
- `<Vm>` Is the name of the second SIMD&FP source register, encoded in the "Rm" field.
- `<T>` Is an arrangement specifier, encoded in “size:Q”:

<table>
<thead>
<tr>
<th>size</th>
<th>Q</th>
<th>&lt;T&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>0</td>
<td>8B</td>
</tr>
<tr>
<td>00</td>
<td>1</td>
<td>16B</td>
</tr>
<tr>
<td>01</td>
<td>0</td>
<td>4H</td>
</tr>
<tr>
<td>01</td>
<td>1</td>
<td>8H</td>
</tr>
<tr>
<td>10</td>
<td>0</td>
<td>2S</td>
</tr>
<tr>
<td>10</td>
<td>1</td>
<td>4S</td>
</tr>
<tr>
<td>11</td>
<td>x</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

```java
integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rm);

if size == '11' then UNDEFINED;
integer esize = 8 << if size == '11' then ReservedValue();
integer esize = 8 << UInt(size);
integer datasize = if Q == '1' then 128 else 64;
integer elements = datasize DIV esize;

boolean unsigned = (U == '1');
boolean minimum = (o1 == '1');
```
Operation

```c
CheckFPAdvSIMDEnabled64();
bits(datasize) operand1 = V[n];
bits(datasize) operand2 = V[m];
bits(datasize) result;
bits(2*datasize) concat = operand2:operand1;
integer element1;
integer element2;
integer maxmin;
for e = 0 to elements-1
    element1 = Int(Elem[concat, 2*e, esize], unsigned);
    element2 = Int(Elem[concat, (2*e)+1, esize], unsigned);
    maxmin = if minimum then Min(element1, element2) else Max(element1, element2);
    Elem[result, e, esize] = maxmin<esize-1:0>;
V[d] = result;
```

Operational information

If PSTATE.DIT is 1:

- The execution time of this instruction is independent of:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
- The response of this instruction to asynchronous exceptions does not vary based on:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
UMAXV

Unsigned Maximum across Vector. This instruction compares all the vector elements in the source SIMD&FP register, and writes the largest of the values as a scalar to the destination SIMD&FP register. All the values in this instruction are unsigned integer values.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

```
<table>
<thead>
<tr>
<th>31</th>
<th>30</th>
<th>29</th>
<th>28</th>
<th>27</th>
<th>26</th>
<th>25</th>
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<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
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<td>0</td>
<td>0</td>
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</tr>
</tbody>
</table>
```

Advanced SIMD

```
UMAXV <V><d>, <Vn><T>

integer d = UInt(Rd);
integer n = UInt(Rn);
if size:Q == '100' then UNDEFINED;
if size == '11' then UNDEFINED;
integer esize = 8 << (if size:Q == '100' then ReservedValue(1);
if size == '11' then ReservedValue(1);
integer esize = 8 << UInt(size);
integer datasize = if Q == '1' then 128 else 64;
integer elements = datasize DIV esize;

boolean unsigned = (U == '1');
boolean min = (op == '1');
```

Assembler Symbols

```
<V> Is the destination width specifier, encoded in "size":

<table>
<thead>
<tr>
<th>size</th>
<th>&lt;V&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>B</td>
</tr>
<tr>
<td>01</td>
<td>H</td>
</tr>
<tr>
<td>10</td>
<td>S</td>
</tr>
<tr>
<td>11</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

<d> Is the number of the SIMD&FP destination register, encoded in the "Rd" field.

<Vn> Is the name of the SIMD&FP source register, encoded in the "Rn" field.

<T> Is an arrangement specifier, encoded in "size:Q":

<table>
<thead>
<tr>
<th>size</th>
<th>Q</th>
<th>&lt;T&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>0</td>
<td>8B</td>
</tr>
<tr>
<td>00</td>
<td>1</td>
<td>16B</td>
</tr>
<tr>
<td>01</td>
<td>0</td>
<td>4H</td>
</tr>
<tr>
<td>01</td>
<td>1</td>
<td>8H</td>
</tr>
<tr>
<td>10</td>
<td>0</td>
<td>RESERVED</td>
</tr>
<tr>
<td>10</td>
<td>1</td>
<td>4S</td>
</tr>
<tr>
<td>11</td>
<td>x</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>
```
Operation

```c
CheckFPAdvSIMDEnabled64();
bits(datasize) operand = V[n];
integer maxmin;
integer element;

maxmin = int(Elem[operand, 0, esize], unsigned);
for e = 1 to elements-1
    element = int(Elem[operand, e, esize], unsigned);
    maxmin = if min then Min(maxmin, element) else Max(maxmin, element);
V[d] = maxmin<esize-1:0>;
```

Operational information

If PSTATE.DIT is 1:

- The execution time of this instruction is independent of:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
- The response of this instruction to asynchronous exceptions does not vary based on:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.

Internal version only: isa v30.25 v29.05, AdvSIMD v27.01 v26.0, pseudocode v85-xml-00bet8_rc3beta ; Build timestamp: 2018-09-13T13:2018-06-16T09:045

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**UMIN**

Unsigned Minimum (vector). This instruction compares corresponding vector elements in the two source SIMD&FP registers, places the smaller of each of the two unsigned integer values into a vector, and writes the vector to the destination SIMD&FP register.

Depending on the settings in the `CPACR_EL1, CPTR_EL2, and CPTR_EL3` registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

```
|   31  |  30  |  29  |  28  |  27  |  26  |  25  |  24  |  23  |  22  |  21  |  20  |  19  |  18  |  17  |  16  |  15  |  14  |  13  |  12  |  11  |  10  |  9   |  8   |  7   |  6   |  5   |  4   |  3   |  2   |  1   |  0   |
|-------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|
|   0   |   Q |  1   |  0   |  1   |  1   |  0   | size |  1   | Rm   |  0   |  1   |  0   |   1  |   1  |   1  |   0  |   Rn  |   Rd  |  0   |
| U     |     |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
```

Three registers of the same type

```
UMIN <Vd>.<T>, <Vn>.<T>, <Vm>.<T>
```

```
integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rm);
if size == '11' then UNDEFINED;
integer esize = 8 << if size == '11' then ReservedValue();
integer esize = 8 << UInt(size);
integer datasize = if Q == '1' then 128 else 64;
integer elements = datasize DIV esize;

boolean unsigned = (U == '1');
boolean minimum = (o1 == '1');
```

**Assembler Symbols**

```
<Vd> Is the name of the SIMD&FP destination register, encoded in the "Rd" field.
<T> Is an arrangement specifier, encoded in "size:Q":

<table>
<thead>
<tr>
<th>size</th>
<th>Q</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>8B</td>
</tr>
<tr>
<td>00</td>
<td>16B</td>
</tr>
<tr>
<td>01</td>
<td>4H</td>
</tr>
<tr>
<td>01</td>
<td>8H</td>
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<tr>
<td>10</td>
<td>2S</td>
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<tr>
<td>10</td>
<td>4S</td>
</tr>
<tr>
<td>11</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>
```

```
<Vn> Is the name of the first SIMD&FP source register, encoded in the "Rn" field.
<Vm> Is the name of the second SIMD&FP source register, encoded in the "Rm" field.
```

**Operation**

```
CheckFPAdvSIMDEnabled64();
b bits(datasize) operand1 = V[n];
b bits(datasize) operand2 = V[m];
b bits(datasize) result;
integer element1;
integer element2;
integer maxmin;

for e = 0 to elements-1
    element1 = Int(Elem[operand1, e, esize], unsigned);
    element2 = Int(Elem[operand2, e, esize], unsigned);
    maxmin = if minimum then Min(element1, element2) else Max(element1, element2);
    Elem[result, e, esize] = maxmin<esize-1:0>;

V[d] = result;
```
Operational information

If PSTATE.DIT is 1:

- The execution time of this instruction is independent of:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.

- The response of this instruction to asynchronous exceptions does not vary based on:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
Unsigned Minimum Pairwise. This instruction creates a vector by concatenating the vector elements of the first source SIMD&FP register after the vector elements of the second source SIMD&FP register, reads each pair of adjacent vector elements in the two source SIMD&FP registers, writes the smallest of each pair of unsigned integer values into a vector, and writes the vector to the destination SIMD&FP register.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

Three registers of the same type

<table>
<thead>
<tr>
<th>U</th>
<th>size</th>
<th>Rm</th>
<th>Rd</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
</tbody>
</table>

Assembler Symbols

- `<Vd>`  
  Is the name of the SIMD&FP destination register, encoded in the "Rd" field.

- `<T>`  
  Is an arrangement specifier, encoded in "size:Q":

<table>
<thead>
<tr>
<th>size</th>
<th>Q</th>
<th>&lt;T&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>0</td>
<td>8B</td>
</tr>
<tr>
<td>00</td>
<td>1</td>
<td>16B</td>
</tr>
<tr>
<td>01</td>
<td>0</td>
<td>4H</td>
</tr>
<tr>
<td>01</td>
<td>1</td>
<td>8H</td>
</tr>
<tr>
<td>10</td>
<td>0</td>
<td>2S</td>
</tr>
<tr>
<td>10</td>
<td>1</td>
<td>4S</td>
</tr>
<tr>
<td>11</td>
<td>x</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

- `<Vn>`  
  Is the name of the first SIMD&FP source register, encoded in the "Rn" field.

- `<Vm>`  
  Is the name of the second SIMD&FP source register, encoded in the "Rm" field.
Operation

```c
CheckFPAdvSIMDEnabled64();
bits(datasize) operand1 = V[n];
bits(datasize) operand2 = V[m];
bits(datasize) result;
bits(2*datasize) concat = operand2:operand1;
integer element1;
integer element2;
integer maxmin;

for e = 0 to elements-1
    element1 = Int(Elem[concat, 2*e, esize], unsigned);
    element2 = Int(Elem[concat, (2*e)+1, esize], unsigned);
    maxmin = if minimum then Min(element1, element2) else Max(element1, element2);
    Elem[result, e, esize] = maxmin<esize-1:0>;
V[d] = result;
```

Operational information

If PSTATE.DIT is 1:
- The execution time of this instruction is independent of:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
- The response of this instruction to asynchronous exceptions does not vary based on:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.

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Unsigned Minimum across Vector. This instruction compares all the vector elements in the source SIMD&FP register, and writes the smallest of the values as a scalar to the destination SIMD&FP register. All the values in this instruction are unsigned integer values.

Depending on the settings in the `CPACR_EL1`, `CPTR_EL2`, and `CPTR_EL3` registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

```
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9  | 8  | 7  | 6  | 5  | 4  | 3  | 2  | 1  | 0  |
|-----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0   | Q  | 1  | 0  | 1  | 1  | 1  | 0  | size | 1  | 1  | 0  | 0  | 0  | 1  | 1  | 0  | 1  | 0  | Rd |
| U   | op |     |    |    |    |    |    |     |    |    |    |    |    |    |    |    |    |    |    |
```

**Advanced SIMD**

```
UMINV <V><d>, <Vn>.<T>

integer d = UInt(Rd);
integer n = UInt(Rn);

if size:Q == '100' then UNDEFINED;
if size == '11' then UNDEFINED;
integer esize = 8 << if size:Q == '100' then ReservedValue();
if size == '11' then ReservedValue();
integer esize = 8 << UInt(size);
integer datasize = if Q == '1' then 128 else 64;
integer elements = datasize DIV esize;

boolean unsigned = (U == '1');
boolean min = (op == '1');
```

**Assembler Symbols**

- `<V>` Is the destination width specifier, encoded in “size”:

<table>
<thead>
<tr>
<th>size</th>
<th>&lt;V&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>B</td>
</tr>
<tr>
<td>01</td>
<td>H</td>
</tr>
<tr>
<td>10</td>
<td>S</td>
</tr>
<tr>
<td>11</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

- `<d>` Is the number of the SIMD&FP destination register, encoded in the “Rd” field.

- `<Vn>` Is the name of the SIMD&FP source register, encoded in the "Rn" field.

- `<T>` Is an arrangement specifier, encoded in “size:Q”:

<table>
<thead>
<tr>
<th>size</th>
<th>Q</th>
<th>&lt;T&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>0</td>
<td>8B</td>
</tr>
<tr>
<td>00</td>
<td>1</td>
<td>16B</td>
</tr>
<tr>
<td>01</td>
<td>0</td>
<td>4H</td>
</tr>
<tr>
<td>01</td>
<td>1</td>
<td>8H</td>
</tr>
<tr>
<td>10</td>
<td>0</td>
<td>RESERVED</td>
</tr>
<tr>
<td>10</td>
<td>1</td>
<td>4S</td>
</tr>
<tr>
<td>11</td>
<td>x</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>
Operation

```c
CheckFPAdvSIMEnabled64();
bits(datasize) operand = V[n];
integer maxmin;
integer element;

maxmin = int(Elem[operand, 0, esize], unsigned);
for e = 1 to elements-1
    element = int(Elem[operand, e, esize], unsigned);
    maxmin = if min then Min(maxmin, element) else Max(maxmin, element);
V[d] = maxmin<esize-1:0>;
```

Operational information

If PSTATE.DIT is 1:

- The execution time of this instruction is independent of:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
- The response of this instruction to asynchronous exceptions does not vary based on:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
UMLAL, UMLAL2 (by element)

Unsigned Multiply-Add Long (vector, by element). This instruction multiplies each vector element in the lower or upper half of the first source SIMD&FP register by the specified vector element of the second source SIMD&FP register and accumulates the results with the vector elements of the destination SIMD&FP register. The destination vector elements are twice as long as the elements that are multiplied.

The UMLAL instruction extracts vector elements from the lower half of the first source register, while the UMLAL2 instruction extracts vector elements from the upper half of the first source register.

Depending on the settings in the `CPACR_EL1`, `CPTR_EL2`, and `CPTR_EL3` registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

<table>
<thead>
<tr>
<th>Q</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>absent</td>
</tr>
<tr>
<td>1</td>
<td>present</td>
</tr>
</tbody>
</table>

Is the second and upper half specifier. If present it causes the operation to be performed on the upper 64 bits of the registers holding the narrower elements, and is encoded in “Q”:

<Vd> Is the name of the SIMD&FP destination register, encoded in the "Rd" field.

<Ta> Is an arrangement specifier, encoded in “size”:

<table>
<thead>
<tr>
<th>size</th>
<th>&lt;Ta&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>RESERVED</td>
</tr>
<tr>
<td>01</td>
<td>4S</td>
</tr>
<tr>
<td>10</td>
<td>2D</td>
</tr>
<tr>
<td>11</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

Is an arrangement specifier, encoded in “size:Q”:

<Vn> Is the name of the first SIMD&FP source register, encoded in the "Rn" field.

<Tb> Is an arrangement specifier, encoded in “size:Q”:

integer idxdsize = if H == '1' then 128 else 64;
integer index;
bit Rmhi;
case size of
    when '01' index = UInt(H:L:M); Rmhi = '0';
    when '10' index = UInt(H:L);   Rmhi = M;
otherwise UNDEFINED;

integer d = otherwise UnallocatedEncoding(A);
integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rmhi:Rm);
integer esize = 8 << UInt(size);
integer datasize = 64;
integer part = UInt(Q);
integer elements = datasize DIV esize;

boolean unsigned = (U == '1');
boolean sub_op = (o2 == '1');
### Operation

```c
CheckFPAdvSIMDEnabled64();

bits(datasize) operand1 = Vpart[n, part];
bits(idxdsize) operand2 = V[m];
bits(2*datasize) operand3 = V[d];
bits(2*datasize) result;
integer element1;
integer element2;
bits(2*esize) product;

element2 = Int(Elem[operand2, index, esize], unsigned);
for e = 0 to elements-1
  element1 = Int(Elem[operand1, e, esize], unsigned);
  product = (element1 * element2)<2*esize-1:0>;
  if sub_op then
    Elem[result, e, 2*esize] = Elem[operand3, e, 2*esize] - product;
  else
    Elem[result, e, 2*esize] = Elem[operand3, e, 2*esize] + product;

V[d] = result;
```

### Operational information

If PSTATE.DIT is 1:

- The execution time of this instruction is independent of:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
- The response of this instruction to asynchronous exceptions does not vary based on:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
UMLAL, UMLAL2 (vector)

Unsigned Multiply-Add Long (vector). This instruction multiplies the vector elements in the lower or upper half of the first source SIMD&FP register by the corresponding vector elements of the second source SIMD&FP register, and accumulates the results with the vector elements of the destination SIMD&FP register. The destination vector elements are twice as long as the elements that are multiplied.

The UMLAL instruction extracts vector elements from the lower half of the first source register, while the UMLAL2 instruction extracts vector elements from the upper half of the first source register.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

<table>
<thead>
<tr>
<th>U</th>
<th>Q</th>
<th>size</th>
<th>Rm</th>
<th>Rd</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Three registers, not all the same type

UMLAL[2] <Vd>, <Ta>, <Vn>, <Vm>, <Tb>

```plaintext
integer d = Uint(Rd);
integer n = Uint(Rn);
integer m = Uint(Rm);

if size == '11' then UNDEFINED;
integer esize = 8 << if size == '11' then ReservedValue();
integer esize = 8 << Uint(size);
integer datasize = 64;
integer part = Uint(Q);
integer elements = datasize DIV esize;
boolean sub_op = (o1 == '1');
boolean unsigned = (U == '1');
```

Assembler Symbols

2          Is the second and upper half specifier. If present it causes the operation to be performed on the upper 64 bits of the registers holding the narrower elements, and is encoded in "Q":

<table>
<thead>
<tr>
<th>Q</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>[absent]</td>
</tr>
<tr>
<td>1</td>
<td>[present]</td>
</tr>
</tbody>
</table>

<Vd>          Is the name of the SIMD&FP destination register, encoded in the "Rd" field.
<Ta>          Is an arrangement specifier, encoded in “size”:

<table>
<thead>
<tr>
<th>size</th>
<th>&lt;Ta&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>8H</td>
</tr>
<tr>
<td>01</td>
<td>4S</td>
</tr>
<tr>
<td>10</td>
<td>2D</td>
</tr>
<tr>
<td>11</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

<Vn>          Is the name of the first SIMD&FP source register, encoded in the "Rn" field.
<Tb>          Is an arrangement specifier, encoded in “size-Q”:

<table>
<thead>
<tr>
<th>size</th>
<th>Q</th>
<th>&lt;Tb&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>0</td>
<td>8B</td>
</tr>
<tr>
<td>00</td>
<td>1</td>
<td>16B</td>
</tr>
<tr>
<td>01</td>
<td>0</td>
<td>4H</td>
</tr>
<tr>
<td>01</td>
<td>1</td>
<td>8H</td>
</tr>
<tr>
<td>10</td>
<td>0</td>
<td>2S</td>
</tr>
<tr>
<td>10</td>
<td>1</td>
<td>4S</td>
</tr>
<tr>
<td>11</td>
<td>x</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

<Vm>          Is the name of the second SIMD&FP source register, encoded in the "Rm" field.
Operation

```c
CheckFPAdvSIMEnabled64();
bits(datasize) operand1 = Vpart[n, part];
bits(datasize) operand2 = Vpart[m, part];
bits(2*datasize) operand3 = V[d];
bits(2*datasize) result;
integer element1;
integer element2;
bits(2*esize) product;
bits(2*esize) accum;

for e = 0 to elements-1
    element1 = Int(Elem[operand1, e, esize], unsigned);
    element2 = Int(Elem[operand2, e, esize], unsigned);
    product = (element1 * element2)<2*esize-1:0>;
    if sub_op then
        accum = Elem[operand3, e, 2*esize] - product;
    else
        accum = Elem[operand3, e, 2*esize] + product;
    Elem[result, e, 2*esize] = accum;
V[d] = result;
```

Operational information

If PSTATE.DIT is 1:

- The execution time of this instruction is independent of:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
- The response of this instruction to asynchronous exceptions does not vary based on:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
UMLSL, UMLSL2 (by element)

Unsigned Multiply-Subtract Long (vector, by element). This instruction multiplies each vector element in the lower or upper half of the first source SIMD&FP register by the specified vector element of the second source SIMD&FP register and subtracts the results from the vector elements of the destination SIMD&FP register. The destination vector elements are twice as long as the elements that are multiplied.

The UMLSL instruction extracts vector elements from the lower half of the first source register, while the UMLSL2 instruction extracts vector elements from the upper half of the first source register.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 |  9 |  8 |  7 |  6 |  5 |  4 |  3 |  2 |  1 |  0 |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| O  | Q  | 1  | 0  | 1  | 1  | 1  | 1  | size| L  | M  | Rm | 0  | 1  | 0  | H  | 0  | Rn | Rd |

Vector

UMLSL[2] <Vd>, <Ta>, <Vn>, <Tb>, <Vm>, <Ts>[<index>]

integer idxdsize = if H == '1' then 128 else 64;
integer index;
bit Rmhi;
case size of
  when '01' index = UInt(H:L:M); Rmhi = '0';
  when '10' index = UInt(H:L);   Rmhi = M;
  otherwise UNDEFINED;
integer d = otherwise UnallocatedEncoding(A);

integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rmhi:Rm);

integer esize = 8 << UInt(size);
integer datasize = 64;
integer part = UInt(Q);
integer elements = datasize DIV esize;

boolean unsigned = (U == '1');
boolean sub_op = (o2 == '1');

Assembler Symbols

<table>
<thead>
<tr>
<th>Q</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>[absent]</td>
</tr>
<tr>
<td>1</td>
<td>[present]</td>
</tr>
</tbody>
</table>

<Vd> Is the name of the SIMD&FP destination register, encoded in the "Rd" field.

<Ta> Is an arrangement specifier, encoded in “size”:

<table>
<thead>
<tr>
<th>size</th>
<th>&lt;Ta&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>RESERVED</td>
</tr>
<tr>
<td>01</td>
<td>4S</td>
</tr>
<tr>
<td>10</td>
<td>2D</td>
</tr>
<tr>
<td>11</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

<Vn> Is the name of the first SIMD&FP source register, encoded in the "Rn" field.

<Tb> Is an arrangement specifier, encoded in “size:Q”:
<table>
<thead>
<tr>
<th>size</th>
<th>Q</th>
<th>&lt;Tb&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>x</td>
<td>RESERVED</td>
</tr>
<tr>
<td>01</td>
<td>0</td>
<td>4H</td>
</tr>
<tr>
<td>01</td>
<td>1</td>
<td>8H</td>
</tr>
<tr>
<td>10</td>
<td>0</td>
<td>2S</td>
</tr>
<tr>
<td>10</td>
<td>1</td>
<td>4S</td>
</tr>
<tr>
<td>11</td>
<td>x</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

**<Vm>**

Is the name of the second SIMD&FP source register, encoded in “size:M:Rm”:

<table>
<thead>
<tr>
<th>size</th>
<th>&lt;Vm&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>RESERVED</td>
</tr>
<tr>
<td>01</td>
<td>0:Rm</td>
</tr>
<tr>
<td>10</td>
<td>M:Rm</td>
</tr>
<tr>
<td>11</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

Restricted to V0-V15 when element size <Ts> is H.

**<Ts>**

Is an element size specifier, encoded in “size”:

<table>
<thead>
<tr>
<th>size</th>
<th>&lt;Ts&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>RESERVED</td>
</tr>
<tr>
<td>01</td>
<td>H</td>
</tr>
<tr>
<td>10</td>
<td>S</td>
</tr>
<tr>
<td>11</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

**<index>**

Is the element index, encoded in “size:L:H:M”:

<table>
<thead>
<tr>
<th>size</th>
<th>&lt;index&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>RESERVED</td>
</tr>
<tr>
<td>01</td>
<td>H:L:M</td>
</tr>
<tr>
<td>10</td>
<td>H:L</td>
</tr>
<tr>
<td>11</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

### Operation

```c
CheckFPAdvSIMDEnabled64();
bits(datasize) operand1 = Vpart[n, part];
bits(idxsizes) operand2 = V[m];
bits(2*datasize) operand3 = V[d];
bits(2*datasize) result;
integer element1;
integer element2;
bits(2*esize) product;

element2 = Int(Elem[operand2, index, esize], unsigned);
for e = 0 to elements-1
    element1 = Int(Elem[operand1, e, esize], unsigned);
    product = (element1 * element2)<2*esize-1:0>;
    if sub_op then
        Elem[result, e, 2*esize] = Elem[operand3, e, 2*esize] - product;
    else
        Elem[result, e, 2*esize] = Elem[operand3, e, 2*esize] + product;

V[d] = result;
```

### Operational information

If PSTATE.DIT is 1:

- The execution time of this instruction is independent of:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
- The response of this instruction to asynchronous exceptions does not vary based on:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
UMLSL, UMLSL2 (vector)

Unsigned Multiply-Subtract Long (vector). This instruction multiplies corresponding vector elements in the lower or upper half of the two source SIMD&FP registers, and subtracts the results from the vector elements of the destination SIMD&FP register. The destination vector elements are twice as long as the elements that are multiplied. All the values in this instruction are unsigned integer values.

The UMLSL instruction extracts each source vector from the lower half of each source register, while the UMLSL2 instruction extracts each source vector from the upper half of each source register.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

Three registers, not all the same type

UMLSL[2] <Vd>,<Ta>, <Vn>,<Tb>, <Vm>,<Tb>

integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rm);

if size == '11' then UNDEFINED;
integer esize = 8 << if size == '11' then ReservedValue();
integer esize = 8 << UInt(size);
integer datasize = 64;
integer part = UInt(Q);
integer elements = datasize DIV esize;
boolean sub_op = (o1 == '1');
boolean unsigned = (U == '1');

Assembler Symbols

2

Is the second and upper half specifier. If present it causes the operation to be performed on the upper 64 bits of the registers holding the narrower elements, and is encoded in “Q”:

<table>
<thead>
<tr>
<th>Q</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>[absent]</td>
</tr>
<tr>
<td>1</td>
<td>[present]</td>
</tr>
</tbody>
</table>

<Vd>

Is the name of the SIMD&FP destination register, encoded in the "Rd" field.

<Ta>

Is an arrangement specifier, encoded in “size”:

<table>
<thead>
<tr>
<th>size</th>
<th>&lt;Ta&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>8H</td>
</tr>
<tr>
<td>01</td>
<td>4S</td>
</tr>
<tr>
<td>10</td>
<td>2D</td>
</tr>
<tr>
<td>11</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

<Vn>

Is the name of the first SIMD&FP source register, encoded in the "Rn" field.

<Tb>

Is an arrangement specifier, encoded in “size:Q”:

<table>
<thead>
<tr>
<th>size</th>
<th>Q</th>
<th>&lt;Tb&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>0</td>
<td>8B</td>
</tr>
<tr>
<td>00</td>
<td>1</td>
<td>16B</td>
</tr>
<tr>
<td>01</td>
<td>0</td>
<td>4H</td>
</tr>
<tr>
<td>01</td>
<td>1</td>
<td>8H</td>
</tr>
<tr>
<td>10</td>
<td>0</td>
<td>2S</td>
</tr>
<tr>
<td>10</td>
<td>1</td>
<td>4S</td>
</tr>
<tr>
<td>11</td>
<td>x</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

<Vm>

Is the name of the second SIMD&FP source register, encoded in the "Rm" field.
Operation

```c
CheckFPAdvSIMEnabled64();
bits(datasize) operand1 = Vpart[n, part];
bias(datasize) operand2 = Vpart[m, part];
bias(2*datasize) operand3 = V[d];
bias(2*datasize) result;
integer element1;
integer element2;
bias(2*esize) product;
bias(2*esize) accum;
for e = 0 to elements-1
  element1 = Int(Elem[operand1, e, esize], unsigned);
  element2 = Int(Elem[operand2, e, esize], unsigned);
  product = (element1 * element2)<2*esize-1:0>;
  if sub_op then
    accum = Elem[operand3, e, 2*esize] - product;
  else
    accum = Elem[operand3, e, 2*esize] + product;
  Elem[result, e, 2*esize] = accum;
V[d] = result;
```

Operational information

If PSTATE.DIT is 1:

- The execution time of this instruction is independent of:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
- The response of this instruction to asynchronous exceptions does not vary based on:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
UMNEGL

Unsigned Multiply-Negate Long multiplies two 32-bit register values, negates the product, and writes the result to the 64-bit destination register.

This is an alias of UMSUBL. This means:

- The encodings in this description are named to match the encodings of UMSUBL.
- The description of UMSUBL gives the operational pseudocode for this instruction.

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9  | 8  | 7  | 6  | 5  | 4  | 3  | 2  | 1  | 0  |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 1  | 0  | 0  | 1  | 1  | 0  | 1  | 1  | 0  | 0  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  |

Rm | U |
---|---|
Rn | o0 |
Rd | Ra |

64-bit

UMNEGL <Xd>, <Wn>, <Wm>

is equivalent to

UMSUBL <Xd>, <Wn>, <Wm>, XZR

and is always the preferred disassembly.

Assembler Symbols

<Xd> Is the 64-bit name of the general-purpose destination register, encoded in the "Rd" field.

<Wn> Is the 32-bit name of the first general-purpose source register holding the multiplicand, encoded in the "Rn" field.

<Wm> Is the 32-bit name of the second general-purpose source register holding the multiplier, encoded in the "Rm" field.

Operation

The description of UMSUBL gives the operational pseudocode for this instruction.

Operational information

If PSTATE.DIT is 1:

- The execution time of this instruction is independent of:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
- The response of this instruction to asynchronous exceptions does not vary based on:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
UMOV

Unsigned Move vector element to general-purpose register. This instruction reads the unsigned integer from the source SIMD&FP register, zero-extends it to form a 32-bit or 64-bit value, and writes the result to the destination general-purpose register.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

This instruction is used by the alias MOV (to general).

32-bit (Q == 0)

UMOV <Wd>, <Vn>.<Ts>[<index>]

64-reg, UMOV-64-reg (Q == 1 && imm5 == x1000)

UMOV <Xd>, <Vn>.<Ts>[<index>]

```
integer d = UInt(Rd);
integer n = UInt(Rn);

integer size;
case Q:imm5 of
  when '0xxxx1' size = 0; // UMOV Wd, Vn.B
  when '0xxx10' size = 1; // UMOV Wd, Vn.H
  when '0xx100' size = 2; // UMOV Wd, Vn.S
  when '1x1000' size = 3; // UMOV Xd, Vn.D
  otherwise     UNDEFINED;

integer idxdsize = if imm5<4> == '1' then 128 else 64;
integer index = otherwise UnallocatedEncoding();

integer idxdsize = if imm5<4> == '1' then 128 else 64;
integer index = UInt(imm5<4:size+1>);
integer esize = 8 << size;
integer datasize = if Q == '1' then 64 else 32;
```

Assembler Symbols

<Wd> Is the 32-bit name of the general-purpose destination register, encoded in the "Rd" field.

<Xd> Is the 64-bit name of the general-purpose destination register, encoded in the "Rd" field.

<Vn> Is the name of the SIMD&FP source register, encoded in the "Rn" field.

<Ts> For the 32-bit variant: is an element size specifier, encoded in “imm5”:

<table>
<thead>
<tr>
<th>imm5</th>
<th>&lt;Ts&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>xx000</td>
<td>RESERVED</td>
</tr>
<tr>
<td>xxxx1</td>
<td>B</td>
</tr>
<tr>
<td>xxxx10</td>
<td>H</td>
</tr>
<tr>
<td>xx100</td>
<td>S</td>
</tr>
</tbody>
</table>

For the 64-reg, UMOV-64-reg variant: is an element size specifier, encoded in “imm5”:

<table>
<thead>
<tr>
<th>imm5</th>
<th>&lt;Ts&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>x0000</td>
<td>RESERVED</td>
</tr>
<tr>
<td>xxxx1</td>
<td>RESERVED</td>
</tr>
<tr>
<td>xxxx10</td>
<td>RESERVED</td>
</tr>
<tr>
<td>xx100</td>
<td>RESERVED</td>
</tr>
<tr>
<td>x1000</td>
<td>D</td>
</tr>
</tbody>
</table>

<index> For the 32-bit variant: is the element index encoded in “imm5”:
For the 64-reg, UMOV-64-reg variant: is the element index encoded in "imm5<4>".

**Alias Conditions**

<table>
<thead>
<tr>
<th>Alias</th>
<th>Is preferred when</th>
</tr>
</thead>
<tbody>
<tr>
<td>MOV (to general)</td>
<td>imm5 == 'x1000'</td>
</tr>
<tr>
<td>MOV (to general)</td>
<td>imm5 == 'xx100'</td>
</tr>
</tbody>
</table>

**Operation**

```c
CheckFPAdvSIMEnabled64();
blts(idxdsize) operand = V[n];
X[d] = ZeroExtend(Elem[operand, index, esize], datasize);
```

**Operational information**

If PSTATE.DIT is 1:
- The execution time of this instruction is independent of:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
- The response of this instruction to asynchronous exceptions does not vary based on:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
UMULL, UMULL2 (by element)

Unsigned Multiply Long (vector, by element). This instruction multiplies each vector element in the lower or upper half of the first source SIMD&FP register by the specified vector element of the second source SIMD&FP register, places the results in a vector, and writes the vector to the destination SIMD&FP register. The destination vector elements are twice as long as the elements that are multiplied.

The UMULL instruction extracts vector elements from the lower half of the first source register, while the UMULL2 instruction extracts vector elements from the upper half of the first source register.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
0 1 1 1 1 size L M Rm 1 0 1 0 H 0 Rn Rd

Vector

UMULL2 \{2\} \(<Vd>.<Ta>, <Vn>.<Tb>, <Vm>.<Ts>[<index>]\)

integer idxxdsiz = if H == '1' then 128 else 64;
integer index;
bit Rmhi;

case size of
  when '01' index = UInt(H:L:M); Rmhi = '0';
  when '10' index = UInt(H:L); Rmhi = M;
  otherwise UNDEFINED;

integer d = otherwise UnallocatedEncoding(A);
integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rmhi:Rm);

integer esize = 8 << UInt(size);
integer datasize = 64;
integer part = UInt(Q);
integer elements = datasize DIV esize;
boolean unsigned = (U == '1');

Assembler Symbols

2

Is the second and upper half specifier. If present it causes the operation to be performed on the upper 64 bits of the registers holding the narrower elements, and is encoded in “Q”:

<table>
<thead>
<tr>
<th>Q</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>[absent]</td>
</tr>
<tr>
<td>1</td>
<td>[present]</td>
</tr>
</tbody>
</table>

\(<Vd>\)

Is the name of the SIMD&FP destination register, encoded in the “Rd” field.

\(<Ta>\)

Is an arrangement specifier, encoded in “size”:

<table>
<thead>
<tr>
<th>size</th>
<th>(&lt;Ta&gt;)</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>RESERVED</td>
</tr>
<tr>
<td>01</td>
<td>4S</td>
</tr>
<tr>
<td>10</td>
<td>2D</td>
</tr>
<tr>
<td>11</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

\(<Vn>\)

Is the name of the first SIMD&FP source register, encoded in the “Rn” field.

\(<Tb>\)

Is an arrangement specifier, encoded in “size:Q”:
<Vm> Is the name of the second SIMD&FP source register, encoded in “size:M:Rm”:  

| size | <Vm> | 00 | RESERVED | 01 | 0:Rm | 10 | M:Rm | 11 | RESERVED |

Restricted to V0-V15 when element size <Ts> is H.

<Ts> Is an element size specifier, encoded in “size”:  

| size | <Ts> | 00 | RESERVED | 01 | H | 10 | S | 11 | RESERVED |

:index> Is the element index, encoded in “size:L:H:M”:  

| size | <index> | 00 | RESERVED | 01 | H:L:M | 10 | H:L | 11 | RESERVED |

Operation

```c
CheckFPAdvSIMDEnabled64();
bits(datasize) operand1 = Vpart[n, part];
bits(idxdsize) operand2 = V[m];
bits(2*datasize) result;
integer element1;
integer element2;
bits(2*esize) product;

element2 = Int(Elem[operand2, index, esize], unsigned);
for e = 0 to elements-1
    element1 = Int(Elem[operand1, e, esize], unsigned);
    product = (element1 * element2)<2*esize-1:0>;
    Elem[result, e, 2*esize] = product;
V[d] = result;
```

Operational information

If PSTATE.DIT is 1:

- The execution time of this instruction is independent of:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
- The response of this instruction to asynchronous exceptions does not vary based on:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
UMULL, UMULL2 (vector)

Unsigned Multiply long (vector). This instruction multiplies corresponding vector elements in the lower or upper half of the two source SIMD&FP registers, places the result in a vector, and writes the vector to the destination SIMD&FP register. The destination vector elements are twice as long as the elements that are multiplied. All the values in this instruction are unsigned integer values.

The UMULL instruction extracts each source vector from the lower half of each source register, while the UMULL2 instruction extracts each source vector from the upper half of each source register.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

```
Three registers, not all the same type

UMULL[2] <Vd>.<Ta>, <Vn>.<Tb>, <Vm>.<Tb>
```

```plaintext
integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rm);

if size == '11' then UNDEFINED;
integer esize = 8 <<if size == '11' then ReservedValue();
integer datasize = 64;
integer part = UInt(Q);
integer elements = datasize DIV esize;
boolean unsigned = (U == '1');
```

Assembler Symbols

2

Is the second and upper half specifier. If present it causes the operation to be performed on the upper 64 bits of the registers holding the narrower elements, and is encoded in “Q”:

<table>
<thead>
<tr>
<th>Q</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>[absent]</td>
</tr>
<tr>
<td>1</td>
<td>[present]</td>
</tr>
</tbody>
</table>

<Vd>

Is the name of the SIMD&FP destination register, encoded in the "Rd" field.

<Ta>

Is an arrangement specifier, encoded in “size”:

<table>
<thead>
<tr>
<th>size</th>
<th>&lt;Ta&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>8H</td>
</tr>
<tr>
<td>01</td>
<td>4S</td>
</tr>
<tr>
<td>10</td>
<td>2D</td>
</tr>
<tr>
<td>11</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

<Vn>

Is the name of the first SIMD&FP source register, encoded in the "Rn" field.

<Tb>

Is an arrangement specifier, encoded in “size:Q”:

<table>
<thead>
<tr>
<th>size</th>
<th>Q</th>
<th>&lt;Tb&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>0</td>
<td>8B</td>
</tr>
<tr>
<td>00</td>
<td>1</td>
<td>16B</td>
</tr>
<tr>
<td>01</td>
<td>0</td>
<td>4H</td>
</tr>
<tr>
<td>01</td>
<td>1</td>
<td>8H</td>
</tr>
<tr>
<td>10</td>
<td>0</td>
<td>2S</td>
</tr>
<tr>
<td>10</td>
<td>1</td>
<td>4S</td>
</tr>
<tr>
<td>11</td>
<td>x</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

<Vm>

Is the name of the second SIMD&FP source register, encoded in the "Rm" field.
Operation

```c
CheckFPAdvSIMDEnabled64();
bits(datasize) operand1 = Vpart[n, part];
bits(datasize) operand2 = Vpart[m, part];
bits(2*datasize) result;
integer element1;
integer element2;

for e = 0 to elements-1
    element1 = Int(Elem[operand1, e, esize], unsigned);
    element2 = Int(Elem[operand2, e, esize], unsigned);
    Elem[result, e, 2*esize] = (element1 * element2)<2*esize-1:0>;

V[d] = result;
```

Operational information

If PSTATE.DIT is 1:

- The execution time of this instruction is independent of:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
- The response of this instruction to asynchronous exceptions does not vary based on:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
UQADD

Unsigned saturating Add. This instruction adds the values of corresponding elements of the two source SIMD&FP registers, places the results into a vector, and writes the vector to the destination SIMD&FP register.

If overflow occurs with any of the results, those results are saturated. If saturation occurs, the cumulative saturation bit FPSR.QC is set. Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

It has encodings from 2 classes: Scalar and Vector

Scalar

Scalar 31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0

0 1 1 1 1 1 0 size 1 Rm 0 0 0 0 1 1 Rn Rd

UQADD <V><d>, <V><n>, <V><m>

integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rm);
integer esize = 8 << UInt(size);
integer datasize = esize;
integer elements = 1;
boolean unsigned = (U == '1');

Vector

Vector 31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0

0 Q 1 0 1 1 0 size 1 Rm 0 0 0 0 1 1 Rn Rd

UQADD <Vd>.<T>, <Vn>.<T>, <Vm>.<T>

integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rm);
if size:Q == '110' then UNDEFINED;
integer esize = 8 << if size:Q == '110' then ReservedValue();
integer esize = 8 << UInt(size);
integer datasize = if Q == '1' then 128 else 64;
integer elements = datasize DIV esize;
boolean unsigned = (U == '1');

Assembler Symbols

<V> Is a width specifier, encoded in "size":

<table>
<thead>
<tr>
<th>size</th>
<th>&lt;V&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>B</td>
</tr>
<tr>
<td>01</td>
<td>H</td>
</tr>
<tr>
<td>10</td>
<td>S</td>
</tr>
<tr>
<td>11</td>
<td>D</td>
</tr>
</tbody>
</table>

<d> Is the number of the SIMD&FP destination register, in the "Rd" field.

<n> Is the number of the first SIMD&FP source register, encoded in the "Rn" field.
Is the number of the second SIMD&FP source register, encoded in the "Rm" field.

Is the name of the SIMD&FP destination register, encoded in the "Rd" field.

Is an arrangement specifier, encoded in "size:Q":

<table>
<thead>
<tr>
<th>size</th>
<th>Q</th>
<th>&lt;T&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>0</td>
<td>8B</td>
</tr>
<tr>
<td>00</td>
<td>1</td>
<td>16B</td>
</tr>
<tr>
<td>01</td>
<td>0</td>
<td>4H</td>
</tr>
<tr>
<td>01</td>
<td>1</td>
<td>8H</td>
</tr>
<tr>
<td>10</td>
<td>0</td>
<td>2S</td>
</tr>
<tr>
<td>10</td>
<td>1</td>
<td>4S</td>
</tr>
<tr>
<td>11</td>
<td>0</td>
<td>RESERVED</td>
</tr>
<tr>
<td>11</td>
<td>1</td>
<td>2D</td>
</tr>
</tbody>
</table>

Is the name of the first SIMD&FP source register, encoded in the "Rn" field.

Is the name of the second SIMD&FP source register, encoded in the "Rm" field.

**Operation**

```c
CheckFPAdvSIMDEnabled64();
bits(datasize) operand1 = V[n];
bits(datasize) operand2 = V[m];
bits(datasize) result;
integer element1;
integer element2;
integer sum;
boolean sat;
for e = 0 to elements-1
    element1 = Int(Elem[operand1, e, esize], unsigned);
    element2 = Int(Elem[operand2, e, esize], unsigned);
    sum = element1 + element2;
    (Elem[result, e, esize], sat) = SatQ(sum, esize, unsigned);
    if sat then FPSR.QC = '1';
V[d] = result;
```

Internal version only: isa v30.25, v29.05, AdvSIMD v27.01, pseudocode v85-xml-00beta3c38c; Build timestamp: 2018-09-13

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UQRSHL

Unsigned saturating Rounding Shift Left (register). This instruction takes each vector element of the first source SIMD&FP register, shifts the vector element by a value from the least significant byte of the corresponding vector element of the second source SIMD&FP register, places the results into a vector, and writes the vector to the destination SIMD&FP register.

If the shift value is positive, the operation is a left shift. Otherwise, it is a right shift. The results are rounded. For truncated results, see UQSHL. If overflow occurs with any of the results, those results are saturated. If saturation occurs, the cumulative saturation bit FPSR.QC is set.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

It has encodings from 2 classes: Scalar and Vector.

Scalar

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9  | 8  | 7  | 6  | 5  | 4  | 3  | 2  | 1  | 0 |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0  | 1  | 1  | 1  | 1  | 1  | 1  | 0  | size | 1  | Rm |   | 0  | 1  | 0  | 1  | 1  | 1  | Rn |   | Rd |   |   |   |   |   |   |   |
| U  | R  | S  |   |    |    |    |    |      |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |

Vector

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9  | 8  | 7  | 6  | 5  | 4  | 3  | 2  | 1  | 0 |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0  | Q | 1  | 0  | 1  | 1  | 1  | 0  | size | 1  | Rm |   | 0  | 1  | 0  | 1  | 1  | 1  | Rn |   | Rd |   |   |   |   |   |   |   |   |   |
| U  | Q | R  | S  |    |    |    |    |      |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |

Assembler Symbols

<V> Is a width specifier, encoded in "size":

integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rm);
integer esize = 8 << UInt(size);
integerdatasize = esize;
integer elements = 1;
boolean unsigned = (U == '1');
boolean rounding = (R == '1');
boolean saturating = (S == '1');
if S == '0' & size != '11' then UNDEFINED;
integer esize = 8 << UInt(size);
integer datasize = if Q == '1' then 128 else 64;
integer elements = datasize DIV esize;
boolean unsigned = (U == '1');
boolean rounding = (R == '1');
boolean saturating = (S == '1');

Assembler Symbols

<V> Is a width specifier, encoded in "size":

integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rm);
if size:Q == '110' then UNDEFINED;
integer esize = 8 << if size:Q == '110' then ReservedValue() else UInt(size);
integer datasize = if Q == '1' then 128 else 64;
integer elements = datasize DIV esize;
boolean unsigned = (U == '1');
boolean rounding = (R == '1');
boolean saturating = (S == '1');
Is the number of the SIMD&FP destination register, in the "Rd" field.

Is the number of the first SIMD&FP source register, encoded in the "Rn" field.

Is the number of the second SIMD&FP source register, encoded in the "Rm" field.

Is the name of the SIMD&FP destination register, encoded in the "Rd" field.

Is an arrangement specifier, encoded in “size:Q”:

Is the name of the first SIMD&FP source register, encoded in the "Rn" field.

Is the name of the second SIMD&FP source register, encoded in the "Rm" field.

Operation

```c
CheckFPAdvSIMDEnabled64();
bits(datasize) operand1 = V[n];
bits(datasize) operand2 = V[m];
bits(datasize) result;

integer round_const = 0;
integer shift;
integer element;
boolean sat;
for e = 0 to elements-1
    shift = SInt(Elem[operand2, e, esize]<7:0>);
    if rounding then
        round_const = 1 << (-shift - 1); // 0 for left shift, 2^(n-1) for right shift
        element = (Int(Elem[operand1, e, esize], unsigned) + round_const) << shift;
        if saturating then
            (Elem[result, e, esize], sat) = SatQ(element, esize, unsigned);
            if sat then FPSR.QC = '1';
        else
            Elem[result, e, esize] = element<esize-1:0>;
    V[d] = result;
```

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UQRSHRN, UQRSHRN2

Unsigned saturating Rounded Shift Right Narrow (immediate). This instruction reads each vector element in the source SIMD&FP register, right shifts each result by an immediate value, puts the final result into a vector, and writes the vector to the lower or upper half of the destination SIMD&FP register. All the values in this instruction are unsigned integer values. The results are rounded. For truncated results, see UQSHRN. The UQRSHRN instruction writes the vector to the lower half of the destination register and clears the upper half, while the UQRSHRN2 instruction writes the vector to the upper half of the destination register without affecting the other bits of the register.

If overflow occurs with any of the results, those results are saturated. If saturation occurs, the cumulative saturation bit FPSR QC is set.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

It has encodings from 2 classes: Scalar and Vector

Scalar

| 31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0 |
| 0 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | != 0000 | immh | 1 | 0 | 0 | 1 | 1 | Rn | Rd |

UQRSHRN <Vb><d>, <Va><n>, #<shift>

```plaintext
integer d = UInt(Rd);
integer n = UInt(Rn);

if immh == '0000' then UNDEFINED;
if immh<3> == '1' then UNDEFINED;
integer esize = 8 << if immh == '0000' then ReservedValue();
  if immh<3> == '1' then ReservedValue();
integer esize = 8 << HighestSetBit(immh);
integer datasize = esize;
integer elements = 1;
integer part = 0;

integer shift = (2 * esize) - UInt(immh:immh);
boolean round = (op == '1');
boolean unsigned = (U == '1');
```

Vector

| 31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0 |
| 0 | Q | 1 | 0 | 1 | 1 | 1 | 1 | != 0000 | immh | 1 | 0 | 0 | 1 | 1 | Rn | Rd |

UQRSHRN, UQRSHRN2
Vector

UQRSHRN(2) \(<Vd>\cdot< Tb>\), \(<Vn>\cdot< Ta>\), \#<shift>\n
integer d = UInt(Rd);
integer n = UInt(Rn);

if immh == '0000' then SEE(asimdimm);
if immh <3> == '1' then UNDEFINED;
integer esize = 8 << if immh<3> == '1' then ReservedValue();
integer esize = 8 << HighestSetBit(immh);
integer datasize = 64;
integer part = UInt(Q);
integer elements = datasize DIV esize;

integer shift = (2 * esize) - UInt(immh:immb);
boolean round = (op == '1');
boolean unsigned = (U == '1');

Assembler Symbols

2
Is the second and upper half specifier. If present it causes the operation to be performed on the upper 64 bits of the registers holding the narrower elements, and is encoded in “Q”:

<table>
<thead>
<tr>
<th>Q</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>{absent}</td>
</tr>
<tr>
<td>1</td>
<td>{present}</td>
</tr>
</tbody>
</table>

\(<Vd>\)
Is the name of the SIMD&FP destination register, encoded in the "Rd" field.

\(<Tb>\)
Is an arrangement specifier, encoded in “immh:Q”:

<table>
<thead>
<tr>
<th>immh</th>
<th>Q</th>
<th>&lt;Tb&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0000</td>
<td>x</td>
<td>SEE Advanced SIMD modified immediate</td>
</tr>
<tr>
<td>0001</td>
<td>0</td>
<td>8B</td>
</tr>
<tr>
<td>0001</td>
<td>1</td>
<td>16B</td>
</tr>
<tr>
<td>001x</td>
<td>0</td>
<td>4H</td>
</tr>
<tr>
<td>001x</td>
<td>1</td>
<td>8H</td>
</tr>
<tr>
<td>01xx</td>
<td>0</td>
<td>2S</td>
</tr>
<tr>
<td>01xx</td>
<td>1</td>
<td>4S</td>
</tr>
<tr>
<td>1xxx</td>
<td>x</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

\(<Vn>\)
Is the name of the SIMD&FP source register, encoded in the "Rn" field.

\(<Ta>\)
Is an arrangement specifier, encoded in “immh”:

<table>
<thead>
<tr>
<th>immh</th>
<th>&lt;Ta&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0000</td>
<td>SEE Advanced SIMD modified immediate</td>
</tr>
<tr>
<td>0001</td>
<td>8H</td>
</tr>
<tr>
<td>001x</td>
<td>4S</td>
</tr>
<tr>
<td>01xx</td>
<td>2D</td>
</tr>
<tr>
<td>1xxx</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

\(<Vb>\)
Is the destination width specifier, encoded in “immh”:

<table>
<thead>
<tr>
<th>immh</th>
<th>&lt;Vb&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0000</td>
<td>RESERVED</td>
</tr>
<tr>
<td>0001</td>
<td>B</td>
</tr>
<tr>
<td>001x</td>
<td>H</td>
</tr>
<tr>
<td>01xx</td>
<td>S</td>
</tr>
<tr>
<td>1xxx</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

\(<d>\)
Is the number of the SIMD&FP destination register, in the "Rd" field.

\(<Va>\)
Is the source width specifier, encoded in “immh”:

<table>
<thead>
<tr>
<th>immh</th>
<th>&lt;Va&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0000</td>
<td>RESERVED</td>
</tr>
<tr>
<td>0001</td>
<td>H</td>
</tr>
<tr>
<td>001x</td>
<td>S</td>
</tr>
<tr>
<td>01xx</td>
<td>D</td>
</tr>
<tr>
<td>1xxx</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>
Is the number of the first SIMD&FP source register, encoded in the "Rn" field.

For the scalar variant: is the right shift amount, in the range 1 to the destination operand width in bits, encoded in “immh:immb”:

<table>
<thead>
<tr>
<th>immh</th>
<th>&lt;shift&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0000</td>
<td>RESERVED</td>
</tr>
<tr>
<td>0001</td>
<td>(16-UInt(immh:immb))</td>
</tr>
<tr>
<td>001x</td>
<td>(32-UInt(immh:immb))</td>
</tr>
<tr>
<td>01xx</td>
<td>(64-UInt(immh:immb))</td>
</tr>
<tr>
<td>1xxx</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

For the vector variant: is the right shift amount, in the range 1 to the destination element width in bits, encoded in “immh:immb”:

<table>
<thead>
<tr>
<th>immh</th>
<th>&lt;shift&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0000</td>
<td>SEE Advanced SIMD modified immediate</td>
</tr>
<tr>
<td>0001</td>
<td>(16-UInt(immh:immb))</td>
</tr>
<tr>
<td>001x</td>
<td>(32-UInt(immh:immb))</td>
</tr>
<tr>
<td>01xx</td>
<td>(64-UInt(immh:immb))</td>
</tr>
<tr>
<td>1xxx</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

Operation

```c
CheckFPAdvSIMDEnabled64();
bits(datasize*2) operand = V[n];
bits(datasize) result;
integer round_const = if round then (1 << (shift - 1)) else 0;
integer element;
boolean sat;
for e = 0 to elements-1
   element = (Int(Elem[operand, e, 2*esize], unsigned) + round_const) >> shift;
   (Elem[result, e, esize], sat) = SatQ(element, esize, unsigned);
if sat then FPSR.QC = '1';
Vpart[d, part] = result;
```
UQSHL (immediate)

Unsigned saturating Shift Left (immediate). This instruction takes each vector element in the source SIMD&FP register, shifts it by an immediate value, places the results in a vector, and writes the vector to the destination SIMD&FP register. The results are truncated. For rounded results, see `UQRSHL`.

If overflow occurs with any of the results, those results are saturated. If saturation occurs, the cumulative saturation bit `FPSR.QC` is set.

Depending on the settings in the `CPACR_EL1`, `CPTR_EL2`, and `CPTR_EL3` registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

It has encodings from 2 classes: Scalar and Vector.

### Scalar

| 31  | 30  | 29  | 28  | 27  | 26  | 25  | 24  | 23  | 22  | 21  | 20  | 19  | 18  | 17  | 16  | 15  | 14  | 13  | 12  | 11  | 10  | 9   | 8   | 7   | 6   | 5   | 4   | 3   | 2   | 1   | 0   |
|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| U   | immh| op  |     |     | Rn  |     | Rd  |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |

| Scalar <V><d>, <V><n>, #<shift> |

```plaintext
integer d = Uint(Rd);
integer n = Uint(Rn);

if immh == '0000' then UNDEFINED;
integer esize = 8 << if immh == '0000' then ReservedValue();
integer esize = 8 << HighestSetBit(immh);
integer datasize = esize;
integer elements = 1;

integer shift = Uint(immh:immb) - esize;

boolean src_unsigned;
boolean dst_unsigned;
case op:U of
  when '00' UnallocatedEncoding(immh:immb) - esize;
  when '01' src_unsigned = FALSE; dst_unsigned = TRUE;
  when '10' src_unsigned = FALSE; dst_unsigned = FALSE;
  when '11' src_unsigned = TRUE; dst_unsigned = TRUE;
```

### Vector

<table>
<thead>
<tr>
<th>31</th>
<th>30</th>
<th>29</th>
<th>28</th>
<th>27</th>
<th>26</th>
<th>25</th>
<th>24</th>
<th>23</th>
<th>22</th>
<th>21</th>
<th>20</th>
<th>19</th>
<th>18</th>
<th>17</th>
<th>16</th>
<th>15</th>
<th>14</th>
<th>13</th>
<th>12</th>
<th>11</th>
<th>10</th>
<th>9</th>
<th>8</th>
<th>7</th>
<th>6</th>
<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>!= 0000</td>
<td>immh</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>Rn</td>
<td></td>
<td></td>
<td>Rd</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| Vector |

```plaintext
#HTMLDIFF from-
```
Vector

UQSHL <Vd>, <T>, <Vn>, <T>, uintptr <shift>

integer d = |UInt| (Rd);
integer n = |UInt| (Rn);

if immh == '0000' then SEE(asimdimm);
if immh[3]:q == '10' then UNDEFINED;
integer esize = 8 << if immh[3]:q == '10' then ReservedValue();
inmediate esize = 8 << HighestSetBit(immh);
integer datasize = if Q == '1' then 128 else 64;
inmediate elements = datasize DIV esize;

integer shift = |UInt| (immh:immb) - esize;

boolean src_unsigned;
boolean dst_unsigned;
case op:U of
when '00' UNDEFINED;
when '01' src_unsigned = FALSE; dst_unsigned = TRUE;
when '10' src_unsigned = FALSE; dst_unsigned = FALSE;
when '11' src_unsigned = TRUE; dst_unsigned = TRUE;

Assembler Symbols

<V> Is a width specifier, encoded in “immh”:

<table>
<thead>
<tr>
<th>immh</th>
<th>&lt;V&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0000</td>
<td>RESERVED</td>
</tr>
<tr>
<td>0001</td>
<td>B</td>
</tr>
<tr>
<td>001x</td>
<td>H</td>
</tr>
<tr>
<td>01xx</td>
<td>S</td>
</tr>
<tr>
<td>1xxx</td>
<td>D</td>
</tr>
</tbody>
</table>

<d> Is the number of the SIMD&FP destination register, in the "Rd" field.

<n> Is the number of the first SIMD&FP source register, encoded in the "Rn" field.

<Vd> Is the name of the SIMD&FP destination register, encoded in the "Rd" field.

<T> Is an arrangement specifier, encoded in “immh:Q”:

<table>
<thead>
<tr>
<th>immh</th>
<th>Q</th>
<th>&lt;T&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0000</td>
<td>x</td>
<td>SEE Advanced SIMD modified immediate</td>
</tr>
<tr>
<td>0001</td>
<td>0</td>
<td>8B</td>
</tr>
<tr>
<td>0001</td>
<td>1</td>
<td>16B</td>
</tr>
<tr>
<td>001x</td>
<td>0</td>
<td>4H</td>
</tr>
<tr>
<td>001x</td>
<td>1</td>
<td>8H</td>
</tr>
<tr>
<td>01xx</td>
<td>0</td>
<td>2S</td>
</tr>
<tr>
<td>01xx</td>
<td>1</td>
<td>4S</td>
</tr>
<tr>
<td>1xxx</td>
<td>0</td>
<td>RESERVED</td>
</tr>
<tr>
<td>1xxx</td>
<td>1</td>
<td>2D</td>
</tr>
</tbody>
</table>

<Vn> Is the name of the SIMD&FP source register, encoded in the "Rn" field.

<shift> For the scalar variant: is the left shift amount, in the range 0 to the operand width in bits minus 1, encoded in “immh:immb”:

<table>
<thead>
<tr>
<th>immh</th>
<th>&lt;shift&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0000</td>
<td>RESERVED</td>
</tr>
<tr>
<td>0001</td>
<td>(UInt (immh:immb) - 8)</td>
</tr>
<tr>
<td>001x</td>
<td>(UInt (immh:immb) - 16)</td>
</tr>
<tr>
<td>01xx</td>
<td>(UInt (immh:immb) - 32)</td>
</tr>
<tr>
<td>1xxx</td>
<td>(UInt (immh:immb) - 64)</td>
</tr>
</tbody>
</table>

For the vector variant: is the left shift amount, in the range 0 to the element width in bits minus 1, encoded in “immh:immb”:
### Operation

```c
CheckFPAdvSIMDEnabled64();
bits(datasize) operand = V[n];
bias(datasize) result;
integer element;
boolean sat;
for e = 0 to elements-1
    element = Int(Elem[operand, e, esize], src_unsigned) << shift;
    (Elem[result, e, esize], sat) = SatQ(element, esize, dst_unsigned);
    if sat then FPSR.QC = '1';
V[d] = result;
```

UQSHL (register)

Unsigned saturating Shift Left (register). This instruction takes each element in the vector of the first source SIMD&FP register, shifts the element by a value from the least significant byte of the corresponding element of the second source SIMD&FP register, places the results in a vector, and writes the vector to the destination SIMD&FP register.

If the shift value is positive, the operation is a left shift. Otherwise, it is a right shift. The results are truncated. For rounded results, see UQRSHL. If overflow occurs with any of the results, those results are saturated. If saturation occurs, the cumulative saturation bit FPSR.QC is set.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

It has encodings from 2 classes: Scalar and Vector.

Scalar

| 31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0 |
| 0 | 1 | 1 | 1 | 1 | 1 | 0 | size | 1 | Rm | 0 | 1 | 0 | 0 | 1 | 1 | Rn | Rd |
| U | R | S |

Scalar

UQSHL <V><d>, <V><n>, <V><m>

```java
integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rm);
integer esize = 8 << UInt(size);
integer datasize = esize;
integer elements = 1;
boolean unsigned = (U == '1');
boolean rounding = (R == '1');
boolean saturating = (S == '1');
if S == '0' && size != '11' then UNDEFINED;
integer esize = 8 << UInt(size);
integer datasize = if Q == '1' then 128 else 64;
integer elements = datasize DIV esize;
boolean unsigned = (U == '1');
boolean rounding = (R == '1');
boolean saturating = (S == '1');
```

Vector

| 31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0 |
| 0 | Q | 1 | 0 | 1 | 1 | 1 | 0 | size | 1 | Rm | 0 | 1 | 0 | 0 | 1 | 1 | Rn | Rd |
| U | R | S |

Vector

UQSHL <Vd>, <Vn>, <Vm>

```java
integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rm);
if size:Q == '110' then UNDEFINED;
integer esize = 8 << if size:Q == '110' then ReservedValue() else UInt(size);
integer datasize = if Q == '1' then 128 else 64;
integer elements = datasize DIV esize;
boolean unsigned = (U == '1');
boolean rounding = (R == '1');
boolean saturating = (S == '1');
```

Assembler Symbols

<V> Is a width specifier, encoded in "size".
<d> Is the number of the SIMD&FP destination register, in the "Rd" field.

<n> Is the number of the first SIMD&FP source register, encoded in the "Rn" field.

<m> Is the number of the second SIMD&FP source register, encoded in the "Rm" field.

<Vd> Is the name of the SIMD&FP destination register, encoded in the "Rd" field.

<T> Is an arrangement specifier, encoded in “size:Q”:

<table>
<thead>
<tr>
<th>size</th>
<th>&lt;T&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>0</td>
</tr>
<tr>
<td>01</td>
<td>1</td>
</tr>
<tr>
<td>10</td>
<td>0</td>
</tr>
<tr>
<td>11</td>
<td>1</td>
</tr>
</tbody>
</table>

<Vn> Is the name of the first SIMD&FP source register, encoded in the "Rn" field.

<Vm> Is the name of the second SIMD&FP source register, encoded in the "Rm" field.

**Operation**

```c
void CheckFPAdvSIMDEnabled64();

bits(datasize) operand1 = V[n];
bits(datasize) operand2 = V[m];
bits(datasize) result;

integer round_const = 0;
integer shift;
integer element;
boolean sat;

for e = 0 to elements-1
    shift = SInt(Elem[operand2, e, esize]<7:0>);
    if rounding then
        round_const = 1 << (shift - 1); // 0 for left shift, 2^(n-1) for right shift
    element = (Int(Elem[operand1, e, esize], unsigned) + round_const) << shift;
    if saturating then
        (Elem[result, e, esize], sat) = SatQ(element, esize, unsigned);
        if sat then FPSR.QC = '1';
    else
        Elem[result, e, esize] = element<esize-1:0>;

V[d] = result;
```

Internal version only: isa v30.25, AdvSIMD v27.0, pseudocode v85-xml-00bet8_rc3, Build timestamp: 2018-09-13T13:00:00.454779Z

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UQSHRN, UQSHRN2

Unsigned saturating Shift Right Narrow (immediate). This instruction reads each vector element in the source SIMD&FP register, right shifts each result by an immediate value, saturates each shifted result to a value that is half the original width, puts the final result into a vector, and writes the vector to the lower or upper half of the destination SIMD&FP register. All the values in this instruction are unsigned integer values.

The results are truncated. For rounded results, see UQRSHRN.

The UQSHRN instruction writes the vector to the lower half of the destination register and clears the upper half, while the UQSHRN2 instruction writes the vector to the upper half of the destination register without affecting the other bits of the register.

If overflow occurs with any of the results, those results are saturated. If saturation occurs, the cumulative saturation bit FPSR.QC is set.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

It has encodings from 2 classes: Scalar and Vector

**Scalar**

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9  | 8  | 7  | 6  | 5  | 4  | 3  | 2  | 1  | 0  |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0  | 1  | 1  | 1  | 1  | 1  | 1  | 0  | ! = 0000 | immb | 1  | 0  | 1  | 0  | 1  | Rn |    |    |    |    |    |    |    |    |    |    |    |
| U  | immh | op |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |

Scalar

```plaintext
UQSHRN <Vb><d>, <Va><n>, #<shift>

integer d = UInt(Rd);
integer n = UInt(Rn);

if immh == '0000' then UNDEFINED;
if immh<3> == '1' then UNDEFINED;
integer esize = 8 <<if immh == '0000' then ReservedValue();
if immh<3> == '1' then ReservedValue();
integer esize = 8 <<HighestSetBit(immh);
integer datasize = esize;
integer elements = 1;
integer part = 0;

integer shift = (2 * esize) - UInt(immh:immb);
boolean round = (op == '1');
boolean unsigned = (U == '1');
```

**Vector**

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9  | 8  | 7  | 6  | 5  | 4  | 3  | 2  | 1  | 0  |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0  | Q  | 1  | 0  | 1  | 1  | 1  | 1  | 0  | != 0000 | immb | 1  | 0  | 1  | 0  | 1  | Rn |    |    |    |    |    |    |    |    |    |    |    |
| U  | immh | op |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
Vector

UQSHRN\{2\} \texttt{<Vd>}, \texttt{<Tb>}, \texttt{<Vn>}, \texttt{<Ta>}, \#<\texttt{shift}>

\begin{verbatim}
integer d = UInt(Rd);
integer n = UInt(Rn);

if immh == '0000' then SEE(asimdimm);
if immh<3> == '1' then UNDEFINED;
integer esize = 8 << if immh<3> == '1' then ReservedValue();
integer esize = 8 << HighestSetBit(immh);
integer datasize = 64;
integer part = UInt(Q);
integer elements = datasize DIV esize;

integer shift = (2 * esize) - UInt(immh:immb);
boolean round = (op == '1');
boolean unsigned = (U == '1');
\end{verbatim}

Assembler Symbols

2

Is the second and upper half specifier. If present it causes the operation to be performed on the upper 64 bits of the registers holding the narrower elements, and is encoded in “Q”:

\[
\begin{array}{c|c}
Q & 2 \\
0 & \text{[absent]} \\
1 & \text{[present]} \\
\end{array}
\]

\texttt{<Vd>}

Is the name of the SIMD&FP destination register, encoded in the "Rd" field.

\texttt{<Tb>}

Is an arrangement specifier, encoded in “immh:Q”:

\begin{verbatim}
<table>
<thead>
<tr>
<th>immh</th>
<th>Q</th>
<th>\texttt{&lt;Tb&gt;}</th>
</tr>
</thead>
<tbody>
<tr>
<td>0000</td>
<td>x</td>
<td>\texttt{SEE Advanced SIMD modified immediate}</td>
</tr>
<tr>
<td>0001</td>
<td>0</td>
<td>8B</td>
</tr>
<tr>
<td>0001</td>
<td>1</td>
<td>16B</td>
</tr>
<tr>
<td>001x</td>
<td>0</td>
<td>4H</td>
</tr>
<tr>
<td>001x</td>
<td>1</td>
<td>8H</td>
</tr>
<tr>
<td>01xx</td>
<td>0</td>
<td>2S</td>
</tr>
<tr>
<td>01xx</td>
<td>1</td>
<td>4S</td>
</tr>
<tr>
<td>1xxx</td>
<td>x</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>
\end{verbatim}

\texttt{<Vn>}

Is the name of the SIMD&FP source register, encoded in the "Rn" field.

\texttt{<Ta>}

Is an arrangement specifier, encoded in “immh”:

\begin{verbatim}
<table>
<thead>
<tr>
<th>immh</th>
<th>\texttt{&lt;Ta&gt;}</th>
</tr>
</thead>
<tbody>
<tr>
<td>0000</td>
<td>\texttt{SEE Advanced SIMD modified immediate}</td>
</tr>
<tr>
<td>0001</td>
<td>8H</td>
</tr>
<tr>
<td>001x</td>
<td>4S</td>
</tr>
<tr>
<td>01xx</td>
<td>2D</td>
</tr>
<tr>
<td>1xxx</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>
\end{verbatim}

\texttt{<Vb>}

Is the destination width specifier, encoded in “immh”:

\begin{verbatim}
<table>
<thead>
<tr>
<th>immh</th>
<th>\texttt{&lt;Vb&gt;}</th>
</tr>
</thead>
<tbody>
<tr>
<td>0000</td>
<td>RESERVED</td>
</tr>
<tr>
<td>0001</td>
<td>B</td>
</tr>
<tr>
<td>001x</td>
<td>H</td>
</tr>
<tr>
<td>01xx</td>
<td>S</td>
</tr>
<tr>
<td>1xxx</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>
\end{verbatim}

\texttt{<d>}

Is the number of the SIMD&FP destination register, in the "Rd" field.

\texttt{<Va>}

Is the source width specifier, encoded in “immh”:

\begin{verbatim}
<table>
<thead>
<tr>
<th>immh</th>
<th>\texttt{&lt;Va&gt;}</th>
</tr>
</thead>
<tbody>
<tr>
<td>0000</td>
<td>RESERVED</td>
</tr>
<tr>
<td>0001</td>
<td>H</td>
</tr>
<tr>
<td>001x</td>
<td>S</td>
</tr>
<tr>
<td>01xx</td>
<td>D</td>
</tr>
<tr>
<td>1xxx</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>
\end{verbatim}
Is the number of the first SIMD&FP source register, encoded in the “Rn” field.

For the scalar variant: is the right shift amount, in the range 1 to the destination operand width in bits, encoded in “immh:immb”:

<table>
<thead>
<tr>
<th>immh</th>
<th>&lt;shift&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0000</td>
<td>RESERVED</td>
</tr>
<tr>
<td>0001</td>
<td>(16-UInt(immh:immb))</td>
</tr>
<tr>
<td>001x</td>
<td>(32-UInt(immh:immb))</td>
</tr>
<tr>
<td>01xx</td>
<td>(64-UInt(immh:immb))</td>
</tr>
<tr>
<td>1xxx</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

For the vector variant: is the right shift amount, in the range 1 to the destination element width in bits, encoded in “immh:immb”:

<table>
<thead>
<tr>
<th>immh</th>
<th>&lt;shift&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0000</td>
<td>SEE Advanced SIMD modified immediate</td>
</tr>
<tr>
<td>0001</td>
<td>(16-UInt(immh:immb))</td>
</tr>
<tr>
<td>001x</td>
<td>(32-UInt(immh:immb))</td>
</tr>
<tr>
<td>01xx</td>
<td>(64-UInt(immh:immb))</td>
</tr>
<tr>
<td>1xxx</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

**Operation**

```c
CheckFPAdvSIMDEnabled64();
bits(datasize*2) operand = V[n];
bits(datasize) result;
integer round_const = if round then (1 << (shift - 1)) else 0;
integer element;
boolean sat;
for e = 0 to elements-1
  element = (Int(Elem[operand, e, 2*esize], unsigned) + round_const) >> shift;
  (Elem[result, e, esize], sat) = SatQ(element, esize, unsigned);
  if sat then FPSR.QC = '1';
Vpart[d, part] = result;
```

(Internal version only: isa v30.25, v29.05, AdvSIMD v27.01, v26.0, pseudocode v85-xml-00bet8_rc3d35 ; Build timestamp: 2018-09-13T13:52:00Z)
UQSUB

Unsigned saturating Subtract. This instruction subtracts the element values of the second source SIMD&FP register from the corresponding element values of the first source SIMD&FP register, places the results into a vector, and writes the vector to the destination SIMD&FP register. If overflow occurs with any of the results, those results are saturated. If saturation occurs, the cumulative saturation bit FPSR.QC is set. Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

It has encodings from 2 classes: Scalar and Vector

Scalar

<table>
<thead>
<tr>
<th>31</th>
<th>30</th>
<th>29</th>
<th>28</th>
<th>27</th>
<th>26</th>
<th>25</th>
<th>24</th>
<th>23</th>
<th>22</th>
<th>21</th>
<th>20</th>
<th>19</th>
<th>18</th>
<th>17</th>
<th>16</th>
<th>15</th>
<th>14</th>
<th>13</th>
<th>12</th>
<th>11</th>
<th>10</th>
<th>9</th>
<th>8</th>
<th>7</th>
<th>6</th>
<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>size</td>
<td>1</td>
<td>Rm</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>Rn</td>
<td>Rd</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

U

Scalar

UQSUB <V><d>, <V><n>, <V><m>

integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rm);
integer esize = 8 << UInt(size);
integer datasmie = esize;
integer elements = 1;
boolean unsigned = (U == '1');

Vector

<table>
<thead>
<tr>
<th>31</th>
<th>30</th>
<th>29</th>
<th>28</th>
<th>27</th>
<th>26</th>
<th>25</th>
<th>24</th>
<th>23</th>
<th>22</th>
<th>21</th>
<th>20</th>
<th>19</th>
<th>18</th>
<th>17</th>
<th>16</th>
<th>15</th>
<th>14</th>
<th>13</th>
<th>12</th>
<th>11</th>
<th>10</th>
<th>9</th>
<th>8</th>
<th>7</th>
<th>6</th>
<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Q</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>size</td>
<td>1</td>
<td>Rm</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>Rn</td>
<td>Rd</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

U

Vector

UQSUB <Vd>.<T>, <Vn>.<T>, <Vm>.<T>

integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rm);
if size:Q == '110' then UNDEFINED;
integer esize = 8 << if size:Q == '110' then ReservedValue() else UInt(size);
integer datasmie = if Q == '1' then 128 else 64;
integer elements = datasmie DIV esize;
boolean unsigned = (U == '1');

Assembler Symbols

<V> Is a width specifier, encoded in "size":

<table>
<thead>
<tr>
<th>size</th>
<th>&lt;V&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>B</td>
</tr>
<tr>
<td>01</td>
<td>H</td>
</tr>
<tr>
<td>10</td>
<td>S</td>
</tr>
<tr>
<td>11</td>
<td>D</td>
</tr>
</tbody>
</table>

<d> Is the number of the SIMD&FP destination register, in the "Rd" field.

<n> Is the number of the first SIMD&FP source register, encoded in the "Rn" field.
Is the number of the second SIMD&FP source register, encoded in the "Rm" field.

Is the name of the SIMD&FP destination register, encoded in the "Rd" field.

Is an arrangement specifier, encoded in "size:Q":

<table>
<thead>
<tr>
<th>size</th>
<th>Q</th>
<th>&lt;T&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>0</td>
<td>8B</td>
</tr>
<tr>
<td>00</td>
<td>1</td>
<td>16B</td>
</tr>
<tr>
<td>01</td>
<td>0</td>
<td>4H</td>
</tr>
<tr>
<td>01</td>
<td>1</td>
<td>8H</td>
</tr>
<tr>
<td>10</td>
<td>0</td>
<td>2S</td>
</tr>
<tr>
<td>10</td>
<td>1</td>
<td>4S</td>
</tr>
<tr>
<td>11</td>
<td>0</td>
<td>RESERVED</td>
</tr>
<tr>
<td>11</td>
<td>1</td>
<td>2D</td>
</tr>
</tbody>
</table>

Is the name of the first SIMD&FP source register, encoded in the "Rn" field.

Is the name of the second SIMD&FP source register, encoded in the "Rm" field.

**Operation**

```c
CheckFPAdvSIMDEnabled64();
bits(datasize) operand1 = V[n];
bits(datasize) operand2 = V[m];
bits(datasize) result;
integer element1;
integer element2;
integer diff;
boolean sat;
for e = 0 to elements-1
  element1 = Int(Elem[operand1, e, esize], unsigned);
  element2 = Int(Elem[operand2, e, esize], unsigned);
  diff = element1 - element2;
  (Elem[result, e, esize], sat) = SatQ(diff, esize, unsigned);
  if sat then FPSR.QC = '1';
V[d] = result;
```

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UQXTN, UQXTN2

Unsigned saturating extract Narrow. This instruction reads each vector element from the source SIMD&FP register, saturates each value to half the original width, places the result into a vector, and writes the vector to the destination SIMD&FP register. All the values in this instruction are unsigned integer values.

If saturation occurs, the cumulative saturation bit FFSR.QC is set.

The UQXTN instruction writes the vector to the lower half of the destination register and clears the upper half, while the UQXTN2 instruction writes the vector to the upper half of the destination register without affecting the other bits of the register.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

It has encodings from 2 classes: Scalar and Vector

Scalar

```
 0 1 1 1 1 0 0 0 1 1 1 1 1 0 1 0 0 0 1 1 1 1 1 0 1 0 0 0 1 0 0 1 0 0 1 0 0 1 0
```

Scalar

```
UQXTN <Vb><d>, <Va><n>
```

```
integer d = UInt(Rd);
integer n = UInt(Rn);
if size == '11' then UNDEFINED;
integer esize = 8 << (if size == '11' then ReservedValue() ;
integer esize = 8 << UInt(size);
integer datasize = esize;
integer part = 0;
integer elements = 1;
boolean unsigned = (U == '1');
```

Vector

```
 0 1 1 1 1 0 1 0 0 0 0 1 1 1 1 1 1 0 1 0 0 0 1 0 1 0 0 1 0 0 1 0 0 1 0 0 1 0
```

Vector

```
UQXTN{2} <Vd>.<Tb>, <Vn>.<Ta>
```

```
integer d = UInt(Rd);
integer n = UInt(Rn);
if size == '11' then UNDEFINED;
integer esize = 8 << (if size == '11' then ReservedValue() ;
integer esize = 8 << UInt(size);
integer datasize = 64;
integer part = UInt(Q);
integer elements = datasize DIV esize;
boolean unsigned = (U == '1');
```
Assembler Symbols

2 Is the second and upper half specifier. If present it causes the operation to be performed on the upper 64 bits of the registers holding the narrower elements, and is encoded in "Q":

<table>
<thead>
<tr>
<th>Q</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>[absent]</td>
</tr>
<tr>
<td>1</td>
<td>[present]</td>
</tr>
</tbody>
</table>

<Vd> Is the name of the SIMD&FP destination register, encoded in the "Rd" field.

<Tb> Is an arrangement specifier, encoded in “size:Q”:

<table>
<thead>
<tr>
<th>size</th>
<th>Q</th>
<th>&lt;Tb&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>0</td>
<td>8B</td>
</tr>
<tr>
<td>00</td>
<td>1</td>
<td>16B</td>
</tr>
<tr>
<td>01</td>
<td>0</td>
<td>4H</td>
</tr>
<tr>
<td>01</td>
<td>1</td>
<td>8H</td>
</tr>
<tr>
<td>10</td>
<td>0</td>
<td>2S</td>
</tr>
<tr>
<td>10</td>
<td>1</td>
<td>4S</td>
</tr>
<tr>
<td>11</td>
<td>x</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

<Vn> Is the name of the SIMD&FP source register, encoded in the "Rn" field.

<Ta> Is an arrangement specifier, encoded in “size”:

<table>
<thead>
<tr>
<th>size</th>
<th>&lt;Ta&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>8H</td>
</tr>
<tr>
<td>01</td>
<td>4S</td>
</tr>
<tr>
<td>10</td>
<td>2D</td>
</tr>
<tr>
<td>11</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

<Vb> Is the destination width specifier, encoded in “size”:

<table>
<thead>
<tr>
<th>size</th>
<th>&lt;Vb&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>B</td>
</tr>
<tr>
<td>01</td>
<td>H</td>
</tr>
<tr>
<td>10</td>
<td>S</td>
</tr>
<tr>
<td>11</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

<d> Is the number of the SIMD&FP destination register, encoded in the "Rd" field.

<Va> Is the source width specifier, encoded in “size”:

<table>
<thead>
<tr>
<th>size</th>
<th>&lt;Va&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>H</td>
</tr>
<tr>
<td>01</td>
<td>S</td>
</tr>
<tr>
<td>10</td>
<td>D</td>
</tr>
<tr>
<td>11</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

<n> Is the number of the SIMD&FP source register, encoded in the "Rn" field.

Operation

```c
CheckFPAdvSIMDEnabled64();
bits(2*datasize) operand = V[n];
bits(datasize) result;
bits(2*esize) element;
boolean sat;
for e = 0 to elements-1
    element = Elem[operand, e, 2*esize];
    (Elem[result, e, esize], sat) = SatQ(Int(element, unsigned), esize, unsigned);
    if sat then FPSR.QC = '1';
Vpart[d, part] = result;
```

Internal version only: isa v30.25, AdvSIMD v27.01, pseudocode v85-xml-00bet8 rc3254 ; Build timestamp: 2018-09-13T13:2018-06-16T09:044

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**URECPE**

Unsigned Reciprocal Estimate. This instruction reads each vector element from the source SIMD&FP register, calculates an approximate inverse for the unsigned integer value, places the result into a vector, and writes the vector to the destination SIMD&FP register.

Depending on the settings in the `CPACR_EL1`, `CPTR_EL2`, and `CPTR_EL3` registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

<table>
<thead>
<tr>
<th>Bits</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rn</td>
<td>SIMD&amp;FP source</td>
</tr>
<tr>
<td>Rd</td>
<td>SIMD&amp;FP destination</td>
</tr>
</tbody>
</table>

**Vector**

```plaintext
URECPE <Vd>.<T>, <Vn>.<T>
```

- `integer d = UInt(Rd);`
- `integer n = UInt(Rn);`
- `if sz == '1' then UNDEFINED;`  
- `integer esize = 32;`
- `integer datasize = if Q == '1' then 128 else 64;`
- `integer elements = datasize DIV esize; if sz == '1' then ReservedValue();`  
- `integer esize = 32;`
- `integer datasize = if Q == '1' then 128 else 64;`
- `integer elements = datasize DIV esize;`

**Assembler Symbols**

- `<Vd>` Is the name of the SIMD&FP destination register, encoded in the "Rd" field.
- `<T>` Is an arrangement specifier, encoded in "sz:Q":
  - `sz` `Q` `<T>`
  - 0 0 2S
  - 0 1 4S
  - 1 x RESERVED
- `<Vn>` Is the name of the SIMD&FP source register, encoded in the "Rn" field.

**Operation**

```plaintext
CheckFPAdvSIMDEnabled64();
bits(datasize) operand = V[n];
bits(datasize) result;
bits(32) element;
for e = 0 to elements-1
  element = Elem[operand, e, 32];
  Elem[result, e, 32] = UnsignedRecipEstimate(element);
V[d] = result;
```

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URHADD

Unsigned Rounding Halving Add. This instruction adds corresponding unsigned integer values from the two source SIMD&FP registers, shifts each result right one bit, places the results into a vector, and writes the vector to the destination SIMD&FP register.

The results are rounded. For truncated results, see \textit{UHADD}.

Depending on the settings in the \textit{CPACR\_EL1}, \textit{CPTR\_EL2}, and \textit{CPTR\_EL3} registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

<table>
<thead>
<tr>
<th>31</th>
<th>30</th>
<th>29</th>
<th>28</th>
<th>27</th>
<th>26</th>
<th>25</th>
<th>24</th>
<th>23</th>
<th>22</th>
<th>21</th>
<th>20</th>
<th>19</th>
<th>18</th>
<th>17</th>
<th>16</th>
<th>15</th>
<th>14</th>
<th>13</th>
<th>12</th>
<th>11</th>
<th>10</th>
<th>9</th>
<th>8</th>
<th>7</th>
<th>6</th>
<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>size</td>
<td>1</td>
<td>Rm</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>Rn</td>
<td>Rd</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Three registers of the same type

\textbf{URHADD} \(<Vd>.\langle T\rangle, \ <Vn>.\langle T\rangle, \ <Vm>.\langle T\rangle\)

\begin{verbatim}
integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rm);
if size == '11' then UNDEFINED;
integer esize = 8 << if size == '11' then ReservedValue();
integer esize = 8 << UInt(size);
integer datasize = if Q == '1' then 128 else 64;
integer elements = datasize DIV esize;
boolean unsigned = (U == '1');
\end{verbatim}

Assembler Symbols

\textbf{<Vd>} Is the name of the SIMD&FP destination register, encoded in the "Rd" field.

\textbf{<T>} Is an arrangement specifier, encoded in “size:Q”:

<table>
<thead>
<tr>
<th>size</th>
<th>Q</th>
<th>&lt;T&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>0</td>
<td>8B</td>
</tr>
<tr>
<td>00</td>
<td>1</td>
<td>16B</td>
</tr>
<tr>
<td>01</td>
<td>0</td>
<td>4H</td>
</tr>
<tr>
<td>01</td>
<td>1</td>
<td>8H</td>
</tr>
<tr>
<td>10</td>
<td>0</td>
<td>2S</td>
</tr>
<tr>
<td>10</td>
<td>1</td>
<td>4S</td>
</tr>
<tr>
<td>11</td>
<td>x</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

\textbf{<Vn>} Is the name of the first SIMD&FP source register, encoded in the "Rn" field.

\textbf{<Vm>} Is the name of the second SIMD&FP source register, encoded in the "Rm" field.

Operation

\begin{verbatim}
CheckFPAdvSIMDEnabled64();
bits(datasize) operand1 = \textit{V}[n];
bits(datasize) operand2 = \textit{V}[m];
bits(datasize) result;
integer element1;
integer element2;

for e = 0 to elements-1
    element1 = Int(\textit{Elem}[operand1, e, esize], unsigned);
    element2 = Int(\textit{Elem}[operand2, e, esize], unsigned);
    \textit{Elem}[result, e, esize] = (element1 + element2 + 1)<esize:1>;
\textit{V}[d] = result;
\end{verbatim}
URSHL

Unsigned Rounding Shift Left (register). This instruction takes each element in the vector of the first source SIMD&FP register, shifts the vector element by a value from the least significant byte of the corresponding element of the second source SIMD&FP register, places the results in a vector, and writes the vector to the destination SIMD&FP register.

If the shift value is positive, the operation is a left shift. If the shift value is negative, it is a rounding right shift.

Depending on the settings in the $CPACR_EL1$, $CPTR_EL2$, and $CPTR_EL3$ registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

It has encodings from 2 classes: Scalar and Vector

Scalar

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0  | 1  | 1  | 1  | 1  | 1  | 0  | size | 1  | Rm | 0  | 1  | 0  | 1  | 0  | 1  | Rn | 0  | 1  | 0  | 1  | Rd |
| U  | R  | S  |

Scalar

URSHL $<V><d>$, $<V><n>$, $<V><m>$

integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rm);
integer esize = 8 << UInt(size);
integer datasize = esize;
integer elements = 1;
boolean unsigned = (U == '1');
boolean rounding = (R == '1');
boolean saturating = (S == '1');
if S == '0' && size != '1' then UNDEFINED;
integer esize = 8 << UInt(size);
integer datasize = if Q == '110' then UNDEFINED;
integer datasize = esize;
integer elements = 1;
boolean unsigned = (U == '1');
boolean rounding = (R == '1');
boolean saturating = (S == '1');

Vector

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0  | Q  | 1  | 0  | 1  | 1  | 1  | 0  | size | 1  | Rm | 0  | 1  | 0  | 1  | 0  | 1  | Rn | 0  | 1  | 0  | 1  | Rd |
| U  | R  | S  |

Vector

URSHL $<V>.<T>$, $<Vn>.<T>$, $<Vm>.<T>$

integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rm);
if size:Q == '110' then UNDEFINED;
integer esize = 8 << if size:Q == '110' then ReservedValue();
integer esize = 8 << UInt(size);
integer datasize = if Q == '1' then 128 else 64;
integer elements = datasize DIV esize;
boolean unsigned = (U == '1');
boolean rounding = (R == '1');
boolean saturating = (S == '1');

Assembler Symbols

$<V>$ Is a width specifier, encoded in “size”:
<d>
Is the number of the SIMD&FP destination register, in the "Rd" field.

<n>
Is the number of the first SIMD&FP source register, encoded in the "Rn" field.

<m>
Is the number of the second SIMD&FP source register, encoded in the "Rm" field.

<Vd>
Is the name of the SIMD&FP destination register, encoded in the "Rd" field.

<T>
Is an arrangement specifier, encoded in “size:Q”:

<table>
<thead>
<tr>
<th>size</th>
<th>Q</th>
</tr>
</thead>
<tbody>
<tr>
<td>0x</td>
<td>8B</td>
</tr>
<tr>
<td>0x</td>
<td>16B</td>
</tr>
<tr>
<td>0x</td>
<td>4H</td>
</tr>
<tr>
<td>0x</td>
<td>8H</td>
</tr>
<tr>
<td>10</td>
<td>2S</td>
</tr>
<tr>
<td>10</td>
<td>4S</td>
</tr>
<tr>
<td>11</td>
<td>RESERVED</td>
</tr>
<tr>
<td>11</td>
<td>2D</td>
</tr>
</tbody>
</table>

<Vn>
Is the name of the first SIMD&FP source register, encoded in the "Rn" field.

<Vm>
Is the name of the second SIMD&FP source register, encoded in the "Rm" field.

**Operation**

```c
CheckFPAdvSIMDEnabled64();
bits(datasize) operand1 = V[n];
bits(datasize) operand2 = V[m];
bits(datasize) result;

integer round_const = 0;
integer shift;
integer element;
boolean sat;

for e = 0 to elements-1
    shift = SInt(Elem[operand2, e, esize]<7:0>);
    if rounding then
        round Const = 1 << (-shift - 1); // 0 for left shift, 2^(n-1) for right shift
        element = (Int(Elem[operand1, e, esize], unsigned) + round Const) << shift;
    if saturating then
        (Elem[result, e, esize], sat) = SatQ(element, esize, unsigned);
    if sat then FPSR.QC = '1';
    else
        Elem[result, e, esize] = element<esize-1:0>;

V[d] = result;
```

URSHR

Unsigned Rounding Shift Right (immediate). This instruction reads each vector element in the source SIMD&FP register, right shifts each result by an immediate value, writes the final result to a vector, and writes the vector to the destination SIMD&FP register. All the values in this instruction are unsigned integer values. The results are rounded. For truncated results, see USHR.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

It has encodings from 2 classes: Scalar and Vector

Scalar

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9  | 8  | 7  | 6  | 5  | 4  | 3  | 2  | 1  | 0  |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0  | 1  | 1  | 1  | 1  | 1  | 1  | 0  | != 0000 | immb | 0  | 0  | 1  | 0  | 0  | 1  | Rn | Rd |
| U  | immh | o1 | o0 |

Scalar

URSHR <V><d>, <V><n>, #<shift>

integer d = UInt(Rd);
integer n = UInt(Rn);

if immh<3> != '1' then UNDEFINED;
integer esize = 8 << 3;
integer datasize = esize;
integer elements = 1;

integer shift = (esize * 2) - if immh<3> != '1' then ReservedValue();
integer esize = 8 << 3;
integer datasize = esize;
integer elements = 1;

integer shift = (esize * 2) - UInt(immh:immb);
boolean unsigned = (U == '1');
boolean round = (o1 == '1');
boolean accumulate = (o0 == '1');

Vector

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9  | 8  | 7  | 6  | 5  | 4  | 3  | 2  | 1  | 0  |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0  | Q  | 1  | 0  | 1  | 1  | 1  | 0  | != 0000 | immb | 0  | 0  | 1  | 0  | 0  | 1  | Rn | Rd |
| U  | immh | o1 | o0 |
Vector

**URSHR** `<Vd>`., `<T>`, `<Vn>`., `<T>`, `#<shift>`

```plaintext
integer d = *UInt*(Rd);
integer n = *UInt*(Rn);

if immh == '0000' then SEE(asimdimm);
if immh<3>:Q == '10' then UNDEFINED;
integer esize = 8 << if immh<3>:Q == '10' then ReservedValue();
integer esize = 8 << HighestSetBit(immh);
integer datasize = if Q == '1' then 128 else 64;
integer elements = datasize DIV esize;

integer shift = (esize * 2) - *UInt*(immh:immb);
boolean unsigned = (U == '1');
boolean round = (o1 == '1');
boolean accumulate = (o0 == '1');
```

**Assembler Symbols**

- `<V>` is a width specifier, encoded in “immh”:
  - | immh | `<V>` |
  - | 0xxx | RESERVED |
  - | 1xxx | D |

- `<d>` is the number of the SIMD&FP destination register, in the "Rd" field.

- `<n>` is the number of the first SIMD&FP source register, encoded in the "Rn" field.

- `<Vd>` is the name of the SIMD&FP destination register, encoded in the "Rd" field.

- `<T>` is an arrangement specifier, encoded in “immh:Q”:
  - | immh | Q | `<T>` |
  - | 0000 | x | SEE Advanced SIMD modified immediate |
  - | 0001 | 0 | 8B |
  - | 0001 | 1 | 16B |
  - | 001x | 0 | 4H |
  - | 001x | 1 | 8H |
  - | 01xx | 0 | 2S |
  - | 01xx | 1 | 4S |
  - | 1xxx | 0 | RESERVED |
  - | 1xxx | 1 | 2D |

- `<Vn>` is the name of the SIMD&FP source register, encoded in the "Rn" field.

- `<shift>` For the scalar variant: is the right shift amount, in the range 1 to 64, encoded in “immh:immb”:
  - | immh | `<shift>` |
  - | 0xxx | RESERVED |
  - | 1xxx | (128-UInt(immh:immb)) |

  For the vector variant: is the right shift amount, in the range 1 to the element width in bits, encoded in “immh:immb”:
  - | immh | `<shift>` |
  - | 0000 | SEE Advanced SIMD modified immediate |
  - | 0001 | (16-UInt(immh:immb)) |
  - | 001x | (32-UInt(immh:immb)) |
  - | 01xx | (64-UInt(immh:immb)) |
  - | 1xxx | (128-UInt(immh:immb)) |

```
Operation

```c
CheckFPAdvSIMDEnabled64();
bits(datasize) operand = V[n];
bits(datasize) operand2;
bits(datasize) result;
integer round_const = if round then (1 << (shift - 1)) else 0;
integer element;

operand2 = if accumulate then V[d] else Zeros();
for e = 0 to elements-1
    element = (Int(Elem[operand, e, esize], unsigned) + round_const) >> shift;
    Elem[result, e, esize] = Elem[operand2, e, esize] + element<esize-1:0>;
V[d] = result;
```

Internal version only: isa v30.25, AdvSIMD v29.05, pseudocode v85-xml-00bet8_rc3; Build timestamp: 2018-09-13T13:2018-08-01 04:45

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**URSQRTE**

Unsigned Reciprocal Square Root Estimate. This instruction reads each vector element from the source SIMD&FP register, calculates an approximate inverse square root for each value, places the result into a vector, and writes the vector to the destination SIMD&FP register. All the values in this instruction are unsigned integer values.

Depending on the settings in the `CPACR_EL1`, `CPTR_EL2`, and `CPTR_EL3` registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0  | Q | 1 | 0 | 1 | 1 | 0 | 1 | sz | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 0 |

**Vector**

`URSQRTE <Vd>.<T>, <Vn>.<T>`

```plaintext
integer d = UInt(Rd);
integer n = UInt(Rn);

if sz == '1' then UNDEFINED;
integer esize = 32;
integer datasize = if Q == '1' then 128 else 64;
integer elements = datasize DIV esize;
integer esize = 32;
integer datasize = if Q == '1' then 128 else 64;
integer elements = datasize DIV esize;
```

**Assembler Symbols**

- `<Vd>` Is the name of the SIMD&FP destination register, encoded in the “Rd” field.
- `<T>` Is an arrangement specifier, encoded in “sz:Q”:
  - | sz | Q | <T> |
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>2S</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>4S</td>
</tr>
<tr>
<td>1</td>
<td>x</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>
- `<Vn>` Is the name of the SIMD&FP source register, encoded in the "Rn" field.

**Operation**

```plaintext
CheckFPAdvSIMDEnabled64();
bits(datasize) operand = V[n];
bits(datasize) result;
bits(32) element;

for e = 0 to elements - 1
    element = Elem[operand, e, 32];
    Elem[result, e, 32] = UnsignedRSqrtEstimate(element);

V[d] = result;
```

Internal version only: isa v30.25-29.05, AdvSIMD v27.01-26.01, pseudocode v85-xml-00bet8_rc3-5; Build timestamp: 2018-09-13T11:06:04Z 0645

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**URSRA**

Unsigned Rounding Shift Right and Accumulate (immediate). This instruction reads each vector element in the source SIMD&FP register, right shifts each result by an immediate value, and accumulates the final results with the vector elements of the destination SIMD&FP register. All the values in this instruction are unsigned integer values. The results are rounded. For truncated results, see **USRA**.

Depending on the settings in the **CPACR_EL1**, **CPTR_EL2**, and **CPTR_EL3** registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

It has encodings from 2 classes: **Scalar** and **Vector**

### Scalar

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 0  | ! = 0000 | immb | 0  | 0  | 1  | 1  | 0  | 1  | Rn | Rd |

### Vector

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| Q  | 1  | 0  | 1  | 1  | 1  | 1  | 0  | ! = 0000 | immb | 0  | 0  | 1  | 1  | 0  | 1  | Rn | Rd |

Scalar

URSRA `<V><d>`, `<V><n>`, `#<shift>`

\[
\text{integer } d = \text{UInt}(Rd); \\
\text{integer } n = \text{UInt}(Rn); \\
\text{if immh}[3] != '1' \text{ then UNDEFINED;} \\
\text{integer esize} = 8 << 3; \\
\text{integer datasize} = \text{esize}; \\
\text{integer elements} = 1; \\
\text{integer shift} = (\text{esize} \times 2) - \text{if immh}[3] != '1' \text{ then ReservedValue()}; \\
\text{integer esize} = 8 << 3; \\
\text{integer datasize} = \text{esize}; \\
\text{integer elements} = 1; \\
\text{integer shift} = (\text{esize} \times 2) - \text{UInt}(\text{immh:immb}); \\
\text{boolean unsigned} = (U == '1'); \\
\text{boolean round} = (o1 == '1'); \\
\text{boolean accumulate} = (o0 == '1');
\]
Vector

URSRA <Vd>.<T>, <Vn>.<T>, #<shift>

```plaintext
integer d = UInt(Rd);
integer n = UInt(Rn);

if immh == '0000' then SEE(asimdimm);
if immh<3>:Q == '10' then UNDEFINED;
integer esize = 8 << if immh<3>:Q == '10' then ReservedValue() else HighestSetBit(immh);
integer datasize = if Q == '1' then 128 else 64;
integer elements = datasize DIV esize;

integer shift = (esize * 2) - UInt(immh:immb);
boolean unsigned = (U == '1');
boolean round = (o1 == '1');
boolean accumulate = (o0 == '1');
```

Assembler Symbols

<\V> Is a width specifier, encoded in “immh”:

<table>
<thead>
<tr>
<th>immh</th>
<th>&lt;\V&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0xxx</td>
<td>RESERVED</td>
</tr>
<tr>
<td>1xx</td>
<td>D</td>
</tr>
</tbody>
</table>

<d> Is the number of the SIMD&FP destination register, in the "Rd" field.

<n> Is the number of the first SIMD&FP source register, encoded in the "Rn" field.

<Vd> Is the name of the SIMD&FP destination register, encoded in the "Rd" field.

<T> Is an arrangement specifier, encoded in “immh:Q”:

<table>
<thead>
<tr>
<th>immh</th>
<th>Q</th>
<th>&lt;\T&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0000</td>
<td>x</td>
<td>SEE Advanced SIMD modified immediate</td>
</tr>
<tr>
<td>0001</td>
<td>0</td>
<td>8B</td>
</tr>
<tr>
<td>0001</td>
<td>1</td>
<td>16B</td>
</tr>
<tr>
<td>001x</td>
<td>0</td>
<td>4H</td>
</tr>
<tr>
<td>001x</td>
<td>1</td>
<td>8H</td>
</tr>
<tr>
<td>01xx</td>
<td>0</td>
<td>2S</td>
</tr>
<tr>
<td>01xx</td>
<td>1</td>
<td>4S</td>
</tr>
<tr>
<td>1xx</td>
<td>0</td>
<td>RESERVED</td>
</tr>
<tr>
<td>1xx</td>
<td>1</td>
<td>2D</td>
</tr>
</tbody>
</table>

<Vn> Is the name of the SIMD&FP source register, encoded in the "Rn" field.

<shift> For the scalar variant: is the right shift amount, in the range 1 to 64, encoded in “immh:immb”:

<table>
<thead>
<tr>
<th>immh</th>
<th>&lt;shift&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0xxx</td>
<td>RESERVED</td>
</tr>
<tr>
<td>1xx</td>
<td>128-UInt(immh:immb)</td>
</tr>
</tbody>
</table>

For the vector variant: is the right shift amount, in the range 1 to the element width in bits, encoded in “immh:immb”:

<table>
<thead>
<tr>
<th>immh</th>
<th>&lt;shift&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0000</td>
<td>SEE Advanced SIMD modified immediate</td>
</tr>
<tr>
<td>0001</td>
<td>(16-UInt(immh:immb))</td>
</tr>
<tr>
<td>001x</td>
<td>(32-UInt(immh:immb))</td>
</tr>
<tr>
<td>01xx</td>
<td>(64-UInt(immh:immb))</td>
</tr>
<tr>
<td>1xxx</td>
<td>(128-UInt(immh:immb))</td>
</tr>
</tbody>
</table>
Operation

CheckFPAdvSIMDEnabled64();
bits(datasize) operand = V[n];
bits(datasize) operand2;
bits(datasize) result;
integer round_const = if round then (1 << (shift - 1)) else 0;
integer element;

operand2 = if accumulate then V[d] else Zeros();
for e = 0 to elements-1
    element = (Int(Elem(operand, e, esize), unsigned) + round_const) >> shift;
    Elem[result, e, esize] = Elem[operand2, e, esize] + element<esize-1:0>;
V[d] = result;

Internal version only: isa v30.25 v29.05, AdvSIMD v27.01 v26.0, pseudocode v85-xml-00bet8_rc30355; Build timestamp: 2018-09-13T13:2018-08-16T09:04:45

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USHL

Unsigned Shift Left (register). This instruction takes each element in the vector of the first source SIMD&FP register, shifts each element by a value from the least significant byte of the corresponding element of the second source SIMD&FP register, places the results in a vector, and writes the vector to the destination SIMD&FP register.

If the shift value is positive, the operation is a left shift. If the shift value is negative, it is a truncating right shift. For a rounding shift, see USHR.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

It has encodings from 2 classes: Scalar and Vector

Scalar

31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
0 1 1 1 1 1 0 size 1 Rm 0 1 0 0 1 1 Rn Rd
U R S

Scalar

USHL <V><d>, <V><n>, <V><m>

integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rm);
integer esize = 8 << UInt(size);
integer datasize = esize;
integer elements = 1;
boolean unsigned = (U == '1');
boolean rounding = (R == '1');
boolean saturating = (S == '1');
if S == '0' && size != '11' then UNDEFINED;
boolean saturating = (S == '1');
integer esize = 8 << UInt(size);
integer esize = 8 << UInt(size);
integer datasize = if Q == '1' then 128 else 64;
integer elements = datasize DIV esize;
boolean unsigned = (U == '1');
boolean rounding = (R == '1');
boolean saturating = (S == '1');

Vector

31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
0 1 0 1 1 1 0 size 1 Rm 0 1 0 0 1 1 Rn Rd
U R S

Vector

USHL <Vd><T>, <Vn><T>, <Vm><T>

integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rm);
if size:Q == '110' then UNDEFINED;
integer esize = 8 << if size:Q == '110' then ReservedValue();
integer esize = 8 << UInt(size);
integer esize = 8 << UInt(size);
integer datasize = if Q == '1' then 128 else 64;
integer elements = datasize DIV esize;
boolean unsigned = (U == '1');
boolean rounding = (R == '1');
boolean saturating = (S == '1');

Assembler Symbols

<V> Is a width specifier, encoded in “size”:

USHL
Is the number of the SIMD&FP destination register, in the "Rd" field.

<n>
Is the number of the first SIMD&FP source register, encoded in the "Rn" field.

<m>
Is the number of the second SIMD&FP source register, encoded in the "Rm" field.

<Vd>
Is the name of the SIMD&FP destination register, encoded in the "Rd" field.

<T>
Is an arrangement specifier, encoded in “size:Q”:

<table>
<thead>
<tr>
<th>size</th>
<th>Q</th>
<th>&lt;T&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>0</td>
<td>8B</td>
</tr>
<tr>
<td>00</td>
<td>1</td>
<td>16B</td>
</tr>
<tr>
<td>01</td>
<td>0</td>
<td>4H</td>
</tr>
<tr>
<td>01</td>
<td>1</td>
<td>8H</td>
</tr>
<tr>
<td>10</td>
<td>0</td>
<td>2S</td>
</tr>
<tr>
<td>10</td>
<td>1</td>
<td>4S</td>
</tr>
<tr>
<td>11</td>
<td>0</td>
<td>RESERVED</td>
</tr>
<tr>
<td>11</td>
<td>1</td>
<td>2D</td>
</tr>
</tbody>
</table>

<Vn>
Is the name of the first SIMD&FP source register, encoded in the "Rn" field.

<Vm>
Is the name of the second SIMD&FP source register, encoded in the "Rm" field.

Operation

```c
CheckFPAdvSIMDEnabled64();
bits(datasize) operand1 = V[n];
bits(datasize) operand2 = V[m];
bits(datasize) result;

integer round_const = 0;
integer shift;
integer element;
boolean sat;
for e = 0 to elements-1
    shift = SInt(Elem[operand2, e, esize]<7:0>);
    if rounding then
        round_const = 1 << (-shift - 1); // 0 for left shift, 2^(n-1) for right shift
        element = (Int(Elem[operand1, e, esize], unsigned) + round_const) << shift;
    if saturating then
        (Elem[result, e, esize], sat) = SatQ(element, esize, unsigned);
    if sat then FPSR.QC = '1';
    else
        Elem[result, e, esize] = element<esize-1:0>;
V[d] = result;
```

Operational information

If PSTATE.DIT is 1:
- The execution time of this instruction is independent of:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
- The response of this instruction to asynchronous exceptions does not vary based on:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.

Internal version only: isa v30.25+22.05, AdvSIMD v27.01+22.05, pseudocode v85+xml-008ec8_fc3e35-; Build timestamp: 2018-09-13T13:2018-06-16T09:044
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USHLL, USHLL2

Unsigned Shift Left Long (immediate). This instruction reads each vector element in the lower or upper half of the source SIMD&FP register, shifts the unsigned integer value left by the specified number of bits, places the result into a vector, and writes the vector to the destination SIMD&FP register. The destination vector elements are twice as long as the source vector elements.

The USHLL instruction extracts vector elements from the lower half of the source register, while the USHLL2 instruction extracts vector elements from the upper half of the source register.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

This instruction is used by the alias UXTL, UXTL2.

Vector

USHLL{2} <Vd>.<Ta>, <Vn>.<Tb>, #<shift>

```
integer d = UInt(Rd);
integer n = UInt(Rn);
if immh == '0000' then SEE(asimdimm);
if immh<3> == '1' then UNDEFINED;
integer esize = 8 << HighestSetBit(immh);
integer datasize = 64;
integer part = UInt(Q);
integer elements = datasize DIV esize;
integer shift = UInt(immh:immb) - esize;
boolean unsigned = (U == '1');
```

Assembler Symbols

2 Is the second and upper half specifier. If present it causes the operation to be performed on the upper 64 bits of the registers holding the narrower elements, and is encoded in “Q”:

<table>
<thead>
<tr>
<th>0</th>
<th>absent</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>present</td>
</tr>
</tbody>
</table>

<Vd> Is the name of the SIMD&FP destination register, encoded in the “Rd” field.

<Ta> Is an arrangement specifier, encoded in “immh”:

<table>
<thead>
<tr>
<th>immh</th>
<th>&lt;Ta&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0000</td>
<td>SEE Advanced SIMD modified immediate</td>
</tr>
<tr>
<td>0001</td>
<td>8H</td>
</tr>
<tr>
<td>001x</td>
<td>4S</td>
</tr>
<tr>
<td>01xx</td>
<td>2D</td>
</tr>
<tr>
<td>1xxx</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

<Vn> Is the name of the SIMD&FP source register, encoded in the "Rn" field.

<Tb> Is an arrangement specifier, encoded in “immh:Q”:
### Is the left shift amount, in the range 0 to the source element width in bits minus 1, encoded in “immh:immb”:

- **immh**
  - 0000: SEE Advanced SIMD modified immediate
  - 0001: (UInt(immh:immb)-8)
  - 001x: (UInt(immh:immb)-16)
  - 01xx: (UInt(immh:immb)-32)
  - lxxx: RESERVED

### Alias Conditions

<table>
<thead>
<tr>
<th>Alias</th>
<th>Is preferred when</th>
</tr>
</thead>
<tbody>
<tr>
<td>UXTL, UXTL2</td>
<td><code>immb == '000' &amp;&amp; BitCount(immh) == 1</code></td>
</tr>
</tbody>
</table>

### Operation

```c
CheckFPAdvSIMDEnabled64();
bias(datasize) operand = Vpart[n, part];
bias(datasize*2) result;
integer element;
for e = 0 to elements-1
  element = Int(Elem[operand, e, esize], unsigned) << shift;
  Elem[result, e, 2*esize] = element<2*esize-1:0>;
V[d] = result;
```

### Operational information

If PSTATE.DIT is 1:

- The execution time of this instruction is independent of:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
- The response of this instruction to asynchronous exceptions does not vary based on:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
USHR

Unsigned Shift Right (immediate). This instruction reads each vector element in the source SIMD&FP register, right shifts each result by an immediate value, writes the final result to a vector, and writes the vector to the destination SIMD&FP register. All the values in this instruction are unsigned integer values. The results are truncated. For rounded results, see *URSHR*.

Depending on the settings in the *CPACR_EL1*, *CPTR_EL2*, and *CPTR_EL3* registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

It has encodings from 2 classes: *Scalar* and *Vector*

**Scalar**

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0  | 1  | 1  | 1  | 1  | 1  | 1  | 0  | != 0000 | immh | 0  | 0  | 0  | 0  | 1  | Rn  | Rd  |

**Vector**

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0  | Q  | 1  | 0  | 1  | 1  | 1  | 0  | != 0000 | immh | 0  | 0  | 0  | 0  | 1  | Rn  | Rd  |

integer d = UInt(Rd);
integer n = UInt(Rn);

if immh<3> != '1' then UNDEFINED;
integer esize = 8 << 3;
integer datasize = esize;
integer elements = 1;

integer shift = (esize * 2) -
if immh<3> != '1' then ReservedValue();
integer esize = 8 << 3;
integer datasize = esize;
integer elements = 1;

integer shift = (esize * 2) -
if immh<3> != '1' then ReservedValue();
integer esize = 8 << 3;
integer datasize = esize;
integer elements = 1;

integer shift = (esize * 2) -
if immh<3> != '1' then ReservedValue();

boolean unsigned = (U == '1');
boolean round = (o1 == '1');
boolean accumulate = (o0 == '1');

USHR
Vector

USHR $<Vd>$,$<T>$, $<Vn>$,$<T>$, #$<shift>$

```plaintext
integer d = UInt(Rd);
integer n = UInt(Rn);

if immh == '0000' then SEE(asimdimm);
if immh<3>:Q == '10' then UNDEFINED;
integer esize = 8 << if immh<3>:Q == '10' then ReservedValue();
integer esize = 8 << HighestSetBit(immh);
integer datasize = if Q == '1' then 128 else 64;
integer elements = datasize DIV esize;

integer shift = (esize * 2) - UInt(immh:immb);
boolean unsigned = (U == '1');
boolean round = (o1 == '1');
boolean accumulate = (o0 == '1');
```

Assembler Symbols

$<V>$ is a width specifier, encoded in “immh”:

<table>
<thead>
<tr>
<th>immh</th>
<th>$&lt;V&gt;$</th>
</tr>
</thead>
<tbody>
<tr>
<td>0xxx</td>
<td>RESERVED</td>
</tr>
<tr>
<td>1xxx</td>
<td>D</td>
</tr>
</tbody>
</table>

$<d>$ is the number of the SIMD&FP destination register, in the "Rd" field.

$<n>$ is the number of the first SIMD&FP source register, encoded in the "Rn" field.

$<Vd>$ is the name of the SIMD&FP destination register, encoded in the "Rd" field.

$<T>$ is an arrangement specifier, encoded in “immh:Q”:

<table>
<thead>
<tr>
<th>immh</th>
<th>Q</th>
</tr>
</thead>
<tbody>
<tr>
<td>0000</td>
<td>x</td>
</tr>
<tr>
<td>0001</td>
<td>0</td>
</tr>
<tr>
<td>0001</td>
<td>1</td>
</tr>
<tr>
<td>001x</td>
<td>0</td>
</tr>
<tr>
<td>001x</td>
<td>1</td>
</tr>
<tr>
<td>01xx</td>
<td>0</td>
</tr>
<tr>
<td>01xx</td>
<td>1</td>
</tr>
<tr>
<td>1xxx</td>
<td>0</td>
</tr>
<tr>
<td>1xxx</td>
<td>1</td>
</tr>
</tbody>
</table>

$<Vn>$ is the name of the SIMD&FP source register, encoded in the "Rn" field.

$<shift>$ is the right shift amount, in the range 1 to 64, encoded in “immh:immb”:

For the scalar variant:

<table>
<thead>
<tr>
<th>immh</th>
<th>$&lt;shift&gt;$</th>
</tr>
</thead>
<tbody>
<tr>
<td>0xxx</td>
<td>RESERVED</td>
</tr>
<tr>
<td>1xxx</td>
<td>(128-UInt(immh:immb))</td>
</tr>
</tbody>
</table>

For the vector variant:

<table>
<thead>
<tr>
<th>immh</th>
<th>$&lt;shift&gt;$</th>
</tr>
</thead>
<tbody>
<tr>
<td>0000</td>
<td>SEE Advanced SIMD modified immediate</td>
</tr>
<tr>
<td>0001</td>
<td>(16-UInt(immh:immb))</td>
</tr>
<tr>
<td>001x</td>
<td>(32-UInt(immh:immb))</td>
</tr>
<tr>
<td>01xx</td>
<td>(64-UInt(immh:immb))</td>
</tr>
<tr>
<td>1xxx</td>
<td>(128-UInt(immh:immb))</td>
</tr>
</tbody>
</table>
Operation

```c
CheckFPAdvSIMDEnabled64();
bits(datasize) operand = V[n];
bits(datasize) operand2;
bits(datasize) result;
integer round_const = if round then (1 << (shift - 1)) else 0;
integer element;
operand2 = if accumulate then V[d] else Zeros();
for e = 0 to elements-1
    element = (Int(Elem(operand, e, esize), unsigned) + round_const) >> shift;
    Elem[result, e, esize] = Elem(operand2, e, esize) + element<esize-1:0>;
V[d] = result;
```

Operational information

If PSTATE.DIT is 1:

- The execution time of this instruction is independent of:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
- The response of this instruction to asynchronous exceptions does not vary based on:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
USQADD

Unsigned saturating Accumulate of Signed value. This instruction adds the signed integer values of the vector elements in the source SIMD&FP register to corresponding unsigned integer values of the vector elements in the destination SIMD&FP register, and accumulates the resulting unsigned integer values with the vector elements of the destination SIMD&FP register.

If overflow occurs with any of the results, those results are saturated. If saturation occurs, the cumulative saturation bit FPSR.QC is set. Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

It has encodings from 2 classes: Scalar and Vector

Scalar

USQADD <V><d>, <V><n>

integer d = UInt(Rd);
integer n = UInt(Rn);

integer esize = 8 << UInt(size);
integer datasize = esize;
integer elements = 1;

boolean unsigned = (U == '1');

Vector

USQADD <Vd>.,<T>, <Vn>.,<T>

integer d = UInt(Rd);
integer n = UInt(Rn);

if size:Q == '110' then UNDEFINED;
integer esize = 8 << UInt(size);
integer datasize = if Q == '1' then 128 else 64;
integer elements = datasize DIV esize;

boolean unsigned = (U == '1');

Assembler Symbols

<V> Is a width specifier, encoded in “size”:

<table>
<thead>
<tr>
<th>size</th>
<th>&lt;V&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>B</td>
</tr>
<tr>
<td>01</td>
<td>H</td>
</tr>
<tr>
<td>10</td>
<td>S</td>
</tr>
<tr>
<td>11</td>
<td>D</td>
</tr>
</tbody>
</table>
Is the number of the SIMD&FP destination register, encoded in the "Rd" field.

Is the number of the SIMD&FP source register, encoded in the "Rn" field.

Is the name of the SIMD&FP destination register, encoded in the "Rd" field.

Is the number of the SIMD&FP source register, encoded in the "Rn" field.

<table>
<thead>
<tr>
<th>size</th>
<th>Q</th>
<th>&lt;T&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>0</td>
<td>8B</td>
</tr>
<tr>
<td>00</td>
<td>1</td>
<td>16B</td>
</tr>
<tr>
<td>01</td>
<td>0</td>
<td>4H</td>
</tr>
<tr>
<td>01</td>
<td>1</td>
<td>8H</td>
</tr>
<tr>
<td>10</td>
<td>0</td>
<td>2S</td>
</tr>
<tr>
<td>10</td>
<td>1</td>
<td>4S</td>
</tr>
<tr>
<td>11</td>
<td>0</td>
<td>RESERVED</td>
</tr>
<tr>
<td>11</td>
<td>1</td>
<td>2D</td>
</tr>
</tbody>
</table>

Is the name of the SIMD&FP source register, encoded in the "Rn" field.

Operation

```c
CheckFPAdvSIMDEnabled64();
bits(datasize) operand = V[n];
bits(datasize) result;

bits(datasize) operand2 = V[d];
integer op1;
integer op2;
boolean sat;

for e = 0 to elements-1
    op1 = Int(Elem[operand, e, esize], !unsigned);
    op2 = Int(Elem[operand2, e, esize], unsigned);
    (Elem[result, e, esize], sat) = SatQ(op1 + op2, esize, unsigned);
    if sat then FPSR.QC = '1';
V[d] = result;
```

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USRA

Unsigned Shift Right and Accumulate (immediate). This instruction reads each vector element in the source SIMD&FP register, right shifts each result by an immediate value, and accumulates the final results with the vector elements of the destination SIMD&FP register. All the values in this instruction are unsigned integer values. The results are truncated. For rounded results, see USRA.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

It has encodings from 2 classes: Scalar and Vector

Scalar

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0  | 1  | 1  | 1  | 1  | 1  | 1  | 0  | != | 0000 | immh | 0  | 0  | 0  | 1  | 0  | 1  | Rn | Rd |
| U  |     | immh |     |     | 0 | 0 | 0 |

Scalar

USRA <V><d>, <V><n>, #<shift>

integer d =UInt(Rd);
integer n =UInt(Rn);
if immh<3> != '1' then UNDEFINED;
integer esize = 8 << 3;
integer datasize = esize;
integer elements = 1;

integer shift = (esize * 2) - if immh<3> != '1' then ReservedValue();
integer esize = 8 << 3;
integer datasize = esize;
integer elements = 1;

integer shift = (esize * 2) = UInt(immh:immb);
boolean unsigned = (U == '1');
boolean round = (o1 == '1');
boolean accumulate = (o0 == '1');

Vector

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0  | Q | 1  | 0  | 1  | 1  | 1  | 0  | != | 0000 | immh | 0  | 0  | 0  | 1  | 0  | 1  | Rn | Rd |
| U  |     | immh |     |     | 0 | 0 | 0 |

USRA
Vector

USRA <Vd>,<T>, <Vn>,<T>, <$shift>

integer d = UInt(Rd);
integer n = UInt(Rn);

if immh == '0000' then SEE(asimdimm);
if immh<3>:Q == '10' then UNDEFINED;
integer esize = 8 << if immh<3>:Q == '10' then ReservedValue();
integer esize = 8 << HighestSetBit(immh);
integer datasize = if Q == '1' then 128 else 64;
integer elements = datasize DIV esize;

integer shift = (esize * 2) - UInt(immh:immb);
boolean unsigned = (U == '1');
boolean round = (o1 == '1');
boolean accumulate = (o0 == '1');

Assembler Symbols

<V> Is a width specifier, encoded in “immh”:

<table>
<thead>
<tr>
<th>immh</th>
<th>&lt;V&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0xxx</td>
<td>RESERVED</td>
</tr>
<tr>
<td>1xx</td>
<td>D</td>
</tr>
</tbody>
</table>

<d> Is the number of the SIMD&FP destination register, in the "Rd" field.

<n> Is the number of the first SIMD&FP source register, encoded in the "Rn" field.

<Vd> Is the name of the SIMD&FP destination register, encoded in the "Rd" field.

<T> Is an arrangement specifier, encoded in “immh:Q”:

<table>
<thead>
<tr>
<th>immh</th>
<th>Q</th>
</tr>
</thead>
<tbody>
<tr>
<td>0000</td>
<td>x</td>
</tr>
<tr>
<td>0001</td>
<td>0</td>
</tr>
<tr>
<td>0001</td>
<td>1</td>
</tr>
<tr>
<td>001x</td>
<td>0</td>
</tr>
<tr>
<td>001x</td>
<td>1</td>
</tr>
<tr>
<td>01xx</td>
<td>0</td>
</tr>
<tr>
<td>01xx</td>
<td>1</td>
</tr>
<tr>
<td>1xx</td>
<td>0</td>
</tr>
<tr>
<td>1xx</td>
<td>1</td>
</tr>
</tbody>
</table>

<Vn> Is the name of the SIMD&FP source register, encoded in the "Rn" field.

<shift> For the scalar variant: is the right shift amount, in the range 1 to 64, encoded in “immh:immb”:

<table>
<thead>
<tr>
<th>immh</th>
<th>&lt;shift&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0xxx</td>
<td>RESERVED</td>
</tr>
<tr>
<td>1xx</td>
<td>128-UInt(immh:immb)</td>
</tr>
</tbody>
</table>

For the vector variant: is the right shift amount, in the range 1 to the element width in bits, encoded in “immh:immb”:

<table>
<thead>
<tr>
<th>immh</th>
<th>&lt;shift&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0000</td>
<td>SEE Advanced SIMD modified immediate</td>
</tr>
<tr>
<td>0001</td>
<td>16-UInt(immh:immb)</td>
</tr>
<tr>
<td>001x</td>
<td>32-UInt(immh:immb)</td>
</tr>
<tr>
<td>01xx</td>
<td>64-UInt(immh:immb)</td>
</tr>
<tr>
<td>1xxx</td>
<td>128-UInt(immh:immb)</td>
</tr>
</tbody>
</table>
Operation

```c
CheckFPAdvSIMDEnabled64();
bits(datasize) operand = V[n];
bits(datasize) operand2;
bits(datasize) result;
integer round_const = if round then (1 << (shift - 1)) else 0;
integer element;

operand2 = if accumulate then V[d] else Zeros();
for e = 0 to elements-1
   element = (Int(Elem(operand, e, esize), unsigned) + round_const) >> shift;
   Elem[result, e, esize] = Elem(operand2, e, esize) + element<esize-1:0>;
V[d] = result;
```

Operational information

If PSTATE.DIT is 1:
- The execution time of this instruction is independent of:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
- The response of this instruction to asynchronous exceptions does not vary based on:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
USUBL, USUBL2

Unsigned Subtract Long. This instruction subtracts each vector element in the lower or upper half of the second source SIMD&FP register from the corresponding vector element of the first source SIMD&FP register, places the result into a vector, and writes the vector to the destination SIMD&FP register. All the values in this instruction are unsigned integer values. The destination vector elements are twice as long as the source vector elements.

The USUBL instruction extracts each source vector from the lower half of each source register, while the USUBL2 instruction extracts each source vector from the upper half of each source register.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

Three registers, not all the same type

USUBL[2] <Vd>.<Ta>, <Vn>.<Tb>, <Vm>.<Tb>

integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rm);
if size == '11' then UNDEFINED;
integer esize = 8 << if size == '11' then ReservedValue();
integer esize = 8 << UInt(size);
integer datasize = 64;
integer part = UInt(Q);
integer elements = datasize DIV esize;

boolean sub_op = (o1 == '1');
boolean unsigned = (U == '1');

Assembler Symbols

2 Is the second and upper half specifier. If present it causes the operation to be performed on the upper 64 bits of the registers holding the narrower elements, and is encoded in “Q”:

<table>
<thead>
<tr>
<th>Q</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>[absent]</td>
</tr>
<tr>
<td>1</td>
<td>[present]</td>
</tr>
</tbody>
</table>

<Vd> Is the name of the SIMD&FP destination register, encoded in the "Rd" field.

<Ta> Is an arrangement specifier, encoded in “size”:

<table>
<thead>
<tr>
<th>size</th>
<th>&lt;Ta&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>8H</td>
</tr>
<tr>
<td>01</td>
<td>4S</td>
</tr>
<tr>
<td>10</td>
<td>2D</td>
</tr>
<tr>
<td>11</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

<Vn> Is the name of the first SIMD&FP source register, encoded in the "Rn" field.

<Tb> Is an arrangement specifier, encoded in “size-Q”:

<table>
<thead>
<tr>
<th>size</th>
<th>Q</th>
<th>&lt;Tb&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>0</td>
<td>8B</td>
</tr>
<tr>
<td>00</td>
<td>1</td>
<td>16B</td>
</tr>
<tr>
<td>01</td>
<td>0</td>
<td>4H</td>
</tr>
<tr>
<td>01</td>
<td>1</td>
<td>8H</td>
</tr>
<tr>
<td>10</td>
<td>0</td>
<td>2S</td>
</tr>
<tr>
<td>10</td>
<td>1</td>
<td>4S</td>
</tr>
<tr>
<td>11</td>
<td>x</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>
Is the name of the second SIMD&FP source register, encoded in the "Rm" field.

### Operation

```c
CheckFPAdvSIMDEnabled64();
bits(datasize) operand1 = Vpart[n, part];
bits(datasize) operand2 = Vpart[m, part];
bits(2*datasize) result;
integer element1;
integer element2;
integer sum;

for e = 0 to elements-1
  element1 = Int(Elem[operand1, e, esize], unsigned);
  element2 = Int(Elem[operand2, e, esize], unsigned);
  if sub_op then
    sum = element1 - element2;
  else
    sum = element1 + element2;
  Elem[result, e, 2*esize] = sum<2*esize-1:0>;

V[d] = result;
```

### Operational information

If PSTATE.DIT is 1:
- The execution time of this instruction is independent of:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
- The response of this instruction to asynchronous exceptions does not vary based on:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
### USUBW, USUBW2

Unsigned Subtract Wide. This instruction subtracts each vector element of the second source SIMD&FP register from the corresponding vector element in the lower or upper half of the first source SIMD&FP register, places the result in a vector, and writes the vector to the SIMD&FP destination register. All the values in this instruction are signed integer values.

The vector elements of the destination register and the first source register are twice as long as the vector elements of the second source register. The USUBW instruction extracts vector elements from the lower half of the first source register, while the USUBW2 instruction extracts vector elements from the upper half of the first source register.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

### Three registers, not all the same type

USUBW(2) <Vd>,<Ta>, <Vn>,<Ta>, <Vm>.

```
integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rm);

if size == '11' then UNDEFINED;
integer esize = 8 << if size == '11' then ReservedValue();
integer esize = 8 << UInt(size);
integer datasize = 64;
integer part = UInt(Q);
integer elements = datasize DIV esize;

boolean sub_op = (o1 == '1');
boolean unsigned = (U == '1');
```

### Assembler Symbols

#### 2

Is the second and upper half specifier. If present it causes the operation to be performed on the upper 64 bits of the registers holding the narrower elements, and is encoded in "Q":

<table>
<thead>
<tr>
<th>Q</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>[absent]</td>
</tr>
<tr>
<td>1</td>
<td>[present]</td>
</tr>
</tbody>
</table>

#### <Vd>

Is the name of the SIMD&FP destination register, encoded in the "Rd" field.

#### <Ta>

Is an arrangement specifier, encoded in “size”:

<table>
<thead>
<tr>
<th>size</th>
<th>&lt;Ta&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>8H</td>
</tr>
<tr>
<td>01</td>
<td>4S</td>
</tr>
<tr>
<td>10</td>
<td>2D</td>
</tr>
<tr>
<td>11</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

#### <Vn>

Is the name of the first SIMD&FP source register, encoded in the "Rn" field.

#### <Vm>

Is the name of the second SIMD&FP source register, encoded in the "Rm" field.

#### <Tb>

Is an arrangement specifier, encoded in “size:Q”:
<table>
<thead>
<tr>
<th>size</th>
<th>Q</th>
<th>&lt;Tb&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>0</td>
<td>8B</td>
</tr>
<tr>
<td>00</td>
<td>1</td>
<td>16B</td>
</tr>
<tr>
<td>01</td>
<td>0</td>
<td>4H</td>
</tr>
<tr>
<td>01</td>
<td>1</td>
<td>8H</td>
</tr>
<tr>
<td>10</td>
<td>0</td>
<td>2S</td>
</tr>
<tr>
<td>10</td>
<td>1</td>
<td>4S</td>
</tr>
<tr>
<td>11</td>
<td>x</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

**Operation**

```c
CheckFPAdvSIMDEnabled64();

bits(2*datasize) operand1 = V[n];
bits(datasize) operand2 = Vpart[m, part];
bits(2*datasize) result;
integer element1;
integer element2;
integer sum;

for e = 0 to elements-1
    element1 = Int(Elem[operand1, e, 2*esize], unsigned);
    element2 = Int(Elem[operand2, e, esize], unsigned);
    if sub_op then
        sum = element1 - element2;
    else
        sum = element1 + element2;
    Elem[result, e, 2*esize] = sum<2*esize-1:0>;
V[d] = result;
```

**Operational information**

If PSTATE.DIT is 1:

- The execution time of this instruction is independent of:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
- The response of this instruction to asynchronous exceptions does not vary based on:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.


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UZP1

Unzip vectors (primary). This instruction reads corresponding even-numbered vector elements from the two source SIMD&FP registers, starting at zero, places the result from the first source register into consecutive elements in the lower half of a vector, and the result from the second source register into consecutive elements in the upper half of a vector, and writes the vector to the destination SIMD&FP register.

This instruction can be used with UZP2 to de-interleave two vectors.

The following figure shows an example of the operation of UZP1 and UZP2 with the arrangement specifier 8B.

```
Vr  | A7 | A6 | A5 | A4 | A3 | A2 | A1 | A0
Vn  | B7 | B6 | B5 | B4 | B3 | B2 | B1 | B0
```

UZP1.8, doubleword  
UZP2.8, doubleword

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

```
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0  | Q  | 0  | 0  | 1  | 1  | 0  | size | 0  | Rm  | 0  | 0  | 0  | 1  | 1  | 0  | Rn  | 1  | 0  | Rd |
```

**Assembler Symbols**

**<Vd>**
Is the name of the SIMD&FP destination register, encoded in the “Rd” field.

**<T>**
Is an arrangement specifier, encoded in “size:Q”:

<table>
<thead>
<tr>
<th>size</th>
<th>Q</th>
<th>&lt;T&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>0</td>
<td>8B</td>
</tr>
<tr>
<td>00</td>
<td>1</td>
<td>16B</td>
</tr>
<tr>
<td>01</td>
<td>0</td>
<td>4H</td>
</tr>
<tr>
<td>01</td>
<td>1</td>
<td>8H</td>
</tr>
<tr>
<td>10</td>
<td>0</td>
<td>2S</td>
</tr>
<tr>
<td>10</td>
<td>1</td>
<td>4S</td>
</tr>
<tr>
<td>11</td>
<td>0</td>
<td>RESERVED</td>
</tr>
<tr>
<td>11</td>
<td>1</td>
<td>2D</td>
</tr>
</tbody>
</table>

**<Vn>**
Is the name of the first SIMD&FP source register, encoded in the “Rn” field.

**<Vm>**
Is the name of the second SIMD&FP source register, encoded in the “Rm” field.
Operation

```
CheckFPAdvSIMDEnabled64();
bits(datasize) operandl = V[n];
bits(datasize) operandh = V[m];
bits(datasize) result;

integer e;
bits(datasize*2) zipped = operandh:operandl;
for e = 0 to elements-1
  Elem[result, e, esize] = Elem[zipped, 2*e+part, esize];

V[d] = result;
```

Operational information

If PSTATE.DIT is 1:

- The execution time of this instruction is independent of:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
- The response of this instruction to asynchronous exceptions does not vary based on:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
UZP2

Unzip vectors (secondary). This instruction reads corresponding odd-numbered vector elements from the two source SIMD&FP registers, places the result from the first source register into consecutive elements in the lower half of a vector, and the result from the second source register into consecutive elements in the upper half of a vector, and writes the vector to the destination SIMD&FP register.

This instruction can be used with UZP1 to de-interleave two vectors.

The following figure shows an example of the operation of UZP1 and UZP2 with the arrangement specifier 8B.

The following table shows the arrangement specifier 8B:

<table>
<thead>
<tr>
<th>Vm</th>
<th>Vn</th>
<th>Rd</th>
</tr>
</thead>
<tbody>
<tr>
<td>B7</td>
<td>B6</td>
<td>B5</td>
</tr>
<tr>
<td>B4</td>
<td>B3</td>
<td>B2</td>
</tr>
<tr>
<td>A7</td>
<td>A6</td>
<td>A5</td>
</tr>
<tr>
<td>A4</td>
<td>A3</td>
<td>A2</td>
</tr>
<tr>
<td>A1</td>
<td>A0</td>
<td>A1</td>
</tr>
</tbody>
</table>

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

Advanced SIMD

UZP2 <Vd>,<T>, <Vn>,<T>, <Vm>,<T>

```plaintext
integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rm);

if size:Q == '110' then UNDEFINED;
integer esize = 8 << if size:Q == '110' then ReservedValue(1);
integer esize = 8 << UInt(size);
integer datasize = if Q == '1' then 128 else 64;
integer elements = datasize DIV esize;
integer part = UInt(op);
```

Assembler Symbols

<Vd> Is the name of the SIMD&FP destination register, encoded in the "Rd" field.

<T> Is an arrangement specifier, encoded in “size:Q”:

<table>
<thead>
<tr>
<th>size</th>
<th>Q</th>
<th>&lt;T&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>0</td>
<td>8B</td>
</tr>
<tr>
<td>00</td>
<td>1</td>
<td>16B</td>
</tr>
<tr>
<td>01</td>
<td>0</td>
<td>4H</td>
</tr>
<tr>
<td>01</td>
<td>1</td>
<td>8H</td>
</tr>
<tr>
<td>10</td>
<td>0</td>
<td>2S</td>
</tr>
<tr>
<td>10</td>
<td>1</td>
<td>4S</td>
</tr>
<tr>
<td>11</td>
<td>0</td>
<td>RESERVED</td>
</tr>
<tr>
<td>11</td>
<td>1</td>
<td>2D</td>
</tr>
</tbody>
</table>

<Vn> Is the name of the first SIMD&FP source register, encoded in the "Rn" field.

<Vm> Is the name of the second SIMD&FP source register, encoded in the "Rm" field.
Operation

```c
CheckFPAdvSIMDEnabled64();
bits(datasize) operandl = V[n];
bits(datasize) operandh = V[m];
bits(datasize) result;

bits(datasize*2) zipped = operandh:operandl;
for e = 0 to elements-1
    Elem[result, e, esize] = Elem[zipped, 2*e+part, esize];
V[d] = result;
```

Operational information

If PSTATE.DIT is 1:

- The execution time of this instruction is independent of:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
- The response of this instruction to asynchronous exceptions does not vary based on:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.

Internal version only: isa v30.25, AdvSIMD v27.0, pseudocode v85-xml-00bet8_rc3_x254; Build timestamp: 2018-09-13T13:44:0045; Build timestamp: 2018-09-16T09:04:45

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WFE

Wait For Event is a hint instruction that indicates that the PE can enter a low-power state and remain there until a wakeup event occurs. Wakeup events include the event signaled as a result of executing the \texttt{SEV} instruction on any PE in the multiprocessor system. For more information, see \textit{Wait For Event mechanism and Send event}.

As described in \textit{Wait For Event mechanism and Send event}, the execution of a WFE instruction that would otherwise cause entry to a low-power state can be trapped to a higher Exception level. See:

- Traps to EL1 of EL0 execution of WFE and WFI instructions.
- Traps to EL2 of Non-secure EL0 and EL1 execution of WFE and WFI instructions.
- Traps to EL3 of EL2, EL1, and EL0 execution of WFE and WFI instructions.

### System

```c
SystemHintOp op;

case CRm:op2 of
    when '0000 000' op = SystemHintOp_NOP;
    when '0000 001' op = SystemHintOp_YIELD;
    when '0000 010' op = SystemHintOp_WFE;
    when '0000 011' op = SystemHintOp_WFI;
    when '0000 100' op = SystemHintOp_SEV;
    when '0000 101' op = SystemHintOp_SEVL;
    when '0000 111'
        SEE "XPACLRI";
    when '0001 xxx'
        SEE "PACIA1716, PACIB1716, AUTIA1716, AUTIB1716";
    when '0010 000'
        if !HaveRASExt() then EndOfInstruction();          // Instruction executes as NOP
        op = SystemHintOp_ESB;
    when '0010 001'
        if !HaveStatisticalProfiling() then EndOfInstruction(); // Instruction executes as NOP
        op = SystemHintOp_PSB;
    when '0010 010'
        if !HaveSelfHostedTrace() then EndOfInstruction();   // Instruction executes as NOP
        op = SystemHintOp_TSB;
    when '0010 100'
        op = SystemHintOp_CSDB;
    when '0011 xxx'
        SEE "PACIAZ, PACIASP, PACIBZ, PACIBSP, AUTIAZ, AUTIASP, AUTIBZ, AUTIBSP";
    when '0100 xx0'
        op = SystemHintOp_BTI;
    otherwise
        BTypeCompatible = BTypeCompatible_BTI(op2<2:1>);
        otherwise
            EndOfInstruction();                               // Instruction executes as NOP
```

WFE
case op of
  when SystemHintOp_YIELDHint_Yield();
  when SystemHintOp_WFE
    if IsEventRegisterSet() then ClearEventRegister();
    else
      if PSTATE.EL == EL0 then // Check for traps described by the OS which may be EL1 or EL2.
        AArch64.CheckForWFxTrap(EL1, TRUE);
      if EL2Enabled() && PSTATE.EL IN {EL0, EL1} && !IsInHost() then // Check for traps described by the Hypervisor.
        AArch64.CheckForWFxTrap(EL2, TRUE);
      if HaveEL(EL3) && PSTATE.EL != EL3 then // Check for traps described by the Secure Monitor.
        AArch64.CheckForWFxTrap(EL3, TRUE);
        WaitForEvent();
  when SystemHintOp_WFI
    if !InterruptPending() then
      if PSTATE.EL == EL0 then // Check for traps described by the OS which may be EL1 or EL2.
        AArch64.CheckForWFxTrap(EL1, FALSE);
      if EL2Enabled() && PSTATE.EL IN {EL0, EL1} && !IsInHost() then // Check for traps described by the Hypervisor.
        AArch64.CheckForWFxTrap(EL2, FALSE);
      if HaveEL(EL3) && PSTATE.EL != EL3 then // Check for traps described by the Secure Monitor.
        AArch64.CheckForWFxTrap(EL3, FALSE);
        WaitForInterrupt();
  when SystemHintOp_SEVSSendEvent();
  when SystemHintOp_SEVLSendEventLocal();
  when SystemHintOp_ESBSynchronizeErrors();
    AArch64.ESBOperation();
    if EL2Enabled() && PSTATE.EL IN {EL0, EL1} then AArch64.vESBOperation();
    TakeUnmaskedErrorInterrupts();
  when SystemHintOp_PSBProfilingSynchronizationBarrier();
  when SystemHintOp_TSB TraceSynchronizationBarrier();
  when SystemHintOp_CSDBConsumptionOfSpeculativeDataBarrier();
    when otherwise // do nothing SystemHintOp_BTI
      BTypeNext = '00';
    otherwise // do nothing

Wait For Interrupt is a hint instruction that indicates that the PE can enter a low-power state and remain there until a wakeup event occurs. For more information, see Wait For Interrupt.

As described in Wait For Interrupt, the execution of a WFI instruction that would otherwise cause entry to a low-power state can be trapped to a higher Exception level. See:

- Traps to EL1 of EL0 execution of WFE and WFI instructions.
- Traps to EL2 of Non-secure EL0 and EL1 execution of WFE and WFI instructions.
- Traps to EL3 of EL2, EL1, and EL0 execution of WFE and WFI instructions.

```c
WFI

System

WFI

SystemHintOp op;

case CRm:op2 of
  when '0000 000' op = SystemHintOp_NOP;
  when '0000 001' op = SystemHintOp_YIELD;
  when '0000 010' op = SystemHintOp_WFE;
  when '0000 011' op = SystemHintOp_WFI;
  when '0000 100' op = SystemHintOp_SEV;
  when '0000 101' op = SystemHintOp_SEVL;
  when '0000 111'
    SEE "XPACLRI";
  when '0001 xxx'
    SEE "PACIA1716, PACIB1716, AUTIA1716, AUTIB1716";
  when '0010 000'
    if !HaveRASExt() then EndOfInstruction();               // Instruction executes as NOP
    op = SystemHintOp_ESB;
  when '0010 001'
    if !HaveStatisticalProfiling() then EndOfInstruction(); // Instruction executes as NOP
    op = SystemHintOp_PSB;
  when '0010 010'
    if !HaveSelfHostedTrace() then EndOfInstruction();     // Instruction executes as NOP
    op = SystemHintOp_TSB;
  when '0010 100'
    op = SystemHintOp_CSDB;
  when '0011 xxx'
    SEE "PACIAZ, PACIASP, PACIBZ, PACIBSP, AUTIAZ, AUTIASP, AUTIBZ, AUTIBSP";
  when '0100 xx0'
    op = otherwise SystemHintOp_BTI;
    BTypeCompatible = BTypeCompatible_BTI(op2<2:1>);
  otherwise EndOfInstruction();                              // Instruction executes as NOP
```
case op of

when SystemHintOp_YIELD Hint Yield();

when SystemHintOp_WFE
  if IsEventRegisterSet() then
    ClearEventRegister();
  else
    if PSTATE.EL == EL0 then
      // Check for traps described by the OS which may be EL1 or EL2.
      AArch64.CheckForWFxTrap(EL1, TRUE);
    if EL2Enabled() && PSTATE.EL IN {EL0, EL1} && !IsInHost() then
      // Check for traps described by the Hypervisor.
      AArch64.CheckForWFxTrap(EL2, TRUE);
    if HaveEL(EL3) && PSTATE.EL != EL0 then
      // Check for traps described by the Secure Monitor.
      AArch64.CheckForWFxTrap(EL3, TRUE);
      WaitForEvent();

when SystemHintOp_WFI
  if !InterruptPending() then
    if PSTATE.EL == EL0 then
      // Check for traps described by the OS which may be EL1 or EL2.
      AArch64.CheckForWFxTrap(EL1, FALSE);
    if EL2Enabled() && PSTATE.EL IN {EL0, EL1} && !IsInHost() then
      // Check for traps described by the Hypervisor.
      AArch64.CheckForWFxTrap(EL2, FALSE);
    if HaveEL(EL3) && PSTATE.EL != EL3 then
      // Check for traps described by the Secure Monitor.
      AArch64.CheckForWFxTrap(EL3, FALSE);
      WaitForInterrupt();

when SystemHintOp_SEVSendEvent();

when SystemHintOp_SEVLSendEventLocal();

when SystemHintOp_ESBSynchronizeErrors();
  AArch64.ESSOperation();
  if !EL2Enabled() && PSTATE.EL IN {EL0, EL1} then
    AArch64.vESBOperation();
    TakeUnmaskedErrorInterrupts();

when SystemHintOp_PSBProfilingSynchronizationBarrier();

when SystemHintOp_TSB
  TraceSynchronizationBarrier();

when SystemHintOp_CSDBConsumptionOfSpeculativeDataBarrier();

  when otherwise // do nothing SystemHintOp_BTI
    BTypeNext = '00';
  otherwise // do nothing

Internal version only: isa v30.25, v29.05, AdvSIMD v27.01, v26.0, pseudocode v85-xml-00bet8_rc325; ; Build timestamp: 2018-09-13T12:00:45Z
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XAFlag

Convert floating-point condition flags from external format to ARM format. This instruction converts the state of the PSTATE.{N,Z,C,V} flags from an alternative representation required by some software to a form representing the result of an ARM floating-point scalar compare instruction.

System (ARMv8.5)

```
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9  | 8  | 7  | 6  | 5  | 4  | 3  | 2  | 1  | 0  |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 1  | 1  | 0  | 1  | 0  | 1  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 1  | 0  | 0  | (0)| (0)| (0)| (0)| 0  | 0  | 1  | 1  | 1  | 1  | 1  |    |
```

Operation

```
if !HaveFlagFormatExt() then UNDEFINED;

bit N = NOT(PSTATE.C) AND NOT(PSTATE.Z);
bit Z = PSTATE.Z AND PSTATE.C;
bit C = PSTATE.C OR PSTATE.Z;
bit V = NOT(PSTATE.C) AND PSTATE.Z;

PSTATE.N = N;
PSTATE.Z = Z;
PSTATE.C = C;
PSTATE.V = V;
```
XAR

Exclusive OR and Rotate performs a bitwise exclusive OR of the 128-bit vectors in the two source SIMD&FP registers, rotates each 64-bit element of the resulting 128-bit vector right by the value specified by a 6-bit immediate value, and writes the result to the destination SIMD&FP register.

This instruction is implemented only when ARMv8.2-SHA is implemented.

Advanced SIMD
(ARMv8.2)

31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0

| Rm | imm6 | Rn | Rd |

Advanced SIMD

XAR <Vd>.2D, <Vn>.2D, <Vm>.2D, #<imm6>

if !HaveSHA3Ext() then UNDEFINED;
integer d = -1 then UnallocatedEncoding();
integer d = UInt(Rd);
integer n = UInt(Rn);
integer m = UInt(Rm);

Assembler Symbols

<Vd> Is the name of the SIMD&FP destination register, encoded in the "Rd" field.
<Vn> Is the name of the first SIMD&FP source register, encoded in the "Rn" field.
<Vm> Is the name of the second SIMD&FP source register, encoded in the "Rm" field.
<imm6> Is a rotation right, encoded in "imm6".

Operation

AArch64.CheckFPAdvSIMDEnabled();

bits(128) Vm = V[m];
bits(128) Vn = V[n];
bits(128) tmp;
tmp = Vn EOR Vm;
V[d] = ROR(tmp<127:64>, UInt(imm6)):ROR(tmp<63:0>, UInt(imm6));

Operational information

If PSTATE.DIT is 1:

• The execution time of this instruction is independent of:
  ◦ The values of the data supplied in any of its registers.
  ◦ The values of the NZCV flags.

• The response of this instruction to asynchronous exceptions does not vary based on:
  ◦ The values of the data supplied in any of its registers.
  ◦ The values of the NZCV flags.
XPACD, XPACI, XPACLRI

Strip Pointer Authentication Code. This instruction removes the pointer authentication code from an address. The address is in the specified general-purpose register for XPACI and XPACD, and is in LR for XPACLRI.

The XPACD instruction is used for data addresses, and XPACI and XPACLRI are used for instruction addresses.

It has encodings from 2 classes: Integer and System

Integer (ARMv8.3)

|   31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 |  9 |  8 |  7 |  6 |  5 |  4 |  3 |  2 |  1 |  0 |
|-----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0   | 1  | 0  | 1  | 0  | 1  | 0  | 1  | 0  | 0  | 0  | 0  | 0  | 0  | 1  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 0  |

XPACD (D == 1)

XPACD <Xd>

XPACI (D == 0)

XPACI <Xd>

System (ARMv8.3)

|   31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 |  9 |  8 |  7 |  6 |  5 |  4 |  3 |  2 |  1 |  0 |
|-----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 1   | 1  | 0  | 1  | 0  | 1  | 0  | 1  | 0  | 0  | 0  | 0  | 0  | 1  | 1  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  |

System

XPACLRI

|   31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 |  9 |  8 |  7 |  6 |  5 |  4 |  3 |  2 |  1 |  0 |
|-----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 1   | 1  | 0  | 1  | 0  | 1  | 0  | 1  | 0  | 0  | 0  | 0  | 0  | 1  | 1  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 0  |

Assembler Symbols

<Xd> Is the 64-bit name of the general-purpose destination register, encoded in the "Rd" field.

Operation

if HavePACExt() then
    X[d] = Strip(X[d], data);
(old)  htmldiff from-  (new)
XTN, XTN2

Extract Narrow. This instruction reads each vector element from the source SIMD&FP register, narrows each value to half the original width, places the result into a vector, and writes the vector to the lower or upper half of the destination SIMD&FP register. The destination vector elements are half as long as the source vector elements.

The XTN instruction writes the vector to the lower half of the destination register and clears the upper half, while the XTN2 instruction writes the vector to the upper half of the destination register without affecting the other bits of the register.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

<table>
<thead>
<tr>
<th>31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 Q 0 0 1 1 1 0</td>
</tr>
</tbody>
</table>

Vector

XTN[2] <Vd>, <Tb>, <Vn>.<Ta>

```plaintext
integer d = UInt(Rd);
integer n = UInt(Rn);

if size == '11' then UNDEFINED;
integer esize = 8 << if size == '11' then ReservedValue();
integer esize = 8 << UInt(size);
integer datasize = 64;
integer part = UInt(Q);
integer elements = datasize DIV esize;
```

Assembler Symbols

2

Is the second and upper half specifier. If present it causes the operation to be performed on the upper 64 bits of the registers holding the narrower elements, and is encoded in “Q”:

<table>
<thead>
<tr>
<th>Q</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>[absent]</td>
</tr>
<tr>
<td>1</td>
<td>[present]</td>
</tr>
</tbody>
</table>

<Vd> Is the name of the SIMD&FP destination register, encoded in the "Rd" field.

<Tb> Is an arrangement specifier, encoded in “size:Q”:

<table>
<thead>
<tr>
<th>size</th>
<th>Q</th>
<th>&lt;Tb&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>0</td>
<td>8B</td>
</tr>
<tr>
<td>00</td>
<td>1</td>
<td>16B</td>
</tr>
<tr>
<td>01</td>
<td>0</td>
<td>4H</td>
</tr>
<tr>
<td>01</td>
<td>1</td>
<td>8H</td>
</tr>
<tr>
<td>10</td>
<td>0</td>
<td>2S</td>
</tr>
<tr>
<td>10</td>
<td>1</td>
<td>4S</td>
</tr>
<tr>
<td>11</td>
<td>x</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>

<Vn> Is the name of the SIMD&FP source register, encoded in the "Rn" field.

<Ta> Is an arrangement specifier, encoded in “size”:

<table>
<thead>
<tr>
<th>size</th>
<th>&lt;Ta&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>8H</td>
</tr>
<tr>
<td>01</td>
<td>4S</td>
</tr>
<tr>
<td>10</td>
<td>2D</td>
</tr>
<tr>
<td>11</td>
<td>RESERVED</td>
</tr>
</tbody>
</table>
Operation

```c
CheckFPAdvSIMDEnabled64();
bits(2*datasize) operand = V[n];
bits(datasize) result;
bits(2*esize) element;

for e = 0 to elements-1
    element = Elem[operand, e, 2*esize];
    Elem[result, e, esize] = element<esize-1:0>;
Vpart[d, part] = result;
```

Operational information

If PSTATE.DIT is 1:

- The execution time of this instruction is independent of:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
- The response of this instruction to asynchronous exceptions does not vary based on:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
YIELD

YIELD is a hint instruction. Software with a multithreading capability can use a YIELD instruction to indicate to the PE that it is performing a task, for example a spin-lock, that could be swapped out to improve overall system performance. The PE can use this hint to suspend and resume multiple software threads if it supports the capability.

For more information about the recommended use of this instruction, see The YIELD instruction.

```c
System

YIELD

SystemHintOp op;

case CRm:op2 of
  when '0000 000' op = SystemHintOp_NOP;
  when '0000 001' op = SystemHintOp_YIELD;
  when '0000 010' op = SystemHintOp_WFE;
  when '0000 011' op = SystemHintOp_WFI;
  when '0000 100' op = SystemHintOp_SEV;
  when '0000 101' op = SystemHintOp_SEVL;
  when '0000 110' op = SystemHintOp_NOP;
  when '0000 111' op = SystemHintOp_NOP;
  when '0001 xxx' op = SystemHintOp_NOP;
  when '0010 000' op = SystemHintOp_ESE;
  when '0010 001' op = SystemHintOp_PSE;
  when '0010 010' op = SystemHintOp_TSE;
  when '0010 100' op = SystemHintOp_CSD;
  when '0011 xxx' op = SystemHintOp_BTI;
  when '0100 xx0' op = SystemHintOp_BTII;
  otherwise op = SystemHintOp_BTII;

BTypeCompatible = BTypeCompatible_BTII(op2<2:1>);

EndOfInstruction();
```

YIELD
case op of
  when SystemHintOp_YIELDHint_Yield();
  when SystemHintOp_WFE
    if IsEventRegisterSet() then
      ClearEventRegister();
    else
      if PSTATE.EL == EL0 then
        // Check for traps described by the OS which may be EL1 or EL2.
        AArch64.CheckForWFXTrap(EL1, TRUE);
      if EL2Enabled() && PSTATE.EL IN {EL0, EL1} && !IsInHost() then
        // Check for traps described by the Hypervisor.
        AArch64.CheckForWFXTrap(EL2, TRUE);
      if HaveEL(EL3) && PSTATE.EL != EL3 then
        // Check for traps described by the Secure Monitor.
        AArch64.CheckForWFXTrap(EL3, TRUE);
      WaitForEvent();
    when SystemHintOp_WFI
      if !InterruptPending() then
        if PSTATE.EL == EL0 then
          // Check for traps described by the OS which may be EL1 or EL2.
          AArch64.CheckForWFXTrap(EL1, FALSE);
        if EL2Enabled() && PSTATE.EL IN {EL0, EL1} && !IsInHost() then
          // Check for traps described by the Hypervisor.
          AArch64.CheckForWFXTrap(EL2, FALSE);
        if HaveEL(EL3) && PSTATE.EL != EL3 then
          // Check for traps described by the Secure Monitor.
          AArch64.CheckForWFXTrap(EL3, FALSE);
        WaitForInterrupt();
      when SystemHintOp_SEVSendEvent();
  when SystemHintOp_SEVLSendEventLocal();
  when SystemHintOp_ESBSynchronizeErrors();
    AArch64.ESBOperation();
    if EL2Enabled() && PSTATE.EL IN {EL0, EL1} then AArch64.vESBOperation();
    TakeUnmaskedErrorInterrupts();
  when SystemHintOp_PSBProfilingSynchronizationBarrier();
  when SystemHintOp_TSB
    TraceSynchronizationBarrier();
  when SystemHintOp_CSDBConsumeSpeculativeDataBarrier();
    when otherwise // do nothing SystemHintOp_BTI
      BTypeNext = '00';
  otherwise // do nothing


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ZIP1

Zip vectors (primary). This instruction reads adjacent vector elements from the upper half of two source SIMD&FP registers as pairs, interleaves the pairs and places them into a vector, and writes the vector to the destination SIMD&FP register. The first pair from the first source register is placed into the two lowest vector elements, with subsequent pairs taken alternately from each source register.

This instruction can be used with ZIP2 to interleave two vectors.

The following figure shows an example of the operation of ZIP1 and ZIP2 with the arrangement specifier 8B.

```
A 2
A 5
A 0
A 1
A 1
A 3
A 3
A 7
A 4
B 1
B 5
A 5
B 3
B 7
B 6
B 2
B 1
B 0
```

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

```
<table>
<thead>
<tr>
<th>31</th>
<th>30</th>
<th>29</th>
<th>28</th>
<th>27</th>
<th>26</th>
<th>25</th>
<th>24</th>
<th>23</th>
<th>22</th>
<th>21</th>
<th>20</th>
<th>19</th>
<th>18</th>
<th>17</th>
<th>16</th>
<th>15</th>
<th>14</th>
<th>13</th>
<th>12</th>
<th>11</th>
<th>10</th>
<th>9</th>
<th>8</th>
<th>7</th>
<th>6</th>
<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Q</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td></td>
<td>size</td>
<td>0</td>
<td>Rm</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td></td>
<td></td>
<td>Rd</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>op</td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>
```

Advanced SIMD

ZIP1 \(<\text{Vd}>.<\text{T}>, <\text{Vn}>.<\text{T}>, <\text{Vm}>.<\text{T}>\)

integer d = \text{UInt}(Rd);
integer n = \text{UInt}(Rn);
integer m = \text{UInt}(Rm);

\begin{verbatim}
if size:Q == '110' then UNDEFINED;
integer esize = 8 << if size:Q == '110' then \text{ReservedValue}(1);
integer esize = 8 << \text{UInt}(size);
integer datasize = if Q == '1' then 128 else 64;
integer elements = datasize DIV esize;
integer part = \text{UInt}(op);
integer pairs = elements DIV 2;
\end{verbatim}

Assembler Symbols

- \(<\text{Vd}>\) is the name of the SIMD&FP destination register, encoded in the "Rd" field.
- \(<\text{T}>\) is an arrangement specifier, encoded in “size:Q”:

```
| size | Q | <T>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>0</td>
<td>8B</td>
</tr>
<tr>
<td>00</td>
<td>1</td>
<td>16B</td>
</tr>
<tr>
<td>01</td>
<td>0</td>
<td>4H</td>
</tr>
<tr>
<td>01</td>
<td>1</td>
<td>8H</td>
</tr>
<tr>
<td>10</td>
<td>0</td>
<td>2S</td>
</tr>
<tr>
<td>10</td>
<td>1</td>
<td>4S</td>
</tr>
<tr>
<td>11</td>
<td>0</td>
<td>RESERVED</td>
</tr>
<tr>
<td>11</td>
<td>1</td>
<td>2D</td>
</tr>
</tbody>
</table>
```

- \(<\text{Vn}>\) is the name of the first SIMD&FP source register, encoded in the "Rn" field.
- \(<\text{Vm}>\) is the name of the second SIMD&FP source register, encoded in the "Rm" field.
Operation

```c
CheckFPAdvSIMDEnabled64();
bits(datosize) operand1 = \text{V}[n];
bits(datosize) operand2 = \text{V}[m];
bits(datosize) result;

integer base = part * pairs;

for p = 0 to pairs-1
    \text{Elem}[result, 2*p+0, esize] = \text{Elem}[operand1, base+p, esize];
    \text{Elem}[result, 2*p+1, esize] = \text{Elem}[operand2, base+p, esize];

\text{V}[d] = result;
```

Operational information

If PSTATE.DIT is 1:

- The execution time of this instruction is independent of:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
- The response of this instruction to asynchronous exceptions does not vary based on:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
ZIP2

Zip vectors (secondary). This instruction reads adjacent vector elements from the lower half of two source SIMD&FP registers as pairs, interleaves the pairs and places them into a vector, and writes the vector to the destination SIMD&FP register. The first pair from the first source register is placed into the two lowest vector elements, with subsequent pairs taken alternately from each source register.

This instruction can be used with ZIP1 to interleave two vectors.

The following figure shows an example of the operation of ZIP1 and ZIP2 with the arrangement specifier 8B.

Depending on the settings in the CPACR_EL1, CPTR_EL2, and CPTR_EL3 registers, and the current Security state and Exception level, an attempt to execute the instruction might be trapped.

Advanced SIMD

ZIP2 \texttt{<Vd>.<T>, <Vn>.<T>, <Vm>.<T>}

integer \( d = \text{UInt}(Rd); \)
integer \( n = \text{UInt}(Rn); \)
integer \( m = \text{UInt}(Rm); \)

\begin{verbatim}
if size:Q == '110' then UNDEFINED;
integer esize = 8 << if size:Q == '110' then ReservedValue(1);  
integer esize = 8 << \text{UInt}(size);  
integer datasize = if Q == '1' then 128 else 64;  
integer elements = datasize DIV esize;  
integer part = \text{UInt}(op);  
integer pairs = elements DIV 2;
\end{verbatim}

Assembler Symbols

\texttt{<Vd>} \hspace{1cm} Is the name of the SIMD&FP destination register, encoded in the "Rd" field.

\texttt{<T>} \hspace{1cm} Is an arrangement specifier, encoded in "size:Q":

\begin{center}
\begin{tabular}{ccc}
size & Q & \texttt{<T>} \\
00 & 0 & 8B \\
00 & 1 & 16B \\
01 & 0 & 4H \\
01 & 1 & 8H \\
10 & 0 & 2S \\
10 & 1 & 4S \\
11 & 0 & RESERVED \\
11 & 1 & 2D \\
\end{tabular}
\end{center}

\texttt{<Vn>} \hspace{1cm} Is the name of the first SIMD&FP source register, encoded in the "Rn" field.

\texttt{<Vm>} \hspace{1cm} Is the name of the second SIMD&FP source register, encoded in the "Rm" field.
Operation

```c
Operation

CheckFPAdvSIMDEnabled64();
bits(datasize) operand1 = V[n];
bits(datasize) operand2 = V[m];
bits(datasize) result;

integer base = part * pairs;

for p = 0 to pairs-1
    Elem[result, 2*p+0, esize] = Elem[operand1, base+p, esize];
    Elem[result, 2*p+1, esize] = Elem[operand2, base+p, esize];

V[d] = result;
```

Operational information

If PSTATE.DIT is 1:

- The execution time of this instruction is independent of:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
- The response of this instruction to asynchronous exceptions does not vary based on:
  - The values of the data supplied in any of its registers.
  - The values of the NZCV flags.
# Top-level encodings for A64

## Decode fields

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<tr>
<th>op0</th>
<th>Instruction details</th>
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<tbody>
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<td>UNALLOCATED Reserved</td>
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<tr>
<td>0001</td>
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</tr>
<tr>
<td>001x</td>
<td>Branches, Exception Generating and System instructions UNALLOCATED</td>
</tr>
<tr>
<td>100x</td>
<td>Data Processing -- Immediate Loads and Stores</td>
</tr>
<tr>
<td>101x</td>
<td>Branches, Exception Generating and System instructions Data Processing -- Register</td>
</tr>
<tr>
<td>x101</td>
<td>Loads and Stores Data Processing -- Scalar Floating-Point and Advanced SIMD</td>
</tr>
<tr>
<td>x111</td>
<td>Data Processing -- Scalar Floating-Point and Advanced SIMD</td>
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</tbody>
</table>

**Reserved**

These instructions are under the top-level.

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<th>op1</th>
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<td>UNALLOCATED</td>
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</table>

## Data Processing -- Immediate

These instructions are under the top-level.

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### PC-rel. addressing

These instructions are under Data Processing -- Immediate.

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<tr>
<td>1111</td>
<td>0x</td>
<td>Bitfield Extract</td>
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<tr>
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<td>Extract</td>
</tr>
</tbody>
</table>
Add/subtract (immediate, with tags)

These instructions are under Data Processing -- Immediate.

Add/subtract Logical (immediate)

These instructions are under Data Processing -- Immediate.

The following constraints also apply to this encoding: shift<1> != 1x && shift<1> != 1x

Top-level encodings for A64

<table>
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Add/subtract Logical (immediate)

These instructions are under Data Processing -- Immediate.

The following constraints also apply to this encoding: shift<1> != 1x && shift<1> != 1x

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<th>Rn</th>
<th>Rd</th>
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Top-level encodings for A64

### Logical Move wide (immediate)

These instructions are under **Data Processing -- Immediate**.

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### Move wide (immediate) Bitfield

These instructions are under **Data Processing -- Immediate**.

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### Bitfield Extract

These instructions are under **Data Processing -- Immediate**.

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These instructions are under **Data Processing -- Immediate**.
### Extract

These instructions are under **Data Processing -- Immediate**.

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### Branches, Exception Generating and System instructions

These instructions are under the **top-level**.

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```
Top-level encodings for A64

### Conditional branch (immediate)

These instructions are under **Branches, Exception Generating and System instructions**.

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#### Decode fields

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### Exception generation

These instructions are under **Branches, Exception Generating and System instructions**.

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#### Decode fields

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System register move

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Unconditional branch (register)

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These instructions are under Branches, Exception Generating and System instructions.
Compare and branch (immediate)

These instructions are under **Branches, Exception Generating and System instructions**.

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Loads and Stores

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**Advanced SIMD load/store multiple structures**

These instructions are under [Loads and Stores](#).
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### Advanced SIMD load/store multiple structures (post-indexed)

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### Advanced SIMD load/store single structure

These instructions are under [Loads and Stores](#).

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**Advanced SIMD load/store single structure (post-indexed)**

These instructions are under [Loads and Stores](#).

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LoadLDAPR/storeSTLR exclusive (unscaled-immediate)

These instructions are under Loads and Stores.

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These instructions are under Loads and Stores.

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**LoadLDAPR/storeSTLR exclusive (unscaled-immediate)**

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### Instruction Details

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Load/store no-allocate pair (offset)

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Load/store register pair (post-indexed)

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These instructions are under [Loads and Stores](#).

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### Load/store register (unscaled immediate)

These instructions are under [Loads and Stores](#).

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Top-level encodings for A64
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These instructions are under **Loads and Stores**.

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### Load/store register (unprivileged)

These instructions are under [Loads and Stores](#).

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### Load/store register (immediate pre-indexed)

These instructions are under [Loads and Stores](#).

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### Atomic memory operations

These instructions are under Loads and Stores.

### Top-level encodings for A64

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### Load/store register (register offset)

These instructions are under **Loads and Stores**.

#### Encoding

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### Summary

- **Load/store register (register offset)**
  - These instructions are under **Loads and Stores**.
  - The encoding table includes fields for `size`, `V`, `A`, `R`, `o3`, and `opc`.
  - The instruction details vary based on the values of these fields.

---

**Note:** The table entries and instructions are extracted from the document and formatted for readability. The document appears to be discussing detailed instructions and their encodings in the context of ARMv8.1 and ARMv8.3 architectures, focusing on load and store operations. The table includes specific instruction details and their corresponding architecture versions.
### Load/store register (pac)

These instructions are under [Loads and Stores](#).

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### Load/store register (unsigned immediate)

These instructions are under [Loads and Stores](#).

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### Data Processing -- Register

These instructions are under the **top-level**.

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<td>Rotate right into flags</td>
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### Data-processing (2 source)

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### Data-processing (1 source)

These instructions are under Data Processing -- Register.

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</table>

**Decoder fields**

- `sf` (Source Field): Determines the type of data being processed.
- `S` (Source Register): Identifies the source register.
- `opcode` (opcode): Represents the specific instruction.

**Instruction Details**

- `Rn` and `Rd` refer to the destination registers.
- Each instruction is categorized under specific architectures.

**Architectures**

- **ARMv8.5**: Instructions specific to ARMv8.5 architecture.

---

#### Top-level encodings for A64

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### Logical (shifted register)

These instructions are under Data Processing — Register.

<table>
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<tr>
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### Add/subtract (shifted register)

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### Add/subtract (extended register)

These instructions are under [Data Processing -- Register](#).

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### Add/subtract (with carry)

These instructions are under [Data Processing -- Register](#).

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### Rotate right into flags

These instructions are under [Data Processing -- Register](#).

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### Conditional compare (register)

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### Conditional compare (immediate)

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### Conditional select

These instructions are under Data Processing -- Register.

### Data-processing (3 source)

These instructions are under Data Processing -- Register.
### Instruction Details

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### Data Processing -- Scalar Floating-Point and Advanced SIMD

These instructions are under the top-level.

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Cryptographic AES

These instructions are under **Data Processing -- Scalar Floating-Point and Advanced SIMD**.

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Top-level encodings for A64
### Cryptographic three-register SHA

These instructions are under [Data Processing -- Scalar Floating-Point and Advanced SIMD](#).

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### Cryptographic two-register SHA

These instructions are under [Data Processing -- Scalar Floating-Point and Advanced SIMD](#).

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### Advanced SIMD scalar copy

These instructions are under [Data Processing -- Scalar Floating-Point and Advanced SIMD](#).

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Advanced SIMD scalar three same FP16

These instructions are under Data Processing -- Scalar Floating-Point and Advanced SIMD.

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Advanced SIMD scalar two-register miscellaneous FP16

These instructions are under Data Processing -- Scalar Floating-Point and Advanced SIMD.

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These instructions are under Data Processing -- Scalar Floating-Point and Advanced SIMD.

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## Advanced SIMD scalar three same

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**Advanced SIMD scalar shift by immediate**

These instructions are under [Data Processing -- Scalar Floating-Point and Advanced SIMD](#).
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**Advanced SIMD scalar x indexed element**

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These instructions are under Data Processing -- Scalar Floating-Point and Advanced SIMD.

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### Advanced SIMD permute

These instructions are under [Data Processing -- Scalar Floating-Point and Advanced SIMD](#).

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These instructions are under [Data Processing -- Scalar Floating-Point and Advanced SIMD](#).

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**Advanced SIMD three same (FP16)**

These instructions are under [Data Processing -- Scalar Floating-Point and Advanced SIMD](#).

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### Advanced SIMD two-register miscellaneous (FP16)

These instructions are under [Data Processing -- Scalar Floating-Point and Advanced SIMD](#).

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**Top-level encodings for A64**
Advanced SIMD three same extra

These instructions are under Data Processing -- Scalar Floating-Point and Advanced SIMD.

Advanced SIMD two-register miscellaneous

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Top-level encodings for A64
### Advanced SIMD across lanes

These instructions are under [Data Processing -- Scalar Floating-Point and Advanced SIMD](#).

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### Advanced SIMD three different

These instructions are under [Data Processing -- Scalar Floating-Point and Advanced SIMD](#).
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### Advanced SIMD three same

These instructions are under [Data Processing -- Scalar Floating-Point and Advanced SIMD](#).

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### Advanced SIMD modified immediate

These instructions are under Data Processing -- Scalar Floating-Point and Advanced SIMD.
### Advanced SIMD shift by immediate

These instructions are under Data Processing -- Scalar Floating-Point and Advanced SIMD.

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Advanced SIMD shift by immediate

These instructions are under Data Processing -- Scalar Floating-Point and Advanced SIMD.

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Advanded SIMD vector x indexed element

These instructions are under Data Processing -- Scalar Floating-Point and Advanced SIMD.
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Cryptographic three-register, imm2

These instructions are under Data Processing -- Scalar Floating-Point and Advanced SIMD.
Cryptographic three-register SHA 512

These instructions are under Data Processing -- Scalar Floating-Point and Advanced SIMD.

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Cryptographic four-register

These instructions are under Data Processing -- Scalar Floating-Point and Advanced SIMD.

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Cryptographic two-register SHA 512

These instructions are under Data Processing -- Scalar Floating-Point and Advanced SIMD.

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Conversion between floating-point and fixed-point

These instructions are under Data Processing -- Scalar Floating-Point and Advanced SIMD.

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### Conversion between floating-point and integer

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These instructions are under Data Processing -- Scalar Floating-Point and Advanced SIMD.

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Floating-point compare
### Floating-point immediate

These instructions are under Data Processing -- Scalar Floating-Point and Advanced SIMD.

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### Floating-point conditional compare

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**Top-level encodings for A64**
### Floating-point data-processing (2 source)

These instructions are under Data Processing -- Scalar Floating-Point and Advanced SIMD.

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### Floating-point conditional select

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### Floating-point data-processing (3 source)

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Shared Pseudocode Functions

This page displays common pseudocode functions shared by many pages.

Pseudocodes

Library pseudocode for aarch32/debug/VCRMatch/AArch32.VCRMatch

```c
// AArch32.VCRMatch()
// ==================

boolean AArch32.VCRMatch(bits(32) vaddress)

    if UsingAAArch32() && ELUsingAAArch32(EL1) && IsZero(vaddress<1:0>) && PSTATE.EL != EL2 then
        // Each bit position in this string corresponds to a bit in DBGVCR and an exception vector.
        match_word = Zeros(32);
    
    if vaddress<31:5> == ExcVectorBase()<31:5> then
        if HaveEL(EL3) && !IsSecure() then
            match_word<UInt(vaddress<4:2>) + 24> = '1';     // Non-secure vectors
        else
            match_word<UInt(vaddress<4:2>) + 0> = '1';      // Secure vectors (or no EL3)
    
    if HaveEL(EL3) && ELUsingAAArch32(EL3) && IsSecure() && vaddress<31:5> == MVBAR<31:5> then
        match_word<UInt(vaddress<4:2>) + 8> = '1';          // Monitor vectors
    
    // Mask out bits not corresponding to vectors.
    if !HaveEL(EL3) then
        mask = '00000000':'00000000':'00000000':'11011110'; // DBGVCR[31:8] are RES0
    elsif !ELUsingAAArch32(EL3) then
        mask = '11011110':'00000000':'00000000':'11011110'; // DBGVCR[15:8] are RES0
    else
        mask = '11011110':'00000000':'11011100':'11011110';
    
    match_word = match_word AND DBGVCR AND mask;
    match = !IsZero(match_word);

    // Check for UNPREDICTABLE case - match on Prefetch Abort and Data Abort vectors
    if !IsZero(match_word<28:27,12:11,4:3>) && DebugTarget() == PSTATE.EL then
        match = ConstrainUnpredictableBool(Unpredictable_VCMATCHDAPA);
    else
        match = FALSE;
    return match;
```

Library pseudocode for aarch32/debug/authentication/AArch32.SelfHostedSecurePrivilegedInvasiveDebugEnabled

```c
// AArch32.SelfHostedSecurePrivilegedInvasiveDebugEnabled()
// ========================================================

boolean AArch32.SelfHostedSecurePrivilegedInvasiveDebugEnabled()

    // The definition of this function is IMPLEMENTATION DEFINED.
    // In the recommended interface, AArch32.SelfHostedSecurePrivilegedInvasiveDebugEnabled returns
    // the state of the (DBGEN AND SPIDEN) signal.
    if HaveEL(EL3) && !IsSecure() then return FALSE;
    return DBGEN == HIGH && SPIDEN == HIGH;
```
Library pseudocode for aarch32/debug/breakpoint/AArch32.BreakpointMatch

```c
// AArch32.BreakpointMatch()
// -------------------------------------------------------------------
// Breakpoint matching in an AArch32 translation regime.

(boolean,boolean) AArch32.BreakpointMatch(integer n, bits(32) vaddress, integer size)

    assert ELUsingAArch32(S1TranslationRegime());
    assert n <= UInt(DBGDIDR.BRPs);
    assert vaddress <= UInt(EL0);
    assert vaddress >= UInt(EL0);
    enabled = DBGBCR[n].E == '1';
    ispriv = PSTATE.EL != EL0;
    linked = DBGBCR[n].BT == '0x01';
    isbreakpnt = TRUE;
    linked_to = FALSE;

    state_match = AArch32.StateMatch(DBGBCR[n].SSC, DBGBCR[n].HMC, DBGBCR[n].PMC,
                         linked, DBGBCR[n].LBN, isbreakpnt, ispriv);
    (value_match, value_mismatch) = AArch32.BreakpointValueMatch(n, vaddress, linked_to);

    if size == 4 then
        // Check second halfword
        // If the breakpoint address and BAS of an Address breakpoint match the address of the
        // second halfword of an instruction, but not the address of the first halfword, it is
        // CONSTRAINED UNPREDICTABLE whether or not this breakpoint generates a Breakpoint debug
        // event.
        (match_i, mismatch_i) = AArch32.BreakpointValueMatch(n, vaddress + 2, linked_to);
        if !value_match && match_i then
            value_match = ConstrainUnpredictableBool(Unpredictable_BPMATCHHALF);
        if value_mismatch && !mismatch_i then
            value_mismatch = ConstrainUnpredictableBool(Unpredictable_BPMISMATCHHALF);

    if vaddress<> == '1' && DBGBCR[n].BAS == '1111' then
        // The above notwithstanding, if DBGBCR[n].BAS == '1111', then it is CONSTRAINED
        // UNPREDICTABLE whether or not a Breakpoint debug event is generated for an instruction
        // at the address DBGVR[n]+2.
        if !value_match then value_match = ConstrainUnpredictableBool(Unpredictable_BPMATCHHALF);
        if !value_mismatch then value_mismatch = ConstrainUnpredictableBool(Unpredictable_BPMISMATCHHALF);

    match = value_match && state_match && enabled;
    mismatch = value_mismatch && state_match && enabled;

    return (match, mismatch);
```

Shared Pseudocode Functions
AArch32.BreakpointValueMatch()

The first result is whether an Address Match or Context breakpoint is programmed on the
instruction at "address". The second result is whether an Address Mismatch breakpoint is
programmed on the instruction, that is, whether the instruction should be stepped.

(boolean, boolean) AArch32.BreakpointValueMatch(integer n, bits(32) vaddress, boolean linked_to)

"n" is the identity of the breakpoint unit to match against.
"vaddress" is the current instruction address, ignored if linked_to is TRUE and for Context
matching breakpoints.
"linked_to" is TRUE if this is a call from StateMatch for linking.

If a non-existent breakpoint then it is CONSTRAINED UNPREDICTABLE whether this gives
no match or the breakpoint is mapped to another UNKNOWN implemented breakpoint.

if n > UInt(DBGDIDR.BRPs) then
  (c, n) = ConstrainUnpredictableInteger(0, UInt(DBGDIDR.BRPs), Unpredictable_BPNOTIMPL);
  assert c IN {Constraint_DISABLED, Constraint_UNKNOWN};
  if c == Constraint_DISABLED then return (FALSE, FALSE);

If this breakpoint is not enabled, it cannot generate a match. (This could also happen on a
call from StateMatch for linking).

if DBGBCR[n].E == '0' then return (FALSE, FALSE);

context_aware = (n >= UInt(DBGDIDR.BRPs) - UInt(DBGDIDR.CTX_CMPs));

If BT is set to a reserved type, behaves either as disabled or as a not-reserved type.
type = DBGBCR[n].BT;

if ((type IN {'011x', '11xx'}) && !HaveVirtHostExt()) ||
    (type == '010x' && HaltonBreakpointOrWatchpoint()) ||
    (type != '0x0x' && !context_aware) ||
    (type == '1xxx' && !HaveEL(EL2)) then
  (c, type) = ConstrainUnpredictableBits(Unpredictable_RESBPTYPE);
  assert c IN {Constraint_DISABLED, Constraint_UNKNOWN};
  if c == Constraint_DISABLED then return (FALSE, FALSE);
// Otherwise the value returned by ConstrainUnpredictableBits must be a not-reserved value

// Determine what to compare against.
match_addr = (type == '0x0x');
mismatch = (type == '010x');
match_vmid = (type == '10xx');
match_cid1 = (type == 'xx1x');
match_cid2 = (type == '11xx');
linked = (type == 'xxx1');

// If this is a call from StateMatch, return FALSE if the breakpoint is not programmed for a
// VMID and/or context ID match, of if not context-aware. The above assertions mean that the
// code can just test for match_addr == TRUE to confirm all these things.
if linked_to && (!linked || match_addr) then return (FALSE, FALSE);

// If called from BreakpointMatch return FALSE for Linked context ID and/or VMID matches.
if !linked_to && linked && !match_addr then return (FALSE, FALSE);

// Do the comparison.
if match_addr then
  byte = UInt(vaddress<1:0>);
  assert byte IN {0, 2}; // "vaddress" is halfword aligned
  byte_select_match = (DBGBCR[n].BAS<byte> == '1')
  BVR_match = vaddress<31:2> == DBGBVR[n]<31:2> && byte_select_match;
elsif match_cid1 then
  BVR_match = (PSTATE.EL != EL2 && CONTEXTIDR == DBGBVR[n]<31:0>);
if match_vmid then
  if ELUsingAArch32(EL2) then
    vmid = ZeroExtend(VTTBR.VMID, 16);
    bvr_vmid = ZeroExtend(DBGBXVR[n]<7:0>, 16);
  elsif !Have16bitVMID() || VTCR_EL2.VS == '0' then
    vmid = ZeroExtend(VTTBR_EL2.VMID<7:0>, 16);
    bvr_vmid = ZeroExtend(DBGBXVR[n]<7:0>, 16);
  else

Shared Pseudocode Functions
vmid = VTTBR_EL2.VMID;
bvr_vmid = DBGBXVR[n]<15:0>;
BXVR_match = (EL2Enabled() && PSTATE.EL IN {EL0,EL1} && vmid == bvr_vmid);
elsif match_cid2 then
  BXVR_match = (!IsSecure() && HaveVirtHostExt() &&
                 !ELUsingAArch32(EL2) &&
                 DBGBXVR[n]<31:0> == CONTEXTIDR_EL2);

bvr_match_valid = (match_addr || match_cid1);
bxvr_match_valid = (match_vmid || match_cid2);

match = (!bxvr_match_valid || BXVR_match) && (!bvr_match_valid || BVR_match);
return (match && !mismatch, !match && mismatch);
boolean AArch32.StateMatch(bits(2) SSC, bit HMC, bits(2) PxC, boolean linked, bits(4) LBN, 
    boolean isbreakpnt, boolean ispriv)
    // "SSC", "HMC", "PxC" are the control fields from the DBGBCR[n] or DBGWCR[n] register.
    // "linked" is TRUE if this is a linked breakpoint/watchpoint type.
    // "LBN" is the linked breakpoint number from the DBGBCR[n] or DBGWCR[n] register.
    // "isbreakpnt" is TRUE for breakpoints, FALSE for watchpoints.
    // "ispriv" is valid for watchpoints, and selects between privileged and unprivileged accesses.
    if ((HMC:SSC:PxC) IN {'011xx','100x0','101x0','11010','11101','1111x'}) ||       // Reserved
        (HMC == '0' && PxC == '00' && !isbreakpnt) ||                             // Usr/Svc/Sys
        (SSC IN {'01','10'} && !HaveEL(EL3)) ||                                  // No EL3
        (HMC:SSC:PxC == '11000' && ELUsingAArch32(EL3)) ||                        // AArch64 only
        (HMC:SSC != '000' && HMC:SSC != '111' && !HaveEL(EL3) && !HaveEL(EL2)) || // No EL3/EL2
        (HMC:SSC:PxC == '11100' && !HaveEL(EL2))) then                            // No EL2
            (c, <HMC,SSC,PxC>) = ConstrainUnpredictableBits(Unpredictable_RESBPWPCTRL);
            assert c IN {Constraint_DISABLED, Constraint_UNKNOWN};
            if c == Constraint_DISABLED then return FALSE;
    // Otherwise the value returned by ConstrainUnpredictableBits must be a not-reserved value
    PL2_match = HaveEL(EL2) && HMC == '1';
    PL1_match = PxC<0> == '1';
    PL0_match = PxC<1> == '1';
    SSU_match = isbreakpnt && HMC == '0' && PxC == '00' && SSC != '11';
    el = PSTATE.EL;
    if !ispriv && !isbreakpnt then
        priv_match = PL0_match;
    elsif SSU_match then
        priv_match = PSTATE.M IN {M32_User,M32_Svc,M32_System};
    else
        case el of
            when EL3 priv_match = PL1_match; // EL3 and EL1 are both PL1
            when EL2 priv_match = PL2_match;
            when EL1 priv_match = PL1_match;
            when EL0 priv_match = PL0_match;
        case SSC of
            when '00' security_state_match = TRUE; // Both
            when '01' security_state_match = !IsSecure(); // Non-secure only
            when '10' security_state_match = IsSecure(); // Secure only
            when '11' security_state_match = TRUE; // Both
        if linked then
            // "LBN" must be an enabled context-aware breakpoint unit. If it is not context-aware then
            // it is CONSTRAINED UNPREDICTABLE whether this gives no match, or LBN is mapped to some
            // UNKNOWN breakpoint that is context-aware.
            bn = UInt(LBN);
            first_ctx_cmp = (UInt(DBGDIDR.BRPs) - UInt(DBGDIDR.CTX_CMPs));
            last_ctx_cmp = UInt(DBGDIDR.BRPs);
            if (bn < first_ctx_cmp || bn > last_ctx_cmp) then
                (c, bn) = ConstrainUnpredictableInteger(first_ctx_cmp, last_ctx_cmp, Unpredictable_BPNOTCTX);
                assert c IN {Constraint_DISABLED, Constraint_NONE, Constraint_UNKNOWN};
                case c of
                    when Constraint_DISABLED return FALSE; // Disabled
                    when Constraint_NONE linked = FALSE; // No linking
                    // Otherwise ConstrainUnpredictableInteger returned a context-aware breakpoint
                    if linked then
                        vaddress = bits(32) UNKNOWN;
                        linked_to = TRUE;
                        (linked_match,) = AArch32.BreakpointValueMatch(bn, vaddress, linked_to);
                    return priv_match && security_state_match && (!linked || linked_match);
Library pseudocode for aarch32/debug/enables/AArch32.GenerateDebugExceptions

```java
// AArch32.GenerateDebugExceptions()
// ---------------------------------

boolean AArch32.GenerateDebugExceptions()
    return AArch32.GenerateDebugExceptionsFrom(PSTATE_EL, IsSecure());
```

Library pseudocode for aarch32/debug/enables/AArch32.GenerateDebugExceptionsFrom

```java
// AArch32.GenerateDebugExceptionsFrom()
// -----------------------------------

boolean AArch32.GenerateDebugExceptionsFrom(bits(2) from, boolean secure)
    if from == EL0 && !ELStateUsingAArch32(EL1, secure) then
        mask = bit UNKNOWN;  // PSTATE.D mask, unused for EL0 case
        return AArch64.GenerateDebugExceptionsFrom(from, secure, mask);
    if DBGOSLSR.OSLK == '1' || DoubleLockStatus() || Halted() then
        return FALSE;
    if HaveEL(EL3) && secure then
        spd = if PLJustUsingAArch32(EL3) then SDCR.SPD else MDCR_EL3.SPD32;
        if spd<1> == '1' then
            enabled = spd<0> == '1';
        else
            enabled = from != EL2;
        return enabled;
```

Library pseudocode for aarch32/debug/pmu/AArch32.CheckForPMUOverflow

```java
// AArch32.CheckForPMUOverflow()
// -----------------------------
// Signal Performance Monitors overflow IRQ and CTI overflow events

boolean AArch32.CheckForPMUOverflow()
    if !ELStateUsingAArch32(EL1) then return AArch64.CheckForPMUOverflow();
    pmuirq = PMCR.E == '1' && PMINTENSET<31> == '1' && PMOVSSET<31> == '1';
    for n = 0 to Uint(PMCR.N) - 1
        if HaveEL(EL2) then
            hpnn = if !ELUsingAArch32(EL2) then MDCR_EL2.HPNN else HDCR.HPNN;
            hpme = if !ELUsingAArch32(EL2) then MDCR_EL2.HPME else HDCR.HPME;
            E = (if n < Uint(hpnn) then PMCR.E else hpme);
        else
            E = PMCR.E;
        if E == '1' && PMINTENSET<n> == '1' && PMOVSSET<n> == '1' then pmuirq = TRUE;
        SetInterruptRequestLevel(InterruptID_PMUIRQ, if pmuirq then HIGH else LOW);
        CTI_SetEventLevel(CrossTriggerIn_PMUOverflow, if pmuirq then HIGH else LOW);
    return pmuirq;
```
// AArch32.CountEvents()
// -------------------
// Return TRUE if counter "n" should count its event. For the cycle counter, n == 31.

boolean AArch32.CountEvents(integer n)
assert n == 31 || n < UInt(PMCR.N);

if !ELUsingAArch32(EL1) then return AArch64.CountEvents(n);
// Event counting is disabled in Debug state
debug = Halted();

// In Non-secure state, some counters are reserved for EL2
if HaveEL(EL2) then
    hpmn = if !ELUsingAArch32(EL2) then MDCR_EL2.HPMN else HDCR.HPMN;
    hpme = if !ELUsingAArch32(EL2) then MDCR_EL2.HPME else HDCR.HPME;
    E = if n < UInt(hpmn) || n == 31 then PMCR.E else hpme;
else
    E = PMCR.E;
enabled = E == '1' && PMCNTENSET<n> == '1';

if !IsSecure() then
    // Event counting in Non-secure state is allowed unless all of:
    // * EL2 and the HPMD Extension are implemented
    // * Executing at EL2
    // * PMN<27> is not reserved for EL2
    // * HDCR.HPMD == 1
    if HaveHPMDExt() && PSTATE.EL == EL2 && (n < UInt(hpmn) || n == 31) then
        prohibited = if !ELUsingAArch32(EL2) then MDCR_EL2.HPMD else HDCR.HPMD;
        prohibited = (prohibited == '1');
    else
        prohibited = FALSE;
else
    // Event counting in Secure state is prohibited unless any one of:
    // * EL3 is not implemented
    // * EL3 is using AArch64 and MDCR_EL3.SPME == 1
    // * EL3 is using AArch32 and SDCR.SPME == 1
    // * Executing at EL0, and SDER.SUNIDEN == 1.
    spme = (if ELUsingAArch32(EL3) then SDCR.SPME else MDCR_EL3.SPME);
    prohibited = HaveEL(EL3) && spme == '0' && (PSTATE.EL != EL0 || SDER.SUNIDEN == '0');

    // The IMPLEMENTATION DEFINED authentication interface might override software controls
    if prohibited && !HaveNoSecurePMUDisableOverride() then
        prohibited = !ExternalSecureNoninvasiveDebugEnabled();

    // For the cycle counter, PMCR.DP enables counting when otherwise prohibited
    if prohibited && n == 31 then prohibited = (PMCR.DP == '1');

    // Event counting can be filtered by the {P, U, NSK, NSU, NSH} bits
    filter = if n == 31 then PMCCFILTR else PMEVTYPER[n];

    P = filter<31>;
    U = filter<30>;
    NSK = if HaveEL(EL3) then filter<29> else '0';
    NSU = if HaveEL(EL3) then filter<28> else '0';
    NSH = if HaveEL(EL2) then filter<27> else '0';

    case PSTATE.EL of
        when EL0 filtered = if IsSecure() then U == '1' else U != NSU;
        when EL1 filtered = if IsSecure() then P == '1' else P != NSK;
        when EL2 filtered = (NSH == '0');
        when EL3 filtered = (P == '1');

    return !debug && enabled && !prohibited && !filtered;
// AArch32.EnterHypModeInDebugState()
// -----------------------------------
// Take an exception in Debug state to Hyp mode.
AArch32.EnterHypModeInDebugState(ExceptionRecord exception)
    SynchronizeContext();
    assert HaveEL(EL2) & !IsSecure() & ELUsingAArch32(EL2);
AArch32.ReportHypEntry(exception);
AArch32.WriteMode(M32_Hyp);
SPSR[] = bits(32) UNKNOWN;
if ELR_hyp = bits(32) UNKNOWN;
    // In Debug state, the PE always execute T32 instructions when in AArch32 state, and
    // PSTATE.(SS,A,I,F) are not observable so behave as UNKNOWN.
    PSTATE.T = '1';                           // PSTATE.J is RES0
    PSTATE.<SS,A,I,F> = bits(4) UNKNOWN;
    DLR = bits(32) UNKNOWN;
    DSPSR = bits(32) UNKNOWN;
    PSTATE.E = HSCTRL.EE;
    PSTATE.IL = '0';
    PSTATE.IT = '00000000';
    EDSR.ERR = '1';
    HaveSSBSExt() then PSTATE.SSBS = bits(1) UNKNOWN;
    ELR_hyp = bits(32) UNKNOWN;
    // In Debug state, the PE always execute T32 instructions when in AArch32 state, and
    // PSTATE.(SS,A,I,F) are not observable so behave as UNKNOWN.
    PSTATE.T = '1';                           // PSTATE.J is RES0
    PSTATE.<SS,A,I,F> = bits(4) UNKNOWN;
    DLR = bits(32) UNKNOWN;
    DSPSR = bits(32) UNKNOWN;
    PSTATE.E = HSCTRL.EE;
    PSTATE.IL = '0';
    PSTATE.IT = '00000000';
    EDSR.ERR = '1';
    UpdateEDSCRFields();
EndOfInstruction();

// AArch32.EnterModeInDebugState()
// ----------------------------------
// Take an exception in Debug state to a mode other than Monitor and Hyp mode.
AArch32.EnterModeInDebugState(bits(5) target_mode)
    SynchronizeContext();
    assert ELUsingAArch32(EL1) & PSTATE.EL != EL2;
if PSTATE.M == M32_Monitor then SCR.NS = '0';
AArch32.WriteMode(target_mode);
SPSR[] = bits(32) UNKNOWN;
if R[14] = bits(32) UNKNOWN; HaveSSBSExt() then PSTATE.SSBS = bits(1) UNKNOWN;
R[14] = bits(32) UNKNOWN;
// In Debug state, the PE always execute T32 instructions when in AArch32 state, and
// PSTATE.(SS,A,I,F) are not observable so behave as UNKNOWN.
    PSTATE.T = '1';                           // PSTATE.J is RES0
    PSTATE.<SS,A,I,F> = bits(4) UNKNOWN;
    DLR = bits(32) UNKNOWN;
    DSPSR = bits(32) UNKNOWN;
    PSTATE.E = SCTLR.EE;
    PSTATE.IL = '0';
    PSTATE.IT = '00000000';
    if HavePANExt() && SCTLR.SPAN == '0' then
        PSTATE.PAN = '1';
        EDSR.ERR = '1';
        UpdateEDSCRFields();
    // Update EDSCR processor state flags.
EndOfInstruction();
// AArch32.EnterMonitorModeInDebugState()
// ---------------------------------------------------
// Take an exception in Debug state to Monitor mode.

AArch32.EnterMonitorModeInDebugState()
    SynchronizeContext();
    assert HaveEL(EL3) && ELUsingAArch32(EL3);
    from_secure = IsSecure();
    if PSTATE.M == M32_Monitor then SCR.NS = '0';
    AArch32.WriteMode(M32_Monitor);
    SPSR[] = bits(32) UNKNOWN;
    if[] = bits(32) UNKNOWN; HaveSSBSExt() then PSTATE.SSBS = bits(1) UNKNOWN;
    R[14] = bits(32) UNKNOWN;
    // In Debug state, the PE always execute T32 instructions when in AArch32 state, and
    // PSTATE.(SS,A,I,F) are not observable so behave as UNKNOWN.
    PSTATE.T = '1';                             // PSTATE.J is RES0
    PSTATE.<SS,A,I,F> = bits(4) UNKNOWN;
    DLR = bits(32) UNKNOWN;
    DSPSR = bits(32) UNKNOWN;
    PSTATE.E = SCTLR.EE;
    PSTATE.IL = '0';
    PSTATE.IT = '00000000';
    if HavePANExt() then
        if !from_secure then
            PSTATE.PAN = '0';
            elsif SCTLR.SPAN == '0' then
                PSTATE.PAN = '1';
        EDSCR.ERR = '1';
        UpdateEDSCRFields();
    // Update EDSCR processor state flags.
    EndOfInstruction();
// AArch32.WatchpointByteMatch()
// -----------------------------------

boolean AArch32.WatchpointByteMatch(integer n, bits(32) vaddress)
bottom = if DBGWVR[n][<2] == '1' then 2 else 3; // Word or doubleword
byte_select_match = (DBGWCR[n].BAS<UInt>(vaddress<bottom-1:0>) != '0');
mask = UInt(DBGWCR[n].MASK);

// If DBGWCR[n].MASK is non-zero value and DBGWCR[n].BAS is not set to '1111111', or
// DBGWCR[n].BAS specifies a non-contiguous set of bytes behavior is CONSTRAINED
// UNPREDICTABLE.
if mask > 0 && !IsOnes(DBGWCR[n].BAS) then
    byte_select_match = ConstrainUnpredictableBool(Unpredictable_WPMASKANDBAS);
else
    LSB = (DBGWCR[n].BAS AND NOT(DBGWCR[n].BAS - 1));  MSB = (DBGWCR[n].BAS + LSB);
    if !IsZero(MSB AND (MSB - 1)) then // Not contiguous
        byte_select_match = ConstrainUnpredictableBool(Unpredictable_WPBASCONTIGUOUS);
        bottom = 3; // For the whole doubleword
    // If the address mask is set to a reserved value, the behavior is CONSTRAINED UNPREDICTABLE.
    if mask > 0 && mask <= 2 then
        (c, mask) = ConstrainUnpredictableInteger(3, 31, Unpredictable_RESWPMASK);
        assert c IN {Constraint_DISABLED, Constraint_NONE, Constraint_UNKNOWN};
        case c of
            when Constraint_DISABLED return FALSE; // Disabled
            when Constraint_NONE mask = 0; // No masking
            // Otherwise the value returned by ConstrainUnpredictableInteger is a not-reserved value
        end case
        if mask > bottom then
            WVR_match = (vaddress<31:mask> == DBGWVR[n]<31:mask>);
            // If masked bits of DBGWVR_EL1[n] are not zero, the behavior is CONSTRAINED UNPREDICTABLE.
            if WVR_match && !IsZero(DBGWVR[n]<mask-1:bottom>) then
                WVR_match = ConstrainUnpredictableBool(Unpredictable_WPMASKEDBITS);
            else
                WVR_match = vaddress<31:bottom> == DBGWVR[n]<31:bottom>;
            end if
        return WVR_match && byte_select_match;

Library pseudocode for aarch32/debug/watchpoint/AArch32.WatchpointMatch

// AArch32.WatchpointMatch()
// -------------------------
// Watchpoint matching in an AArch32 translation regime.

boolean AArch32.WatchpointMatch(integer n, bits(32) vaddress, integer size, boolean ispriv, boolean iswrite)
assert ELUsingAArch32(S1TranslationRegime());
assert n <= UInt(DBGDIDR.WRPs);

assert "ispriv" is FALSE for LDRT/STRT instructions executed at EL1 and all
// load/stores at EL0, TRUE for all other load/stores. "iswrite" is TRUE for stores, FALSE for
// loads.
enabled = DBGWCR[n].E == '1';
linked = DBGWCR[n].WT == '1';
isbreakpnt = FALSE;

state_match = AArch32.StateMatch(DBGWCR[n].SSC, DBGWCR[n].HMC, DBGWCR[n].PAC,
                                  linked, DBGWCR[n].LBN, isbreakpnt, ispriv);
ls_match = (DBGWCR[n].LSC<((if iswrite then 1 else 0))> == '1');
value_match = FALSE;
for byte = 0 to size - 1
    value_match = value_match || AArch32.WatchpointByteMatch(n, vaddress + byte);
return value_match && state_match && ls_match && enabled;
Library pseudocode for aarch32/exceptions/aborts/AArch32.Abort

// AArch32.Abort()
// ===============
// Abort and Debug exception handling in an AArch32 translation regime.

AArch32.Abort(bits(32) vaddress, FaultRecord fault)

    // Check if routed to AArch64 state
    route_to_aarch64 = PSTATE.EL == EL0 && !ELUsingAArch32(EL1);

    if !route_to_aarch64 && ELUsingAArch32(EL2) then
        route_to_aarch64 = (HCR_EL2.TGE == '1' || IsSecondStage(fault) ||
            (HaveRASExt() && HCR2.TEA == '1' && IsExternalAbort(fault)) ||
            (IsDebugException(fault) && MDCR_EL2.TDE == '1'));

    if !route_to_aarch64 && ELUsingAArch32(EL3) then
        route_to_aarch64 = SCR_EL3.EA == '1' && IsExternalAbort(fault);

    if route_to_aarch64 then
        AArch64.Abort(ZeroExtend(vaddress), fault);
    elsif fault.acctype == AccType_IFETCH then
        AArch32.TakePrefetchAbortException(vaddress, fault);
    else
        AArch32.TakeDataAbortException(vaddress, fault);

Library pseudocode for aarch32/exceptions/aborts/AArch32.AbortSyndrome

// AArch32.AbortSyndrome()
// =======================
// Creates an exception syndrome record for Abort exceptions taken to Hyp mode
// from an AArch32 translation regime.

ExceptionRecord AArch32.AbortSyndrome(Exception type, FaultRecord fault, bits(32) vaddress)

    exception = ExceptionSyndrome(type);
    d_side = type == Exception_DataAbort;

    exception.syndrome = AArch32.FaultSyndrome(d_side, fault);
    exception.vaddress = ZeroExtend(vaddress);
    if IPAValid(fault) then
        exception.ipavalid = TRUE;
        exception.NS = fault.ipaddress.NS;
        exception.ipaddress = ZeroExtend(fault.ipaddress.address);
    else
        exception.ipavalid = FALSE;
    return exception;

Library pseudocode for aarch32/exceptions/aborts/AArch32.CheckPCAlignment

// AArch32.CheckPCAlignment()
// ==========================

AArch32.CheckPCAlignment()

    bits(32) pc = ThisInstrAddr();
    if (CurrentInstrSet() == InstrSet_A32 && pc<<1> == '1') || pc<<0> == '1' then
        if AArch32.GeneralExceptionsToAArch64() then AArch64.PCAlignmentFault();

        // Generate an Alignment fault Prefetch Abort exception
        vaddress = pc;
        acctype = AccType_IFETCH;
        iswrite = FALSE;
        secondstage = FALSE;
        AArch32.Abort(vaddress, AArch32.AlignmentFault(acctype, iswrite, secondstage));
// AArch32.ReportDataAbort()
// ----------------------------------------
// Report syndrome information for aborts taken to modes other than Hyp mode.
AArch32.ReportDataAbort(boolean route_to_monitor, FaultRecord fault, bits(32) vaddress)

// The encoding used in the IFSR or DFSR can be Long-descriptor format or Short-descriptor format. Normally, the current translation table format determines the format. For an abort from Non-secure state to Monitor mode, the IFSR or DFSR uses the Long-descriptor format if any of the following applies:
//  * The Secure TTBCR.EAE is set to 1.
//  * The abort is synchronous and either:
//    - It is taken from Hyp mode.
//    - It is taken from EL1 or EL0, and the Non-secure TTBCR.EAE is set to 1.

long_format = FALSE;
if route_to_monitor && !IsSecure() then
    long_format = TTBCR_S.EAE == '1';
else
    long_format = TTBCR.EAE == '1';
d_side = TRUE;
if long_format then
    syndrome = AArch32.FaultStatusLD(d_side, fault);
else
    syndrome = AArch32.FaultStatusSD(d_side, fault);
if fault.acctype == AccType_IC then
    if (!long_format && boolean IMPLEMENTATION_DEFINED "Report I-cache maintenance fault in IFSR") then
        i_syndrome = syndrome;
        syndrome<10,3:0> = EncodeSDFSC(Fault_ICacheMaint, 1);
    else
        i_syndrome = bits(32) UNKNOWN;
    if route_to_monitor then
        IFSR_S = i_syndrome;
    else
        IFSR = i_syndrome;
    if route_to_monitor then
        DFSR_S = syndrome;
        DFAR_S = vaddress;
    else
        DFSR = syndrome;
        DFAR = vaddress;
return;
Library pseudocode for aarch32/exceptions/aborts/AArch32.ReportPrefetchAbort

```c
// AArch32.ReportPrefetchAbort()
// =============================
// Report syndrome information for aborts taken to modes other than Hyp mode.

AArch32.ReportPrefetchAbort(boolean route_to_monitor, FaultRecord fault, bits(32) vaddress)
// The encoding used in the IFSR can be Long-descriptor format or Short-descriptor format.
// Normally, the current translation table format determines the format. For an abort from
// Non-secure state to Monitor mode, the IFSR uses the Long-descriptor format if any of the
// following applies:
// * The Secure TTBCR.EAE is set to 1.
// * It is taken from Hyp mode.
// * It is taken from EL1 or EL0, and the Non-secure TTBCR.EAE is set to 1.
long_format = FALSE;
if route_to_monitor && !IsSecure() then
  long_format = TTBCR_S.EAE == '1' || PSTATE.EL == EL2 || TTBCR.EAE == '1';
else
  long_format = TTBCR.EAE == '1';

d_side = FALSE;
if long_format then
  fsr = AArch32.FaultStatusLD(d_side, fault);
else
  fsr = AArch32.FaultStatusSD(d_side, fault);

if route_to_monitor then
  IFSR_S = fsr;
  IFAR_S = vaddress;
else
  IFSR = fsr;
  IFAR = vaddress;
return;
```

Library pseudocode for aarch32/exceptions/aborts/AArch32.TakeDataAbortException

```c
// AArch32.TakeDataAbortException()
// ================================

AArch32.TakeDataAbortException(bits(32) vaddress, FaultRecord fault)
route_to_monitor = HaveEL(EL3) && SCR.EA == '1' && IsExternalAbort(fault);
route_to_hyp = (HaveEL(EL2) && !IsSecure() && PSTATE.EL IN {EL0,EL1} &&
  (HCR.TGE == '1' || IsSecondStage(fault) ||
  (HaveRASExt() && HCR2.TEA == '1' && IsExternalAbort(fault)) ||
  (IsDebugException(fault) && HDCR.TDE == '1')));

bits(32) preferred_exception_return = ThisInstrAddr();
vec_offset = 0x10;
lr_offset = 8;

if IsDebugException(fault) then DBGDSRext.MOE = fault.debugmoe;
if route_to_monitor then
  AArch32.ReportDataAbort(route_to_monitor, fault, vaddress);
  AArch32.EnterMonitorMode(preferred_exception_return, lr_offset, vec_offset);
elsif PSTATE.EL == EL2 || route_to_hyp then
  exception = AArch32.AbortSyndrome(Exception_DataAbort, fault, vaddress);
  if PSTATE.EL == EL2 then
    AArch32.EnterHypMode(exception, preferred_exception_return, vec_offset);
  else
    AArch32.EnterHypMode(exception, preferred_exception_return, 0x14);
  else
    AArch32.ReportDataAbort(route_to_monitor, fault, vaddress);
    AArch32.EnterMode(M32_Abort, preferred_exception_return, lr_offset, vec_offset);
```
// AArch32.TakePrefetchAbortException(
// -------------------------------------

AArch32.TakePrefetchAbortException(bits(32) vaddress, FaultRecord fault)
  route_to_monitor = HaveEL(EL3) && SCR.EA == '1' && IsExternalAbort(fault);
  route_to_hyp = (HaveEL(EL2) && !IsSecure() && PSTATE.EL IN {EL0, EL1} &&
                  HCR.TGE == '1' || IsSecondStage(fault) ||
                  (HaveRASExt() && HCR2.TEA == '1' && IsExternalAbort(fault)) ||
                  (IsDebugException(fault) && HCR.TDE == '1')));

  bits(32) preferred_exception_return = ThisInstrAddr();
  vect_offset = 0x0C;
  lr_offset = 4;
  if IsDebugException(fault) then DBGDSRext.MOE = fault.debugmoe;
  if route_to_monitor then
    AArch32.ReportPrefetchAbort(route_to_monitor, fault, vaddress);
    AArch32.EnterMonitorMode(preferred_exception_return, lr_offset, vect_offset);
  elsif PSTATE.EL == EL2 || route_to_hyp then
    if fault.type == Fault_Alignment then             // PC Alignment fault
      exception = ExceptionSyndrome(Exception_PCAlignment);
      exception.vaddress = ThisInstrAddr();
    else
      exception = AArch32.AbortSyndrome(Exception_InstructionAbort, fault, vaddress);
    if PSTATE.EL == EL2 then
      AArch32.EnterHypMode(exception, preferred_exception_return, vect_offset);
    else
      AArch32.EnterHypMode(exception, preferred_exception_return, 0x14);
  else
    AArch32.ReportPrefetchAbort(route_to_monitor, fault, vaddress);
    AArch32.EnterMode(M32_Abort, preferred_exception_return, lr_offset, vect_offset);

// BranchTargetException
// ---------------------

// Raise branch target exception.

AArch64.BranchTargetException(bits(52) vaddress)
  route_to_el2 = EL2Enabled() && PSTATE.EL == EL0 && HCR_EL2.TGE == '1';
  bits(64) preferred_exception_return = ThisInstrAddr();
  vect_offset = 0x0;

  exception = ExceptionSyndrome(Exception_BranchTarget);
  exception.syndrome<1:0> = PSTATE.BTYPE;
  exception.syndrome<24:2> = Zeros();         // RES0
  if UInt(PSTATE.EL) > UInt(EL1) then
    AArch64.TakeException(PSTATE.EL, exception, preferred_exception_return, vect_offset);
  elsif route_to_el2 then
    AArch64.TakeException(EL2, exception, preferred_exception_return, vect_offset);
  else
    AArch64.TakeException(EL1, exception, preferred_exception_return, vect_offset);
// EffectiveTCF()
// ==============
// Returns the TCF field applied to Tag Check Fails in the given Exception Level

bits(2) EffectiveTCF(bits(2) el)
if el == EL3 then
tcf = SCTLR_EL3.TCF;
elsif el == EL2 then
tcf = SCTLR_EL2.TCF;
elsif el == EL1 then
tcf = SCTLR_EL1.TCF;
elsif el == EL0 && HCR_EL2.<E2H,TGE> == '11' then
tcf = SCTLR_EL2.TCF0;
elsif el == EL0 && HCR_EL2.<E2H,TGE> != '11' then
tcf = SCTLR_EL1.TCF0;
return tcf;

// RecordTagCheckFail()
// ====================
// Records a tag fail exception into the appropriate TCFR_ELx

ReportTagCheckFail(bits(2) el, bit ttbr)
if el == EL3 then
  assert ttbr == '0';
  TFSR_EL3.TF0 = '1';
elsif el == EL2 then
  if ttbr == '0' then
    TFSR_EL2.TF0 = '1';
  else
    TFSR_EL2.TF1 = '1';
elsif el == EL1 then
  if ttbr == '0' then
    TFSR_EL1.TF0 = '1';
  else
    TFSR_EL1.TF1 = '1';
elsif el == EL0 then
  if ttbr == '0' then
    TFSRE0_EL1.TF0 = '1';
  else
    TFSRE0_EL1.TF1 = '1';

// TagCheckFail()
// ===============
// Handle a tag check fail condition

TagCheckFail(bits(64) vaddress, boolean iswrite)
  bits(2) tcf = EffectiveTCF(PSTATE.EL);
  if tcf == '01' then
    TagCheckFault(vaddress, iswrite);
  elsif tcf == '10' then
    ReportTagCheckFail(PSTATE.EL, vaddress<55>);
Library pseudocode for aarch32/exceptions/aborts/TagCheckFault

// TagCheckFault()
// ===============
// Raise a tag check fail exception.
TagCheckFault(bits(64) va, boolean write)
    bits(2) target_el;
    bits(64) preferred_exception_return = ThisInstrAddr();
    integer vect_offset = 0x8;
    if PSTATE.EL == EL0 then
        target_el = if HCR_EL2.TGE == 0 then EL1 else EL2;
    else
        target_el = PSTATE.EL;
    exception = ExceptionSyndrome(Exception_DataAbort);
    exception.syndrome<5:0> = '010001';
    if write then
        exception.syndrome<6> = '1';
    exception.vaddress = va;
    AArch64.TakeException(target_el, exception, preferred_exception_return, vect_offset);

Library pseudocode for aarch32/exceptions/asynch/AArch32.TakePhysicalFIQException

// AArch32.TakePhysicalFIQException()
// ==================================
AArch32.TakePhysicalFIQException()
    // Check if routed to AArch64 state
    route_to_aarch64 = PSTATE.EL == EL0 && !ELUsingAArch32(EL1);
    if !route_to_aarch64 && EL2Enabled() && !ELUsingAArch32(EL2) then
        route_to_aarch64 = HCR_EL2.TGE == '1' || (HCR_EL2.FMO == '1' && !IsInHost());
    if !route_to_aarch64 && HaveEL(EL3) && !ELUsingAArch32(EL3) then
        route_to_aarch64 = SCR_EL3.FIQ == '1';
    if route_to_aarch64 then AArch64.TakePhysicalFIQException();
    route_to_hyp = HaveEL(EL3) && SCR.FIQ == '1';
    route_to_hyp = (EL2Enabled() && PSTATE.EL IN {EL0, EL1} && (HCR.TGE == '1' || HCR.FMO == '1'));
    bits(32) preferred_exception_return = ThisInstrAddr();
    vect_offset = 0x1C;
    lr_offset = 4;
    if route_to_monitor then
        AArch32.EnterMonitorMode(preferred_exception_return, lr_offset, vect_offset);
    elsif PSTATE.EL == EL2 || route_to_hyp then
        exception = ExceptionSyndrome(Exception_FIQ);
        AArch32.EnterHypMode(exception, preferred_exception_return, vect_offset);
    else
        AArch32.EnterMode(M32_FIQ, preferred_exception_return, lr_offset, vect_offset);
// AArch32.TakePhysicalIRQException()
// ==================================
// Take an enabled physical IRQ exception.

AArch32.TakePhysicalIRQException()

    // Check if routed to AArch64 state
    route_to_aarch64 = PSTATE.EL == EL0 && !ELUsingAArch32(EL1);
    if !route_to_aarch64 && EL2Enabled() && !ELUsingAArch32(EL2) then
        route_to_aarch64 = HCR_EL2.TGE == '1' || (HCR_EL2.IMO == '1' && !IsInHost());
    if !route_to_aarch64 && HaveEL(EL3) && !ELUsingAArch32(EL3) then
        route_to_aarch64 = SCR_EL3.IRQ == '1';
    if route_to_aarch64 then AArch64.TakePhysicalIRQException();
    route_to_monitor = HaveEL(EL3) && SCR.IRQ == '1';
    route_to_hyp = (EL2Enabled() && PSTATE.EL IN {EL0, EL1} &&
                      (HCR.TGE == '1' || HCR.IMO == '1'));
    bits(32) preferred_exception_return = ThisInstrAddr();
    vect_offset = 0x18;
    lr_offset = 4;
    if route_to_monitor then
        AArch32.EnterMonitorMode(preferred_exception_return, lr_offset, vect_offset);
    elsif PSTATE.EL == EL2 || route_to_hyp then
        exception = ExceptionSyndrome(Exception_IRQ);
        AArch32.EnterHypMode(exception, preferred_exception_return, vect_offset);
    else
        AArch32.EnterMode(M32_IRQ, preferred_exception_return, lr_offset, vect_offset);
// AArch32.TakePhysicalSErrorException()
// =====================================
AArch32.TakePhysicalSErrorException(boolean parity, bit extflag, bits(2) errortype,
    boolean impdef_syndrome, bits(24) full_syndrome)

ClearPendingPhysicalSError();
// Check if routed to AArch64 state
route_to_aarch64 = PSTATE.EL == EL0 && !ELUsingAArch32(EL1);

if !route_to_aarch64 && EL2Enabled() && !ELUsingAArch32(EL2) then
    route_to_aarch64 = (HCR_EL2.TGE == '1' || (!IsInHost() && HCR_EL2.AMO == '1'));
if !route_to_aarch64 && HaveEL(EL3) && !ELUsingAArch32(EL3) then
    route_to_aarch64 = SCR_EL3.EA == '1';
if route_to_aarch64 then
    AArch64.TakePhysicalSErrorException(impdef_syndrome, full_syndrome);

route_to_monitor = HaveEL(EL3) && SCR.EA == '1';
route_to_hyp = (EL2Enabled() && PSTATE.EL IN (EL0,EL1) &&
    (HCR.TGE == '1' || HCR.AMO == '1'));
bits(32) preferred_exception_return = ThisInstrAddr();
vect_offset = 0x10;
lr_offset = 8;

fault = AArch32.AsynchExternalAbort(parity, errortype, extflag);
vaddress = bits(32) UNKNOWN;
if route_to_monitor then
    AArch32.ReportDataAbort(route_to_monitor, fault, vaddress);
    AArch32.EnterMonitorMode(preferred_exception_return, lr_offset, vect_offset);
elsif PSTATE.EL == EL2 || route_to_hyp then
    exception = AArch32.Abort Syndrome( Exception_DataAbort, fault, vaddress);
    if PSTATE.EL == EL2 then
        AArch32.EnterHypMode(exception, preferred_exception_return, vect_offset);
    else
        AArch32.EnterHypMode(exception, preferred_exception_return, 0x14);
    else
        AArch32.ReportDataAbort(route_to_monitor, fault, vaddress);
        AArch32.EnterMode(M32_Abort, preferred_exception_return, lr_offset, vect_offset);

// AArch32.TakeVirtualFIQException()
// =================================
AArch32.TakeVirtualFIQException()

assert EL2Enabled() && PSTATE.EL IN (EL0,EL1);
if ELUsingAArch32(EL2) then // Virtual IRQ enabled if TGE==0 and FMO==1
    assert HCR.TGE == '0' && HCR.FMO == '1';
else
    assert HCR_EL2.TGE == '0' && HCR_EL2.FMO == '1';
// Check if routed to AArch64 state
if PSTATE.EL == EL0 && !ELUsingAArch32(EL1) then AArch64.TakeVirtualFIQException();

bits(32) preferred_exception_return = ThisInstrAddr();
vect_offset = 0x1C;
lr_offset = 4;
AArch32.EnterMode(M32_FIQ, preferred_exception_return, lr_offset, vect_offset);
Library pseudocode for aarch32/exceptions/asynch/AArch32.TakeVirtualIRQException

// AArch32.TakeVirtualIRQException()
// -------------------------------------

AArch32.TakeVirtualIRQException()
assert EL2Enabled() && PSTATE.EL IN {EL0, EL1};
if ELUsingAArch32(EL2) then // Virtual IRQs enabled if TGE==0 and IMO==1
    assert HCR.TGE == '0' && HCR.IMO == '1';
else
    assert HCR_EL2.TGE == '0' && HCR_EL2.IMO == '1';

// Check if routed to AArch64 state
if PSTATE.EL == EL0 && !ELUsingAArch32(EL1) then AArch64.TakeVirtualIRQException();
bits(32) preferred_exception_return = ThisInstrAddr();
vec_offset = 0x18;
lr_offset = 4;
AArch32.EnterMode(M32_IRQ, preferred_exception_return, lr_offset, vec_offset);

Library pseudocode for aarch32/exceptions/asynch/AArch32.TakeVirtualSErrorException

// AArch32.TakeVirtualSErrorException()
// -----------------------------------

AArch32.TakeVirtualSErrorException(bit extflag, bits(2) errortype, boolean impdef_syndrome, bits(24) full_syndrome)
assert EL2Enabled() && PSTATE.EL IN {EL0, EL1};
if ELUsingAArch32(EL2) then // Virtual SError enabled if TGE==0 and AMO==1
    assert HCR.TGE == '0' && HCR.AMO == '1';
else
    assert HCR_EL2.TGE == '0' && HCR_EL2.AMO == '1';

// Check if routed to AArch64 state
if PSTATE.EL == EL0 && !ELUsingAArch32(EL1) then AArch64.TakeVirtualSErrorException(impdef_syndrome);
route_to_monitor = FALSE;
bits(32) preferred_exception_return = ThisInstrAddr();
vec_offset = 0x10;
lr_offset = 8;
vaddress = bits(32) UNKNOWN;
parity = FALSE;
if HaveRASExt() then
    if ELUsingAArch32(EL2) then
        fault = AArch32.AsynchExternalAbort(FALSE, VDFSR.AET, VDFSR.ExT);
    else
        fault = AArch32.AsynchExternalAbort(FALSE, VSESR_EL2.AET, VSESR_EL2.ExT);
    else
        fault = AArch32.AsynchExternalAbort(parity, errortype, extflag);
ClearPendingVirtualSError();
AArch32.ReportDataAbort(route_to_monitor, fault, vaddress);
AArch32.EnterMode(M32_Abort, preferred_exception_return, lr_offset, vec_offset);
// AArch32.SoftwareBreakpoint()
// -----------------------------------------------
AArch32.SoftwareBreakpoint(bits(16) immediate)
    if (EL2Enabled() && !ELUsingAArch32(EL2) &&
        (HCR_EL2.TGE == '1' || MDCR_EL2.TDE == '1')) || !ELUsingAArch32(EL1) then
        AArch64.SoftwareBreakpoint(Immediate);
vaddress = bits(32) UNKNOWN;
acctype = AccType_IFETCH;           // Take as a Prefetch Abort
iswrite = FALSE;
entry = DebugException_BKPT;

fault = AArch32_DebugFault(acctype, iswrite, entry);
AArch32_Abort(vaddress, fault);

Library pseudocode for aarch32/exceptions/debug/DebugException

constant bits(4) DebugException_Breakpoint = '0001';
constant bits(4) DebugException_BKPT = '0011';
constant bits(4) DebugException_VectorCatch = '0101';
constant bits(4) DebugException_Watchpoint = '1010';

Library pseudocode for aarch32/exceptions/exceptions/AArch32_CheckAdvSIMDOrFPRegisterTraps

// AArch32.CheckAdvSIMDOrFPRegisterTraps()
// -----------------------------------------------
AArch32.CheckAdvSIMDOrFPRegisterTraps(bits(4) reg)
    if PSTATE_EL1 && EL2Enabled()
        tid0 = if ELUsingAArch32(EL2) then HCR.TID0 else HCR_EL2.TID0;
        tid3 = if ELUsingAArch32(EL2) then HCR.TID3 else HCR_EL2.TID3;
        if (tid0 == '1' && reg == '0000')                             // FPSID
            || (tid3 == '1' && reg IN {'0101', '0110', '0111'}) then    // MVFRx
                if ELUsingAArch32(EL2) then
                    AArch32_AArch32SystemAccessTrap(EL2, ThisInstr());
                else
                    AArch64_AArch32SystemAccessTrap(EL2, ThisInstr());

Shared Pseudocode Functions
// AArch32.ExceptionClass()
// Return the Exception Class and Instruction Length fields for reported in HSR

(integer, bit) AArch32.ExceptionClass(Exception type)

  il = if ThisInstrLength() == 32 then '1' else '0';

  case type of
    when Exception_Uncategorized ec = 0x00; il = '1';
    when Exception_WPITrap ec = 0x01;
    when Exception_CP15RTTrap ec = 0x03;
    when Exception_CP15RRTTrap ec = 0x04;
    when Exception_CP14RTTrap ec = 0x05;
    when Exception_CP14DTRTTrap ec = 0x06;
    when Exception_AdvSIMDFPAccessTrap ec = 0x07;
    when Exception_FPITrap ec = 0x08;
    when Exception_PACTrap ec = 0x09;
    when Exception_CP14RRTRTrap ec = 0x0C;
    when Exception_BranchTarget ec = 0x0D;
    when Exception_IllegalState ec = 0x0E; il = '1';
    when Exception_SupervisorCall ec = 0x11;
    when Exception_HypervisorCall ec = 0x12;
    when Exception_MonitorCall ec = 0x13;
    when Exception_ERetTrap ec = 0x1A;
    when Exception_InstructionAbort ec = 0x20; il = '1';
    when Exception_DataAbort ec = 0x24;
    when Exception_NV2DataAbort ec = 0x25;
    when Exception_FPTrappedException ec = 0x28;
    otherwise Unreachable();

  if ec IN {0x20,0x24} && PSTATE.EL == EL2 then
    ec = ec + 1;

  return (ec, il);

Library pseudocode for aarch32/exceptions/exceptions/AArch32.GeneralExceptionsToAArch64

// AArch32.GeneralExceptionsToAArch64()
// Returns TRUE if exceptions normally routed to EL1 are being handled at an Exception
// level using AArch64, because either EL1 is using AArch64 or TGE is in force and EL2
// is using AArch64.

boolean AArch32.GeneralExceptionsToAArch64()

  return ((PSTATE.EL == EL0 && !ELUsingAArch32(EL1)) ||
           (EL2Enabled() && !ELUsingAArch32(EL2) && HCR_EL2.TGE == '1'));

Library pseudocode for aarch32/exceptions/exceptions/AArch32.ExceptionClass
// AArch32.ReportHypEntry()
// ========================
// Report syndrome information to Hyp mode registers.

AArch32.ReportHypEntry(ExceptionRecord exception)

    Exception type = exception.type;
    (ec,il) = AArch32.ExceptionClass(type);
    iss = exception.syndrome;

    // IL is not valid for Data Abort exceptions without valid instruction syndrome information
    if ec IN {0x24,0x25} && iss<24> == '0' then
        il = '1';
    HSR = ec<5:0>:il:iss;

    if type IN {Exception/InstructionAbort, Exception/PCAlignment} then
        HIFAR = exception.vaddress<31:0>;
        HDFAR = bits(32) UNKNOWN;
    elsif type == Exception/DataAbort then
        HIFAR = bits(32) UNKNOWN;
        HDFAR = exception.vaddress<31:0>;

        if exception.ipavalid then
            HPFAR<31:4> = exception.ipaddress<39:12>;
        else
            HPFAR<31:4> = bits(28) UNKNOWN;
    return;

Library pseudocode for aarch32/exceptions/exceptions/AArch32.ResetControlRegisters

// Resets System registers and memory-mapped control registers that have architecturally-defined
// reset values to those values.
AArch32.ResetControlRegisters(boolean cold_reset);
// AArch32.TakeReset()
// ===================
// Reset into AArch32 state

AArch32.TakeReset(boolean cold_reset)
    assert HighestELUsingAArch32();
    // Enter the highest implemented Exception level in AArch32 state
    if HaveEL(EL3) then
        AArch32.WriteMode(M32_Svc);
        SCR.NS = '0';                     // Secure state
    elsif HaveEL(EL2) then
        AArch32.WriteMode(M32_Hyp);
    else
        AArch32.WriteMode(M32_Svc);

    // Reset the CP14 and CP15 registers and other system components
    AArch32.ResetControlRegisters(cold_reset);
    FPEXC.EN = '0';
    // Reset all other PSTATE fields, including instruction set and endianness according to the
    // SCTLR values produced by the above call to ResetControlRegisters()
    PSTATE.<A,I,F> = '111';       // All asynchronous exceptions masked
    PSTATE.IT = '00000000';       // IT block state reset
    PSTATE.T = SCTLR.TE;          // Instruction set: TE=0: A32, TE=1: T32. PSTATE.J is RES0.
    PSTATE.E = SCTLR.EE;          // Endianness: EE=0: little-endian, EE=1: big-endian
    PSTATE.IL = '0';              // Clear Illegal Execution state bit

    // All registers, bits and fields not reset by the above pseudocode or by the BranchTo() call
    // below are UNKNOWN bitstrings after reset. In particular, the return information registers
    // R14 or ELR_hyp and SPSR have UNKNOWN values, so that it
    // is impossible to return from a reset in an architecturally defined way.
    AArch32.ResetGeneralRegisters();
    AArch32.ResetSIMDFPRegisters();
    AArch32.ResetSpecialRegisters();
    ResetExternalDebugRegisters(cold_reset);

    bits(32) rv;
    // IMPLEMENTATION DEFINED reset vector

    if HaveEL(EL3) then
        if MVBAR<0> == '1' then
            rv = MVBAR<31:1>::'0';
        else
            rv = bits(32) IMPLEMENTATION_DEFINED "reset vector address";
    else
        rv = RVBAR<31:1>::'0';

    // The reset vector must be correctly aligned
    assert rv<0> == '0' && (PSTATE.T == '1' || rv<1> == '0');

    BranchTo(rv, BranchType_RESET, BranchType_UNKNOWN);

// ExcVectorBase()
// ===============

bits(32) ExcVectorBase()
    if SCTLR.V == '1' then // Hivecs selected, base = 0xFFFF0000
        return Ones(16):Zeros(16);
    else
        return VBAR<31:5>::Zeros(5);
Library pseudocode for aarch32/exceptions/ieeefp/AArch32.FPTrappedException

```c
// AArch32.FPTrappedException()
// ============================
AArch32.FPTrappedException(bits(8) accumulated_exceptions)
    if AArch32.GeneralExceptionsToAArch64() then
        is_ae = FALSE;
        element = 0;
        AArch64.FPTrappedException(is_ae, element, accumulated_exceptions);
        FPEXC.DEX = '1';
        FPEXC.TFV = '1';
        FPEXC<7,4:0> = accumulated_exceptions<7,4:0>; // IDF,IXF,UFF,OFF,DZF,IOF
        FPEXC<10:8> = '111'; // VECITR is RES1, FPEXC<7,4:0> = accumulated_exceptions<7,4:0>;
        AArch32.TakeUndefInstrException();
```

Library pseudocode for aarch32/exceptions/syscalls/AArch32.CallHypervisor

```c
// AArch32.CallHypervisor()
// ========================
// Performs a HVC call
AArch32.CallHypervisor(bits(16) immediate)
    assert HaveEL(EL2);
    if !ELUsingAArch32(EL2) then
        AArch64.CallHypervisor(immediate);
    else
        AArch32.TakeHVCException(immediate);
```

Library pseudocode for aarch32/exceptions/syscalls/AArch32.CallSupervisor

```c
// AArch32.CallSupervisor()
// ========================
// Calls the Supervisor
AArch32.CallSupervisor(bits(16) immediate)
    if AArch32.CurrentCond() != '1110' then
        immediate = bits(16) UNKNOWN;
    if AArch32.GeneralExceptionsToAArch64() then
        AArch64.CallSupervisor(immediate);
    else
        AArch32.TakeSVCException(immediate);
```

Library pseudocode for aarch32/exceptions/syscalls/AArch32.TakeHVCException

```c
// AArch32.TakeHVCException()
// =========================
AArch32.TakeHVCException(bits(16) immediate)
    assert HaveEL(EL2) && ELUsingAArch32(EL2);
    assert AArch32.ITAdvance();
    SSAdvance();
    bits(32) preferred_exception_return = NextInstrAddr();
    vect_offset = 0x08;
    exception = ExceptionSyndrome(Exception_HypervisorCall);
    exception.syndrome<15:0> = immediate;
    if PSTATE.EL == EL2 then
        AArch32.EnterHypMode(exception, preferred_exception_return, vect_offset);
    else
        AArch32.EnterHypMode(exception, preferred_exception_return, 0x14);
```
AArch32.TakeSMCExcetion()
// -------------------------

AArch32.TakeSMCExcetion()
assert HaveEL(EL3) && ELUsingAArch32(EL3);
AArch32.ITAdvance();
SSAdvance();
bits(32) preferred_exception_return = NextInstrAddr();
vect_offset = 0x08;
lr_offset = 0;
AArch32.EnterMonitorMode(preferred_exception_return, lr_offset, vect_offset);

AArch32.TakeSVCException(bits(16) immediate)
// -------------------------

AArch32.TakeSVCException(bits(16) immediate)
AArch32.ITAdvance();
SSAdvance();
rout_to_hyp = EL2Enabled() && PSTATE.EL == EL0 && HCR.TGE == '1';
bits(32) preferred_exception_return = NextInstrAddr();
vect_offset = 0x08;
lr_offset = 0;
if PSTATE.EL == EL2 || rout_to_hyp then
    exception = ExceptionSyndrome(Exception_SupervisorCall);
    exception.syndrome<15:0> = immediate;
    if PSTATE.EL == EL2 then
        AArch32.EnterHypMode(exception, preferred_exception_return, vect_offset);
    else
        AArch32.EnterHypMode(exception, preferred_exception_return, 0x14);
    else
        AArch32.EnterMode(M32_Svc, preferred_exception_return, lr_offset, vect_offset);
Library pseudocode for aarch32/exceptions/takeexception/AArch32.EnterHypMode

// AArch32.EnterHypMode()  
// ------------------------
// Take an exception to Hyp mode.

AArch32.EnterHypMode(ExceptionRecord exception, bits(32) preferred_exception_return, integer vect_offset)
    SynchronizeContext();
    assert HaveEL(EL2) && !IsSecure() && ELUsingAArch32(EL2);

    spsr = GetPSRFromPSTATE();
    if !(exception.type IN {Exception_IRQ, Exception_FIQ}) then
        AArch32.ReportHypEntry(exception);
    AArch32.WriteMode(M32_Hyp);
    PSTATE.T = HSCTRL.TE;                       // PSTATE.J is RES0
    PSTATE.SS = '0';
    if !HaveSSBSExt() then PSTATE.SSBS = HSCTRL.DSSBS;
    ELR_hyp = preferred_exception_return;
    PSTATE.T = HSCTRL.TE;                       // PSTATE.J is RES0
    PSTATE.SS = '0';
    if !HaveEL(EL3) || SCR_GEN[].EA == '0' then PSTATE.A = '1';
    if !HaveEL(EL3) || SCR_GEN[].IRQ == '0' then PSTATE.I = '1';
    if !HaveEL(EL3) || SCR_GEN[].FIQ == '0' then PSTATE.F = '1';
    PSTATE.E = HSCTRL.EE;
    PSTATE.IL = '0';
    if !HavePANExt() && SCTLR.SPAN == '0' then
        PSTATE.PAN = '1';
    BranchTo(HVBAR<31:5>:vect_offset<4:0>, BranchType_EXCEPTION,BranchType_UNKNOWN);

EndOfInstruction();

Library pseudocode for aarch32/exceptions/takeexception/AArch32.EnterMode

// AArch32.EnterMode()  
// -------------------
// Take an exception to a mode other than Monitor and Hyp mode.

AArch32.EnterMode(bits(5) target_mode, bits(32) preferred_exception_return, integer lr_offset, integer vect_offset)
    SynchronizeContext();
    assert ELUsingAArch32(EL1) && PSTATE.EL != EL2;

    spsr = GetPSRFromPSTATE();
    if PSTATE.M == M32_Monitor then SCR.NS = '0';
    AArch32.WriteMode(target_mode);
    PSTATE.T = SCTLR.TE;                        // PSTATE.J is RES0
    PSTATE.SS = '0';
    if target_mode == M32_FIQ then
        PSTATE.<A,I,F> = '111';
    elsif target_mode IN {M32_Abort, M32_IRQ} then
        PSTATE.<A,I> = '11';
    else
        PSTATE.I = '1';
    PSTATE.E = SCTLR.EE;
    PSTATE.IL = '0';
    if HavePANExt() && SCTLR.SPAN == '0' then
        PSTATE.PAN = '1';
    BranchTo(ExcVectorBase<31:5>:vect_offset<4:0>, BranchType_EXCEPTION,BranchType_UNKNOWN);

EndOfInstruction();
// AArch32.EnterMonitorMode()  
// ---------------------------  
// Take an exception to Monitor mode.  

AArch32.EnterMonitorMode(bits(32) preferred_exception_return, integer lr_offset,  
integer vect_offset)  
  SynchronizeContext();  
  assert HaveEL(EL3) & ELUsingAArch32(EL3);  
  from_secure = IsSecure();  
  spsr = GetPSRFromPSTATE();  
  if PSTATE.M == M32_Monitor then SCR.NS = '0';  
  AArch32.WriteMode(M32_Monitor);  
  SPSR[] = spsr;  
  if !from_secure then SPSR[] = spsr;  
  if HaveSSBSExt() then PSTATE.SSBS = SCTLR.DSSBS;  
  R[14] = preferred_exception_return + lr_offset;  
  PSTATE.T = SCTLR.TE;  // PSTATE.T is RES0  
  PSTATE.SS = '0';  
  PSTATE.<A,I,F> = '111';  
  PSTATE.E = SCTLR.EE;  
  PSTATE.IL = '0';  
  PSTATE.IT = '00000000';  
  if HavePANExt() then  
    if !from_secure then  
      PSTATE.PAN = '0';  
    elsif SCTLR.SPAN == '0' then  
      PSTATE.PAN = '1';  
    BranchTo(MVBAR<31:5>:vect_offset<4:0>, BranchType_EXCEPTION, BranchType_UNKNOWN);  
  EndOfInstruction();

// AArch32.AArch32SystemAccessTrap()  
// -----------------------------------  
// Trapped AArch32 System register access other than due to CPTR_EL2 or CPACR_EL1.  

AArch32.AArch32SystemAccessTrap(bits(2) target_el, bits(32) instr)  
  assert HaveEL(target_el) & target_el != EL0 & Uint(target_el) >= Uint(PSTATE.EL);  
  if !ELUsingArch32(target_el) || AArch32.GeneralExceptionsToAArch64() then  
    AArch64.AArch32SystemAccessTrap(target_el, instr);  
  assert target_el IN {EL1, EL2};  
  if target_el == EL2 then  
    exception = AArch32.AArch32SystemAccessTrapSyndrome(instr);  
    AArch32.TakeHypTrapException(exception);  
  else  
    AArch32.TakeUndefInstrException();

Shared Pseudocode Functions
// AArch32.AArch32SystemAccessTrapSyndrome()
// =========================================
// Return the syndrome information for traps on AArch32 MCR, MCRR, MRC, MRRC, and VMRS instructions,
// other than traps that are due to HCPTR or CPACR.

ExceptionRecord AArch32.AArch32SystemAccessTrapSyndrome(bits(32) instr)
    ExceptionRecord exception;
    cpnum = UInt(instr<11:8>);
    bits(20) iss = Zeros();
    if instr<27:24> == '1110' && instr<4> == '1' && instr<31:28> != '1111' then
        // MRC/MCR
        case cpnum of
            when 10 exception = ExceptionSyndrome(Exception_FPIDTrap);
            when 14 exception = ExceptionSyndrome(Exception_CP14RTTrap);
            when 15 exception = ExceptionSyndrome(Exception_CP15RTTrap);
            otherwise Unreachable();
        end;
        iss<19:17> = instr<7:5>; // opc2
        iss<16:14> = instr<23:21>; // opc1
        iss<13:10> = instr<19:16>; // CRn
        iss<8:5> = instr<15:12>; // Rt
        iss<4:1> = instr<3:0>; // CRm
    elsif instr<27:21> == '1100010' && instr<31:28> != '1111' then
        // MRRC/MCRR
        case cpnum of
            when 14 exception = ExceptionSyndrome(Exception_CP14RRTTrap);
            when 15 exception = ExceptionSyndrome(Exception_CP15RRTTrap);
            otherwise Unreachable();
        end;
        iss<19:16> = instr<7:4>; // opc1
        iss<13:10> = instr<19:16>; // Rt2
        iss<8:5> = instr<15:12>; // Rt
        iss<4:1> = instr<3:0>; // CRm
    elsif instr<27:25> == '110' && instr<31:28> != '1111' then
        // LDC/STC
        assert cpnum == 14;
        exception = ExceptionSyndrome(Exception_CP14DTTrap);
        iss<19:12> = instr<7:0>; // imm8
        iss<4> = instr<23>; // U
        iss<21:1> = instr<24,21>; // P,W
        if instr<19:16> == '1111' then
            // Rn==15, LDC(Literal addressing)/STC
            iss<8:5> = bits(4) UNKNOWN;
            iss<3> = '1';
        else
            iss<8:5> = instr<19:16>; // Rn
            iss<3> = '0';
        end;
        else Unreachable();
    end;
    iss<0> = instr<20>; // Direction
    exception.syndrome<24:20> = ConditionSyndrome();
    exception.syndrome<19:0> = iss;
    return exception;
// AArch32.CheckAdvSIMDOrFPEnabled()
// -----------------------------------
// Check against CPACR, FPEXC, HCPTR, NSACR, and CPTR_EL3.

AArch32.CheckAdvSIMDOrFPEnabled(boolean fpexc_check, boolean advsimd)
    if PSTATE.EL == EL0 && (!HaveEL(EL2) || (!ELUsingAArch32(EL2) && HCR_EL2.TGE == '0')) && !ELUsingAArch32(EL1)
        AArch64.CheckFPAdvSIMDEnabled();
    elsif PSTATE.EL == EL0 && HaveEL(EL2) && !ELUsingAArch32(EL2) && HCR_EL2.TGE == '1' && !ELUsingAArch32(EL1)
        if fpexc_check && HCR_EL2.RW == '0' then
            fpexc_en = bits(1) IMPLEMENTATION_DEFINED "FPEXC.EN value when TGE==1 and RW==0";
            if fpexc_en == '0' then UNDEFINED;
            AArch64.CheckFPAdvSIMDEnabled();
        else
            cpacr_asedis = CPACR.ASEDIS;
            cpacr_cp10 = CPACR.cp10;
            if HaveEL(EL3) && ELUsingAArch32(EL3) && !IsSecure() then
                // Check if access disabled in NSACR
                if NSACR.NSASEDIS == '1' then cpacr_asedis = '1';
                if NSACR.cp10 == '0' then cpacr_cp10 = '00';
            if PSTATE.EL != EL2 then
                // Check if Advanced SIMD disabled in CPACR
                if advsimd && cpacr_asedis == '1' then UNDEFINED;
                if cpacr_cp10 == '10' then
                    (c, cpacr_cp10) = ConstrainUnpredictableBits(Unpredictable_RESCPACR);
                // Check if access disabled in CPACR
                case cpacr_cp10 of
                    when '00' disabled = TRUE;
                    when '01' disabled = PSTATE.EL == EL0;
                    when '11' disabled = FALSE;
                    if disabled then UNDEFINED;
                // If required, check FPEXC enabled bit.
                if fpexc_check && FPEXC.EN == '0' then UNDEFINED;
                AArch32.CheckFPAdvSIMDTrap(advsimd);    // Also check against HCPTR and CPTR_EL3
            Shared Pseudocode Functions
Library pseudocode for aarch32/exceptions/traps/AArch32.CheckFPAdvSIMDTrap

```plaintext
// AArch32.CheckFPAdvSIMDTrap()
// ---------------------------
// Check against CPTR_EL2 and CPTR_EL3.

AArch32.CheckFPAdvSIMDTrap(booleay advsimd)
    if EL2Enabled() && !ELUsingAArch32(EL2) then
        AArch64.CheckFPAdvSIMDTrap();
    else
        if HaveEL(EL2) && !IsSecure() then
            hcptr_tase = HCPTR.TASE;
            hcptr_cp10 = HCPTR.TCP10;
            if HaveEL(EL3) && ELUsingAArch32(EL3) && !IsSecure() then
                // Check if access disabled in NSACR
                if NSACR.NSASEDIS == '1' then hcptr_tase = '1';
                if NSACR.cp10 == '0' then hcptr_cp10 = '1';

                // Check if access disabled in HCPTR
                if (advsimd && hcptr_tase == '1') || hcptr_cp10 == '1' then
                    exception = ExceptionSyndrome(Exception_AdvSIMDFPAccessTrap);
                    exception.syndrome<24:20> = ConditionSyndrome();
                    if advsimd then
                        exception.syndrome<5> = '1';
                    else
                        exception.syndrome<5> = '0';
                    exception.syndrome<3:0> = '1010';         // coproc field, always 0xA
                    if PSTATE.EL == EL2 then
                        AArch32.TakeUndefInstrException(exception);
                    else
                        AArch32.TakeHypTrapException(exception);
                end
            end
        end
    end
end

Library pseudocode for aarch32/exceptions/traps/AArch32.CheckForSMCUndefOrTrap

```
// AArch32.CheckForWFxTrap()
// ------------------------
// Check for trap on WFE or WFI instruction

AArch32.CheckForWFxTrap(bits(2) target_el, boolean is_wfe)
    assert HaveEL(target_el);

    // Check for routing to AArch64
    if !ELUsingAArch32(target_el) then
        AArch64.CheckForWFxTrap(target_el, is_wfe);
    return;

    case target_el of
        when EL1 trap = (if is_wfe then SCTLR.nTWE else SCTLR.nTWI) == '0';
        when EL2 trap = (if is_wfe then HCR.TWE else HCR.TWI) == '1';
        when EL3 trap = (if is_wfe then SCR.TWE else SCR.TWI) == '1';
    if trap then
        if target_el == EL1 && EL2Enabled() && !ELUsingAArch32(EL2) && HCR_EL2.TGE == '1' then
            AArch64.WFxTrap(target_el, is_wfe);
        if target_el == EL3 then
            AArch32.TakeMonitorTrapException();
        elsif target_el == EL2 then
            exception = ExceptionSyndrome(Exception_WFxTrap);
            exception.syndrome<24:20> = ConditionSyndrome();
            exception.syndrome<0> = if is_wfe then '1' else '0';
            AArch32.TakeHypTrapException(exception);
        else
            AArch32.TakeUndefInstrException();
    return;

// AArch32.CheckITEnabled()
// ------------------------
// Check whether the T32 IT instruction is disabled.

AArch32.CheckITEnabled(bits(4) mask)
    if PSTATE.EL == EL2 then
        it_disabled = HSCTLR.ITD;
    else
        it_disabled = (if ELUsingAArch32(EL1) then SCTLR.ITD else SCTLR[].ITD);
    if it_disabled == '1' then
        if mask != '1000' then UNDEFINED;
        // Otherwise whether the IT block is allowed depends on hw1 of the next instruction.
        next_instr = AArch32.MemSingle[NextInstrAddr(), 2, AccType_IFETCH, TRUE];
        if next_instr IN {'11xxxxxxxxxxxxxx', '1011xxxxxxxxxxxx', '10100xxxxxxxxxxx',
            '01001xxxxxxxxxxx', '010001xxx1111xxx', '010001xx1xxxx111'} then
            // It is IMPLEMENTATION DEFINED whether the Undefined Instruction exception is
            // taken on the IT instruction or the next instruction. This is not reflected in
            // the pseudocode, which always takes the exception on the IT instruction. This
            // also does not take into account cases where the next instruction is UNPREDICTABLE.
            UNDEFINED;
        return;
   
// AArch32.CheckIllegalState()  
// Check PSTATE.IL bit and generate Illegal Execution state exception if set.

AArch32.CheckIllegalState()  
if AArch32.GeneralExceptionsToAArch64() then  
    AArch64.CheckIllegalState();  
elsif PSTATE.IL == '1' then  
    route_to_hyp = EL2Enabled() && PSTATE.EL == EL0 && HCR.TGE == '1';  
    bits(32) preferred_exception_return = ThisInstrAddr();  
    vect_offset = 0x04;  
    if PSTATE.EL == EL2 || route_to_hyp then  
        exception = ExceptionSyndrome(Exception_IllegalState);  
        if PSTATE.EL == EL2 then  
            AArch32.EnterHypMode(exception, preferred_exception_return, vect_offset);  
        else  
            AArch32.EnterHypMode(exception, preferred_exception_return, 0x14);  
    else  
        AArch32.TakeUndefInstrException();

// AArch32.CheckSETENDEnabled()  
// Check whether the AArch32 SETEND instruction is disabled.

AArch32.CheckSETENDEnabled()  
if PSTATE.EL == EL2 then  
    setend_disabled = HSCTLR.SED;  
else  
    setend_disabled = (if ELUsingAArch32(EL1) then SCTLR.SED else SCTLR[].SED);  
if setend_disabled == '1' then  
    UNDEFINED;  
    return;

// AArch32.TakeHypTrapException()  
// Exceptions routed to Hyp mode as a Hyp Trap exception.

AArch32.TakeHypTrapException(ExceptionRecord exception)  
assert HaveEL(EL2) && !IsSecure() && ELUsingAArch32(EL2);  
bits(32) preferred_exception_return = ThisInstrAddr();  
vect_offset = 0x14;  
AArch32.EnterHypMode(exception, preferred_exception_return, vect_offset);

// AArch32.TakeMonitorTrapException()  
// Exceptions routed to Monitor mode as a Monitor Trap exception.

AArch32.TakeMonitorTrapException()  
assert HaveEL(EL3) && ELUsingAArch32(EL3);  
bits(32) preferred_exception_return = ThisInstrAddr();  
vect_offset = 0x04;  
lr_offset = if CurrentInstrSet() == InstrSet_A32 then 4 else 2;  
AArch32.EnterMonitorMode(preferred_exception_return, lr_offset, vect_offset);
Library pseudocode for aarch32/exceptions/traps/AArch32.TakeUndefInstrException

```c
// AArch32.TakeUndefInstrException()
// --------------------------------

AArch32.TakeUndefInstrException()
    exception = ExceptionSyndrome(Exception_Uncategorized);
    AArch32.TakeUndefInstrException(exception);

// AArch32.TakeUndefInstrException()
// --------------------------------

AArch32.TakeUndefInstrException(ExceptionRecord exception)
    route_to_hyp = EL2Enabled() && PSTATE.EL == EL0 && HCR.TGE == '1';
    bits(32) preferred_exception_return = ThisInstrAddr();
    vect_offset = 0x04;
    lr_offset = if CurrentInstrSet() == InstrSet_A32 then 4 else 2;
    if PSTATE.EL == EL2 then
        AArch32.EnterHypMode(exception, preferred_exception_return, vect_offset);
    elsif route_to_hyp then
        AArch32.EnterHypMode(exception, preferred_exception_return, 0x14);
    else
        AArch32.EnterMode(M32_Undef, preferred_exception_return, lr_offset, vect_offset);
```

Library pseudocode for aarch32/exceptions/traps/AArch32.UndefinedFault

```c
// AArch32.UndefinedFault()
// ------------------------

AArch32.UndefinedFault()
    if AArch32.GeneralExceptionsToAArch64() then AArch64.UndefinedFault();
    AArch32.TakeUndefInstrException();
```

Library pseudocode for aarch32/functions/aborts/AArch32.CreateFaultRecord

```c
// AArch32.CreateFaultRecord()
// ---------------------------

FaultRecord AArch32.CreateFaultRecord(Fault type, bits(40) ipaddress, bits(4) domain,
    integer level, AccType acctype, boolean write, bit extflag,
    bits(4) debugmoe, bits(2) errortype, boolean secondstage, boolean s2fs1walk)
    FaultRecord fault;
    fault.type = type;
    if (type != Fault_None && PSTATE.EL != EL2 && TTBCR.EAE == '0' && !secondstage && !s2fs1walk &&
        AArch32.DomainValid(type, level)) then
        fault.domain = domain;
    else
        fault.domain = bits(4) UNKNOWN;
    fault.debugmoe = debugmoe;
    fault.errortype = errortype;
    fault.ipaddress.NS = bit UNKNOWN;
    fault.ipaddress.address = ZeroExtend(ipaddress);
    fault.level = level;
    fault.acctype = acctype;
    fault.write = write;
    fault.extflag = extflag;
    fault.secondstage = secondstage;
    fault.s2fs1walk = s2fs1walk;
    return fault;
```
// AArch32.DomainValid()
// -------------------------
// Returns TRUE if the Domain is valid for a Short-descriptor translation scheme.

boolean AArch32.DomainValid(Fault type, integer level)
assert type != Fault_None;
case type of
    when Fault_Domain
        return TRUE;
    when Fault_Translation, Fault_AccessFlag, Fault_SyncExternalOnWalk, Fault_SyncParityOnWalk
        return level == 2;
    otherwise
        return FALSE;

// AArch32.FaultStatusLD()
// -------------------------
// Creates an exception fault status value for Abort and Watchpoint exceptions taken
// to Abort mode using AArch32 and Long-descriptor format.

bits(32) AArch32.FaultStatusLD(boolean d_side, FaultRecord fault)
assert fault.type != Fault_None;
bits(32) fsr = Zeros();
if HaveRASExt() & IsAsyncAbort(fault) then fsr<15:14> = fault.errortype;
if d_side then
    if fault.acctype IN {AccType_DC, AccType_IC, AccType_AT} then
        fsr<13> = '1'; fsr<11> = '1';
    else
        fsr<11> = if fault.write then '1' else '0';
    if IsExternalAbort(fault) then fsr<12> = fault.extflag;
    fsr<9> = '1';
    fsr<5:0> = EncodeLDFSC(fault.type, fault.level);
    return fsr;

// AArch32.FaultStatusSD()
// -------------------------
// Creates an exception fault status value for Abort and Watchpoint exceptions taken
// to Abort mode using AArch32 and Short-descriptor format.

bits(32) AArch32.FaultStatusSD(boolean d_side, FaultRecord fault)
assert fault.type != Fault_None;
bits(32) fsr = Zeros();
if HaveRASExt() & IsAsyncAbort(fault) then fsr<15:14> = fault.errortype;
if d_side then
    if fault.acctype IN {AccType_DC, AccType_IC, AccType_AT} then
        fsr<13> = '1'; fsr<11> = '1';
    else
        fsr<11> = if fault.write then '1' else '0';
    if IsExternalAbort(fault) then fsr<12> = fault.extflag;
    fsr<9> = '0';
    fsr<10,3:0> = EncodeSDFSC(fault.type, fault.level);
    if d_side then
        fsr<7:4> = fault.domain;               // Domain field (data fault only)
    return fsr;
bits(25) AArch32.FaultSyndrome(boolean d_side, FaultRecord fault) {
    bits(25) iss = Zeros();
    if HaveRASExt() && IsAsyncAbort(fault) then {  
        iss<11:10> = fault.errortype;  // AET
        if d_side then
            if IsSecondStage(fault) && !fault.s2fs1walk then {  
                iss<24:14> = LSImpreciseExceptionSyndrome();
                if fault.acctype IN {AccType_DC, AccType_DC_UNPRIV, AccType_IC, AccType_AT} then
                    iss<8> = '1';  iss<6> = '1';
                else
                    iss<6> = if fault.write then '1' else '0';
                end if
            } else
                iss<6> = if fault.write then '1' else '0';
            end if
        if IsExternalAbort(fault) then {  
            iss<9> = fault.extflag;
            iss<7> = if fault.s2fs1walk then '1' else '0';
            iss<5:0> = EncodeLDFSC(fault.type, fault.level);
        } end if
    }}
    return iss;
}
// EncodeSDFSC()
// =============
// Function that gives the Short-descriptor FSR code for different types of Fault

bits(5) EncodeSDFSC(Fault type, integer level)

    bits(5) result;
    case type of
        when Fault_AccessFlag
            assert level IN {1,2};
            result = if level == 1 then '00011' else '00110';
        when Fault_Alignment
            result = '00001';
        when Fault_Permission
            assert level IN {1,2};
            result = if level == 1 then '01101' else '01111';
        when Fault_Domain
            assert level IN {1,2};
            result = if level == 1 then '01001' else '01011';
        when Fault_Translation
            assert level IN {1,2};
            result = if level == 1 then '00101' else '00111';
        when Fault_SyncExternal
            result = '01000';
        when Fault_SyncExternalOnWalk
            assert level IN {1,2};
            result = if level == 1 then '01100' else '01110';
        when Fault_SyncParity
            result = '11001';
        when Fault_SyncParityOnWalk
            assert level IN {1,2};
            result = if level == 1 then '11100' else '11110';
        when Fault.AsyncParity
            result = '11000';
        when Fault_AsyncExternal
            result = '10110';
        when Fault_Debug
            result = '00010';
        when Fault_TLBCOnflict
            result = '10000';
        when Fault_Lockdown
            result = '10100'; // IMPLEMENTATION DEFINED
        when Fault_Exclusive
            result = '10101'; // IMPLEMENTATION DEFINED
        when Fault_ICacheMaint
            result = '00100';
        otherwise
            Unreachable();
    return result;

Library pseudocode for aarch32/functions/common/A32ExpandImm

// A32ExpandImm()
// =============

bits(32) A32ExpandImm(bits(12) imm12)

    // PSTATE.C argument to following function call does not affect the imm32 result.
    (imm32, -) = A32ExpandImm_C(imm12, PSTATE.C);

    return imm32;
Library pseudocode for aarch32/functions/common/A32ExpandImm_C

// A32ExpandImm_C()
// ================
<bits(32), bit) A32ExpandImm_C(bits(12) imm12, bit carry_in)

unrotated_value = ZeroExtend(imm12<7:0>, 32);
(imm32, carry_out) = Shift_C(unrotated_value, SRTYPE_ROR, 2*UInt(imm12<11:8>), carry_in);
return (imm32, carry_out);

Library pseudocode for aarch32/functions/common/DecodeImmShift

// DecodeImmShift()
// ================
(SRTYPE, integer) DecodeImmShift(bits(2) type, bits(5) imm5)

case type of
  when '00'
  shift_t = SRTYPE_LSL;  shift_n = UInt(imm5);
  when '01'
  shift_t = SRTYPE_LSR;  shift_n = if imm5 == '00000' then 32 else UInt(imm5);
  when '10'
  shift_t = SRTYPE_ASR;  shift_n = if imm5 == '00000' then 32 else UInt(imm5);
  when '11'
  if imm5 == '00000' then
    shift_t = SRTYPE_RRX;  shift_n = 1;
  else
    shift_t = SRTYPE_ROR;  shift_n = UInt(imm5);
return (shift_t, shift_n);

Library pseudocode for aarch32/functions/common/DecodeRegShift

// DecodeRegShift()
// ================
SRTYPE DecodeRegShift(bits(2) type)

case type of
  when '00'  shift_t = SRTYPE_LSL;
  when '01'  shift_t = SRTYPE_LSR;
  when '10'  shift_t = SRTYPE_ASR;
  when '11'  shift_t = SRTYPE_ROR;
return shift_t;

Library pseudocode for aarch32/functions/common/RRX

// RRX()
// =====
<bits(N) RRX(bits(N) x, bit carry_in)
  (result, -) = RRX_C(x, carry_in);
  return result;

Library pseudocode for aarch32/functions/common/RRX_C

// RRX_C()
// ========
<bits(N), bit) RRX_C(bits(N) x, bit carry_in)
  result = carry_in : x<N-1:1>;
  carry_out = x<0>;
  return (result, carry_out);
Library pseudocode for aarch32/functions/common/SRType

```
enumeration SRType {SRType_LSL, SRType_LSR, SRType_ASR, SRType_ROR, SRType_RRX};
```

Library pseudocode for aarch32/functions/common/Shift

```
// Shift()
// ========

bits(N) Shift(bits(N) value, SRType type, integer amount, bit carry_in)
     (result, -) = Shift_C(value, type, amount, carry_in);
     return result;
```

Library pseudocode for aarch32/functions/common/Shift_C

```
// Shift_C()
// =========

(bits(N), bit) Shift_C(bits(N) value, SRType type, integer amount, bit carry_in)
     assert !(type == SRType_RRX && amount != 1);
     if amount == 0 then
         (result, carry_out) = (value, carry_in);
     else
         case type of
             when SRType_LSL
                 (result, carry_out) = LSL_C(value, amount);
             when SRType_LSR
                 (result, carry_out) = LSR_C(value, amount);
             when SRType_ASR
                 (result, carry_out) = ASR_C(value, amount);
             when SRType_ROR
                 (result, carry_out) = ROR_C(value, amount);
             when SRType_RRX
                 (result, carry_out) = RRX_C(value, carry_in);
         return (result, carry_out);
```

Library pseudocode for aarch32/functions/common/T32ExpandImm

```
// T32ExpandImm()
// =============

bits(32) T32ExpandImm(bits(12) imm12)
     // PSTATE.C argument to following function call does not affect the imm32 result.
     (imm32, -) = T32ExpandImm_C(imm12, PSTATE.C);
     return imm32;
```
Library pseudocode for aarch32/functions/common/T32ExpandImm_C

// T32ExpandImm_C()
// ================
(bits(32), bit) T32ExpandImm_C(bits(12) imm12, bit carry_in)

if imm12<11:10> == '00' then
  case imm12<9:8> of
    when '00'
      imm32 = ZeroExtend(imm12<7:0>, 32);
    when '01'
      imm32 = '00000000' : imm12<7:0> : '00000000' : imm12<7:0>;
    when '10'
      imm32 = imm12<7:0> : '00000000' : imm12<7:0> : '00000000';
    when '11'
      imm32 = imm12<7:0> : imm12<7:0> : imm12<7:0> : imm12<7:0>;
  carry_out = carry_in;
else
  unrotated_value = ZeroExtend('1':imm12<6:0>, 32);
  (imm32, carry_out) = ROR_C(unrotated_value, UInt(imm12<11:7>));
return (imm32, carry_out);

Library pseudocode for aarch32/functions/coproc/AArch32.CheckCP15InstrCoarseTraps

// AArch32.CheckCP15InstrCoarseTraps()
// ===================================
// Check for coarse-grained CP15 traps in HSTR and HCR.

boolean AArch32.CheckCP15InstrCoarseTraps(integer CRn, integer nreg, integer CRm)

// Check for coarse-grained Hyp traps
if EL2Enabled() && PSTATE.EL IN {EL0, EL1} then
  if PSTATE.EL == EL0 && !ELUsingAArch32(EL2) then
    return AArch64.CheckCP15InstrCoarseTraps(CRn, nreg, CRm);
  // Check for MCR, MRC, MCRR and MRRC disabled by HSTR<CRn/CRm>
  major = if nreg == 1 then CRn else CRm;
  if !(major IN {4,14}) && HSTR<major> == '1' then
    return TRUE;
  // Check for MRC and MCR disabled by HCR.TIDCP
if (HCR.TIDCP == '1' && nreg == 1 &&
  ((CRn == 9 && CRm IN {0,1,2,5,6,7,8}) ||
   (CRn == 10 && CRm IN {0,1,4,8}) ||
   (CRn == 11 && CRm IN {0,1,2,3,4,5,6,7,8,15}))) then
    return TRUE;
return FALSE;
Library pseudocode for aarch32/functions/coproc/AArch32.CheckSystemAccess
// AArch32.CheckSystemAccess()
// ---------------------------------
// Check System register access instruction for enables and disables

AArch32.CheckSystemAccess(integer cp_num, bits(32) instr)
assert cp_num == UInt(instr<11:8>) && (cp_num IN {14,15});
if PSTATE.EL == EL0 && !ELUsingAArch32(EL1) then
  AArch64.CheckAArch32SystemAccess(instr);
return;

// Decode the AArch32 System register access instruction
if instr<31:28> != '1111' && instr<27:24> == '1110' && instr<4> == '1' then  // MRC/MCR
  cprt = TRUE;  cpdt = FALSE;  nreg = 1;
  opc1 = UInt(instr<23:21>);
  opc2 = UInt(instr<7:5>);
  CRn = UInt(instr<19:16>);
  CRm = UInt(instr<3:0>);
elsif instr<31:28> != '1111' && instr<27:21> == '1100010' then                  // MRRC/MCRR
  cprt = TRUE;  cpdt = FALSE;  nreg = 2;
  opc1 = UInt(instr<7:4>);
  CRm = UInt(instr<3:0>);
elsif instr<31:28> != '1111' && instr<27:25> == '110' && instr<22> == '0' then   // LDC/STC
  cprt = FALSE;  cpdt = TRUE;  nreg = 0;
  opc1 = 0;
  CRn = UInt(instr<15:12>);
else
  allocated = FALSE;

// Coarse-grain decode into CP14 or CP15 encoding space. Each of the CPxxxInstrDecode functions
// returns TRUE if the instruction is allocated at the current Exception level, FALSE otherwise.
if cp_num == 14 then
  // LDC and STC only supported for c5 in CP14 encoding space
  if cpdt && CRn != 5 then
    allocated = FALSE;
  else
    // Coarse-grained decode of CP14 based on opc1 field
    case opc1 of
      when 0    allocated = CP14DebugInstrDecode(instr);
      when 1    allocated = CP14TraceInstrDecode(instr);
      when 7    allocated = CP14JazelleInstrDecode(instr);    // JIDR only
      otherwise allocated = FALSE;    // All other values are unallocated
    end case;
  end if;
elsif cp_num == 15 then
  // LDC and STC not supported in CP15 encoding space
  if !cprt then
    allocated = FALSE;
  else
    allocated = CP15InstrDecode(instr);
  end if;
else
  allocated = CP15InstrDecode(instr);

// Coarse-grain traps to EL2 have a higher priority than exceptions generated because
// the access instruction is UNDEFINED
if AArch32.CheckCP15InstrCoarseTraps(CRn, nreg, CRm) then
  // For a coarse-grain trap, if it is IMPLEMENTATION DEFINED whether an access from
  // User mode is UNDEFINED when the trap is disabled, then it is
  // IMPLEMENTATION DEFINED whether the same access is UNDEFINED or generates a trap
  // when the trap is enabled.
  if PSTATE.EL == EL0 && EL2Enabled() && !allocated then
    if boolean IMPLEMENTATION_DEFINED "UNDEF unallocated CP15 access at EL0" then
      UNDEFINED;
      AArch32.AArch32SystemAccessTrap(EL2, instr);
    else
      allocated = FALSE;
    end if;
  end if;
else
  allocated = FALSE;
end if;

// If the instruction is not UNDEFINED, it might be disabled or trapped to a higher EL.
AArch32.CheckSystemAccessTraps(instr);
return;
// AArch32.CheckSystemAccessEL1Traps()
// ----------------------------------
// Check for configurable disables or traps to EL1 or EL2 of a System register
// access instruction.

AArch32.CheckSystemAccessEL1Traps(bits(32) instr)
assert PSTATE.EL == EL0;
if ((HaveEL(EL1) \\& IsSecure() \\&!ELUsingAArch32(EL1)) || IsInHost()) then
  AArch64.CheckAArch32SystemAccessEL1Traps(instr);
return;
trap = FALSE;
// Decode the AArch32 System register access instruction
(op, cp_num, opc1, CRn, CRm, opc2, write) = AArch32.DecodeSysRegAccess(instr);
if cp_num == 14 then
  if ((op == SystemAccessType_RT \\& opc1 == 0 \\& CRn == 0 \\& CRm == 5 \\& opc2 == 0) || // DBGDTRRXint/DBGDTRTXint
    (op == SystemAccessType_DT \\& CRn == 5 \\& opc2 == 0)) then // DBGDTRRXint/DBGDTRTXint (STC/LDC)
    trap = !Halted() \\& DBGDSCRext.UDCCdis == '1';
  elsif opc1 == 0 then
    trap = DBGDSCRext.UDCCdis == '1';
  elsif opc1 == 1 then
    trap = CPACR.TRCDIS == '1';
  if HaveEL(EL3) \\& ELUsingAArch32(EL3) \\& NSACR.NSTRCDIS == '1' then
    trap = TRUE;
  elsif cp_num == 15 then
    if ((op == SystemAccessType_RT \\& opc1 == 0 \\& CRn == 9 \\& CRm == 12 \\& opc2 == 0) || // PMCR
        (op == SystemAccessType_RT \\& opc1 == 0 \\& CRn == 9 \\& CRm == 12 \\& opc2 == 1) || // PMCNTENSET
        (op == SystemAccessType_RT \\& opc1 == 0 \\& CRn == 9 \\& CRm == 12 \\& opc2 == 2) || // PMCNTENCLR
        (op == SystemAccessType_RT \\& opc1 == 0 \\& CRn == 9 \\& CRm == 12 \\& opc2 == 3) || // PMOVSR
        (op == SystemAccessType_RT \\& opc1 == 0 \\& CRn == 9 \\& CRm == 12 \\& opc2 == 6) || // PMCEID
        (op == SystemAccessType_RT \\& opc1 == 0 \\& CRn == 9 \\& CRm == 12 \\& opc2 == 7) || // PMCEID
        (op == SystemAccessType_RT \\& opc1 == 0 \\& CRn == 9 \\& CRm == 12 \\& opc2 == 1) || // PMXEVTC
        (op == SystemAccessType_RT \\& opc1 == 0 \\& CRn == 9 \\& CRm == 14 \\& opc2 == 3) || // PMOVSS
        (op == SystemAccessType_RT \\& opc1 == 0 \\& CRn == 14 \\& CRm >= 12)) then // PMEVTYPR<n>
      trap = PMUSERENR.EN == '0';
    elsif op == SystemAccessType_RT \\& opc1 == 0 \\& CRn == 9 \\& CRm == 14 \\& opc2 == 4 then // PMSW
      trap = PMUSERENR.EN == '0' \\& PMUSERENR.SW == '0';
    elsif ((op == SystemAccessType_RT \\& opc1 == 0 \\& CRn == 9 \\& CRm == 13 \\& opc2 == 0) || // PMCCNTR
             (op == SystemAccessType_RRT \\& opc1 == 0 \\& CRm == 9)) then // PMCCNTR (MRRC/MCRR)
      trap = PMUSERENR.EN == '0' \\& (write || PMUSERENR.CR == '0');
    elsif ((op == SystemAccessType_RT \\& opc1 == 0 \\& CRn == 9 \\& CRm >= 8 && CRm <= 11)) then // PMEVCNTR<n>
      trap = PMUSERENR.EN == '0' \\& (write || PMUSERENR.ER == '0');
    elsif op == SystemAccessType_RT \\& opc1 == 0 \\& CRn == 9 \\& CRm == 12 \\& opc2 == 5 then // PMSELR
      trap = PMUSERENR.EN == '0' \\& PMUSERENR.ER == '0';
    elsif op == SystemAccessType_RT \\& opc1 == 0 \\& CRn == 14 \\& CRm == 2 && opc2 IN {0,1,2} then // CNTP_TVAL CNTP_CTL CNTP_CVAL
      trap = CNTKCTL.PL0PTEN == '0';
    elsif op == SystemAccessType_RT \\& opc1 == 0 \\& CRn == 14 \\& CRm == 0 && opc2 == 0 then // CNTFRQ
      trap = CNTKCTL.PL0PCTEN == '0' \\& CNTKCTL.PL0VCTEN == '0';
    elsif op == SystemAccessType_RRT \\& opc1 == 1 \\& CRm == 14 then // CNTVCT
      trap = CNTKCTL.PL0VCTEN == '0';
  if trap then
    AArch32.AArch32SystemAccessTrap(EL1, instr);
Library pseudocode for aarch32/functions/coproc/AArch32.CheckSystemAccessEL2Traps
// AArch32.CheckSystemAccessEL2Traps()
// ----------------------------------
// Check for configurable traps to EL2 of a System register access instruction.

AArch32.CheckSystemAccessEL2Traps(bits(32) instr)
assert EL2Enabled() && PSTATE.EL IN {EL0, EL1, EL2};

if EL2Enabled() && !ELUsingAArch32(EL2) then
  AArch64.CheckAArch32SystemAccessEL2Traps(instr);
return;
trap = FALSE;

// Decode the AArch32 System register access instruction
(op, cp_num, opc1, CRn, CRm, opc2, write) = AArch32.DecodeSysRegAccess(instr);

if cp_num == 14 && PSTATE.EL IN {EL0, EL1} then
  if ((op == SystemAccessType_RT && opc1 == 0 && CRn == 1 && CRm == 0 && opc2 == 0) || // DBGDRAR
       (op == SystemAccessType_RRT && opc1 == 0 && CRm == 1) ||                         // DBGDRAR (MRRC)
       (op == SystemAccessType_RT && opc1 == 0 && CRn == 2 && CRm == 0 && opc2 == 0) || // DBGDSAR
       (op == SystemAccessType_RRT && opc1 == 0 && CRm == 2)) then
    trap = HDCR.TDRA == '1' || HDCR.TDE == '1' || HCR.TGE == '1';
  elsif ((op == SystemAccessType_RT && opc1 == 0 && CRn == 1 && CRm == 0 && opc2 == 4) || // DBGOSLAR
           (op == SystemAccessType_RT && opc1 == 0 && CRn == 1 && CRm == 1 && opc2 == 4) ||    // DBGOSLSR
           (op == SystemAccessType_RT && opc1 == 0 && CRn == 1 && CRm == 3 && opc2 == 4) ||    // DBGOSDLR
           (op == SystemAccessType_RT && opc1 == 0 && CRn == 1 && CRm == 4 && opc2 == 4)) then // DBGPRCR
    trap = HDCR.TDOSA == '1' || HDCR.TDE == '1' || HCR.TGE == '1';
  elsif opc1 == 0 && (!Halted() || !(op == SystemAccessType_RT && CRn == 0 && CRm == 5 && opc2 == 0)) then
    trap = HDCR.TDA == '1' || HDCR.TDE == '1' || HCR.TGE == '1';
  elsif opc1 == 1 then
    trap = HCPTR.TTA == '1';
  end
else if op == SystemAccessType_RT && opc1 == 7 && CRn == 0 && CRm == 0 && opc2 == 0 then  // JIDR
    trap = HCR.TID0 == '1';
elsif cp_num == 15 && PSTATE.EL IN {EL0, EL1} then
  if opc1 == 1 then
    trap = HCPTR.TTA == '1';
  elsif cp_num == 15 && PSTATE.EL IN {EL0, EL1} then
    if ((op == SystemAccessType_RT && opc1 == 0 && CRn == 7 && CRm == 0 && opc2 == 0) ||  // SCTLR
         (op == SystemAccessType_RT && opc1 == 0 && CRn == 5 && CRm == 0 && opc2 == 0) ||  // TTBR0
         (op == SystemAccessType_RT && opc1 == 0 && CRn == 6 && CRm == 0 && opc2 == 0) ||  // TTBR1
         (op == SystemAccessType_RT && opc1 == 0 && CRn == 4 && CRm == 0 && opc2 == 0) ||  // TTBR2
         (op == SystemAccessType_RT && opc1 == 0 && CRn == 5 && CRm == 0 && opc2 == 0) ||  // DCSR
         (op == SystemAccessType_RT && opc1 == 0 && CRn == 5 && CRm == 0 && opc2 == 0) ||  // DFSR
         (op == SystemAccessType_RT && opc1 == 0 && CRn == 5 && CRm == 0 && opc2 == 0) ||  // IFSR
         (op == SystemAccessType_RT && opc1 == 0 && CRn == 6 && CRm == 0 && opc2 == 0) ||  // ADFSR
         (op == SystemAccessType_RT && opc1 == 0 && CRn == 5 && CRm == 0 && opc2 == 0) ||  // AIFS
         (op == SystemAccessType_RT && opc1 == 0 && CRn == 10 && CRm == 2 && opc2 == 0) ||  // PRR/M
         (op == SystemAccessType_RT && opc1 == 0 && CRn == 10 && CRm == 2 && opc2 == 1)) then // NMRR/M
    trap = if write then HCR.TVM == '1' else HCR.TRVM == '1';
  elsif op == SystemAccessType_RT && opc1 == 8 then                         // TLBI
    trap = write && HCR.TTLB == '1';
elsif ((op == SystemAccessType_RT && opc1 == 0 && CRn == 7 && CRm == 0 && opc2 == 2) || // DCR
       (op == SystemAccessType_RT && opc1 == 0 && CRn == 7 && CRm == 10 && opc2 == 2)) then // DCR
    trap = write && HCR.TSW == '1';
end
elsif ((op == SystemAccessType_RT && opc1 == 0 && CRn == 7 && CRm == 6 && opc2 == 1) || // DCMVAC
(op == SystemAccessType_RT && opc1 == 0 && CRn == 7 && CRm == 10 && opc2 == 1) ||    // DCCMVAC
(op == SystemAccessType_RT && opc1 == 0 && CRn == 7 && CRm == 14 && opc2 == 1)) then // DCCIMVAC
trap = write && HCR.TPC == '1';

elsif ((op == SystemAccessType_RT && opc1 == 0 && CRn == 7 && CRm == 5 && opc2 == 1) ||  // ICIMVAU
(op == SystemAccessType_RT && opc1 == 0 && CRn == 7 && CRm == 5 && opc2 == 0) ||     // ICIALLU
(op == SystemAccessType_RT && opc1 == 0 && CRn == 7 && CRm == 1 && opc2 == 0) ||     // ICIALLUIS
(op == SystemAccessType_RT && opc1 == 0 && CRn == 7 && CRm == 11 && opc2 == 1)) then // DCCMVAU
trap = write && HCR.TPU == '1';

elsif ((op == SystemAccessType_RT && opc1 == 0 && CRn == 1 && CRm == 0 && opc2 == 1) ||   // ACTLR
(op == SystemAccessType_RT && opc1 == 0 && CRn == 1 && CRm == 0 && opc2 == 3)) then   // ACTLR2
trap = HCR.TAC == '1';

elsif ((op == SystemAccessType_RT && opc1 == 0 && CRn == 0 && CRm == 0 && opc2 == 2) ||  // TCMTR
(op == SystemAccessType_RT && opc1 == 0 && CRn == 0 && CRm == 0 && opc2 == 3) ||     // TLBTR
(op == SystemAccessType_RT && opc1 == 0 && CRn == 0 && CRm == 0 && opc2 == 6) ||     // REVIDR
(op == SystemAccessType_RT && opc1 == 1 && CRn == 0 && CRm == 0 && opc2 == 7)) then  // AIDR
trap = HCR.TID1 == '1';

elsif ((op == SystemAccessType_RT && opc1 == 0 && CRn == 0 && CRm == 1) ||               // ID_ *
(op == SystemAccessType_RT && opc1 == 0 && CRn == 0 && CRm == 2 && opc2 <= 7) ||     // ID_ *
(op == SystemAccessType_RT && opc1 == 0 && CRn == 0 && CRm >= 3 && opc2 <= 1) ||     // Reserved
(op == SystemAccessType_RT && opc1 == 0 && CRn == 0 && CRm == 3 && opc2 == 2) ||     // Reserved
(op == SystemAccessType_RT && opc1 == 0 && CRn == 0 && CRm == 5 && opc2 IN {4,5})) then  // Reserved
trap = HCR.TID3 == '1';

elsif op == SystemAccessType_RT && opc1 == 0 && CRn == 1 && CRm == 0 && opc2 == 2 then   // CPACR
trap = HCPTR.TCPAC == '1';

elsif op == SystemAccessType_RT && opc1 == 0 && CRn == 9 && CRm == 12 && opc2 == 0 then  // PMCR
trap = HDCR.TPMCR == '1' || HDCR.TPM == '1';

elsif ((op == SystemAccessType_RT && opc1 == 0 && CRn == 14 && CRm >= 8) ||      // PMEVCNTR<n>/PMEVTYPER<n>
(op == SystemAccessType_RT && opc1 == 0 && CRn == 9 && CRm IN {12,13,14}) || // PM*
(op == SystemAccessType_RT && opc1 == 0 && CRn == 14 && CRm IN {12,13,14}) || // PMCCNTR (MRRC/MCCR)
trap = HDCR.TPM == '1';

elsif op == SystemAccessType_RT && opc1 == 0 && CRn == 14 && CRm == 2 && opc2 IN {0,1,2} then      // CNTP_TVAL CNTP_CTL CNTP_CVAL
trap = CNTHCTL.PL1PCEN == '0';

elsif op == SystemAccessType_RT && opc1 == 0 && CRn == 14 && CRm == 12 && opc2 == 0 then // PMCFR
trap = HDCR.TPMCR == '1' || HDCR.TPM == '1';

elsif ((op == SystemAccessType_RT && opc1 == 0 && CRn == 14 && CRm == 9)) then // PMEVCNTR (MRRC/MCCR)
trap = HDCR.TPM == '1';

elsif op == SystemAccessType_RT && opc1 == 0 && CRn == 14 && CRm == 2 && opc2 IN {0,1,2} then
trap = HCPTR.TCPAC == '1';

if trap then
AArch32.AArch32SystemAccessTrap(EL2, instr);
Library pseudocode for aarch32/functions/coproc/AArch32.CheckSystemAccessTraps

// AArch32.CheckSystemAccessTraps()
// ================================
// Check for configurable disables or traps to a higher EL of an System register access.
AArch32.CheckSystemAccessTraps(bits(32) instr)
  if PSTATE.EL == EL0 then
    AArch32.CheckSystemAccessEL1Traps(instr);
  if EL2Enabled() && PSTATE.EL IN {EL0, EL1, EL2} && !IsInHost() then
    AArch32.CheckSystemAccessEL2Traps(instr);
  if HaveEL(EL3) && !ELUsingAArch32(EL3) && PSTATE.EL IN {EL0, EL1, EL2} then
    AArch64.CheckAArch32SystemAccessEL3Traps(instr);

Library pseudocode for aarch32/functions/coproc/AArch32.DecodeSysRegAccess

// AArch32.DecodeSysRegAccess()
// ============================
// Decode an AArch32 System register access instruction into its operands.
(SystemAccessType, integer, integer, integer, integer, integer, boolean) AArch32.DecodeSysRegAccess(bits(32) instr)
  cp_num = UInt(instr<11:8>);
  // Decode the AArch32 System register access instruction
  if instr<31:28> != '1111' && instr<27:24> == '1110' && instr<4> == '1' then // MRC/MCR
    op = SystemAccessType_RT;
    opc1 = UInt(instr<23:21>);
    opc2 = UInt(instr<7:5>);
    CRn = UInt(instr<19:16>);
    CRm = UInt(instr<3:0>);
    write = instr<20> == '0';
  elsif instr<31:28> != '1111' && instr<27:21> == '1100010' then // MRRC/MCRR
    op = SystemAccessType_RRT;
    opc1 = UInt(instr<7:4>);
    CRm = UInt(instr<3:0>);
    write = instr<20> == '0';
  elsif instr<31:28> != '1111' && instr<27:25> == '110' then // LDC/STC
    op = SystemAccessType_DT;
    CRn = UInt(instr<15:12>);
    write = instr<20> == '0';
  return (op, cp_num, opc1, CRn, CRm, opc2, write);

Library pseudocode for aarch32/functions/coproc/CP14DebugInstrDecode

// Decodes an accepted access to a debug System register in the CP14 encoding space.
// Returns TRUE if the instruction is allocated at the current Exception level, FALSE otherwise.
boolean CP14DebugInstrDecode(bits(32) instr);

Library pseudocode for aarch32/functions/coproc/CP14JazelleInstrDecode

// Decodes an accepted access to a Jazelle System register in the CP14 encoding space.
// Returns TRUE if the instruction is allocated at the current Exception level, FALSE otherwise.
boolean CP14JazelleInstrDecode(bits(32) instr);

Library pseudocode for aarch32/functions/coproc/CP14TraceInstrDecode

// Decodes an accepted access to a trace System register in the CP14 encoding space.
// Returns TRUE if the instruction is allocated at the current Exception level, FALSE otherwise.
boolean CP14TraceInstrDecode(bits(32) instr);
Library pseudocode for aarch32/functions/coproc/CP15InstrDecode

// Decodes an accepted access to a System register in the CP15 encoding space.
// Returns TRUE if the instruction is allocated at the current Exception level, FALSE otherwise.
boolean CP15InstrDecode(bits(32) instr);

Library pseudocode for aarch32/functions/exclusive/AArch32.ExclusiveMonitorsPass

// AArch32.ExclusiveMonitorsPass()
// ----------------------------------------
// Return TRUE if the Exclusives monitors for the current PE include all of the addresses
// associated with the virtual address region of size bytes starting at address.
// The immediately following memory write must be to the same addresses.

boolean AArch32.ExclusiveMonitorsPass(bits(32) address, integer size)

  // It is IMPLEMENTATION DEFINED whether the detection of memory aborts happens
  // before or after the check on the local Exclusives monitor. As a result a failure
  // of the local monitor can occur on some implementations even if the memory
  // access would give an memory abort.

  acctype = AccType_ATOMIC;
  iswrite = TRUE;
  aligned = (address == Align(address, size));
  if !aligned then
    secondstage = FALSE;
    AArch32.Abort(address, AArch32.AlignmentFault(acctype, iswrite, secondstage));
  
  passed = AArch32.IsExclusiveVA(address, ProcessorID(), size);
  if !passed then
    return FALSE;
  memaddrdesc = AArch32.TranslateAddress(address, acctype, iswrite, aligned, size);

  // Check for aborts or debug exceptions
  if IsFault(memaddrdesc) then
    AArch32.Abort(address, memaddrdesc.fault);
  passed = IsExclusiveLocal(memaddrdesc.paddress, ProcessorID(), size);
  if passed then
    ClearExclusiveLocal(ProcessorID());
    if memaddrdesc.memattrs.shareable then
      passed = IsExclusiveGlobal(memaddrdesc.paddress, ProcessorID(), size);
  return passed;

Library pseudocode for aarch32/functions/exclusive/AArch32.IsExclusiveVA

// An optional IMPLEMENTATION DEFINED test for an exclusive access to a virtual
// address region of size bytes starting at address.
// It is permitted (but not required) for this function to return FALSE and
// cause a store exclusive to fail if the virtual address region is not
// totally included within the region recorded by MarkExclusiveVA().
// It is always safe to return TRUE which will check the physical address only.
boolean AArch32.IsExclusiveVA(bits(32) address, integer processorid, integer size);

Library pseudocode for aarch32/functions/exclusive/AArch32.MarkExclusiveVA

// Optionally record an exclusive access to the virtual address region of size bytes
// starting at address for processorid.
AArch32.MarkExclusiveVA(bits(32) address, integer processorid, integer size);
// AArch32.SetExclusiveMonitors()
// ---------------------------------------------

// Sets the Exclusives monitors for the current PE to record the addresses associated
// with the virtual address region of size bytes starting at address.

AArch32.SetExclusiveMonitors(bits(32) address, integer size)

acctype = AccType_ATOMIC;
iswrite = FALSE;
aligned = (address == Align(address, size));
memaddrdesc = AArch32.TranslateAddress(address, acctype, iswrite, aligned, size);

// Check for aborts or debug exceptions
if IsFault(memaddrdesc) then
    return;

if memaddrdesc.memattrs.shareable then
    MarkExclusiveGlobal(memaddrdesc.paddress, ProcessorID(), size);
    MarkExclusiveLocal(memaddrdesc.paddress, ProcessorID(), size);
AArch32.MarkExclusiveVA(address, ProcessorID(), size);

// CheckAdvSIMDEnabled()
// ---------------------

CheckAdvSIMDEnabled()

fpexc_check = TRUE;
advsimd = TRUE;

AArch32.CheckAdvSIMDOrFPEnabled(fpexc_check, advsimd);

// Make temporary copy of D registers
// _Dclone[] is used as input data for instruction pseudocode
for i = 0 to 31
    _Dclone[i] = D[i];

return;

// CheckAdvSIMDOrVFPEnabled()
// --------------------------

CheckAdvSIMDOrVFPEnabled(boolean include_fpexc_check, boolean advsimd)

AArch32.CheckAdvSIMDOrFPEnabled(include_fpexc_check, advsimd);

// Return from CheckAdvSIMDOrVFPEnabled() occurs only if VFP access is permitted
return;

// CheckCryptoEnabled32()
// -----------------------

CheckCryptoEnabled32()

// Return from CheckAdvSIMDEnabled() occurs only if access is permitted
return;
Library pseudocode for aarch32/functions/float/CheckVFPEnabled

```c
// CheckVFPEnabled()
// =============

CheckVFPEnabled(boolean include_fpexc_check)
    advsimd = FALSE;
    AArch32.CheckAdvSIMDOrFPEnabled(include_fpexc_check, advsimd);
    // Return from CheckAdvSIMDOrFPEnabled() occurs only if VFP access is permitted
    return;
```

Library pseudocode for aarch32/functions/float/FPHalvedSub

```c
// FPHalvedSub()
// =============

bits(N) FPHalvedSub(bits(N) op1, bits(N) op2, FPCRType fpcr)
    assert N IN {16,32,64};
    rounding = FPRoundingMode(fpcr);
    (type1,sign1,value1) = FPUnpack(op1, fpcr);
    (type2,sign2,value2) = FPUnpack(op2, fpcr);
    (done,result) = FPProcessNaNs(type1, type2, op1, op2, fpcr);
    if !done then
        inf1 = (type1 == FPTYPE_INFINITY); inf2 = (type2 == FPTYPE_INFINITY);
        zero1 = (type1 == FPTYPE_ZERO); zero2 = (type2 == FPTYPE_ZERO);
        if inf1 && inf2 && sign1 == sign2 then
            result = FPDefaultNaN();
            FPProcessException(FPExc_InvalidOp, fpcr);
        elsif (inf1 && sign1 == '0') || (inf2 && sign2 == '1') then
            result = FPIInfinity('0');
        elsif (inf1 && sign1 == '1') || (inf2 && sign2 == '0') then
            result = FPIInfinity('1');
        elsif zero1 && zero2 && sign1 != sign2 then
            result = FPZero(sign1);
        else
            result_value = (value1 - value2) / 2.0;
            if result_value == 0.0 then 
                result_sign = if rounding == FPRounding_NEGINF then '1' else '0';
                result = FPZero(result_sign);
            else
                result = FPRound(result_value, fpcr);
        end
    end
    return result;
```

Library pseudocode for aarch32/functions/float/FPRSqrtStep

```c
// FPRSqrtStep()
// =============

bits(N) FPRSqrtStep(bits(N) op1, bits(N) op2)
    assert N IN {16,32};
    FPCRType fpcr = StandardFPSCRValue();
    (type1,sign1,value1) = FPUnpack(op1, fpcr);
    (type2,sign2,value2) = FPUnpack(op2, fpcr);
    (done,result) = FPProcessNaNs(type1, type2, op1, op2, fpcr);
    if !done then
        inf1 = (type1 == FPTYPE_INFINITY); inf2 = (type2 == FPTYPE_INFINITY);
        zero1 = (type1 == FPTYPE_ZERO); zero2 = (type2 == FPTYPE_ZERO);
        bits(N) product;
        if (inf1 && zero2) || (zero1 && inf2) then
            product = FPZero('0');
        else
            product = FPMul(op1, op2, fpcr);
        end
        three = FPThree('0');
        result = FPHalvedSub(three, product, fpcr);
    end
    return result;
```
Library pseudocode for aarch32/functions/float/FPRecipStep

```c
// FPRecipStep()
// =============

bits(N) FPRecipStep(bits(N) op1, bits(N) op2)
assert N IN {16,32};
FPCRType fpcr = StandardFPSCRValue();
(type1,sign1,value1) = FPUnpack(op1, fpcr);
(type2,sign2,value2) = FPUnpack(op2, fpcr);
(done,result) = FPProcessNaNs(type1, type2, op1, op2, fpcr);
if !done then
   inf1 = (type1 == FPTYPE_Infinity);  inf2 = (type2 == FPTYPE_Infinity);
   zero1 = (type1 == FPTYPE_Zero);     zero2 = (type2 == FPTYPE_Zero);
   bits(N) product;
   if (inf1 && zero2) || (zero1 && inf2) then
      product = FPZero('0');
   else
      product = FPMul(op1, op2, fpcr);
   return product;
   bits(N) two = FPTwo('0');
   result = FPSub(two, product, fpcr);
return result;
```

Library pseudocode for aarch32/functions/float/StandardFPSCRValue

```c
// StandardFPSCRValue()
// ====================

FPCRType StandardFPSCRValue()
return '00000' : FPSCR.AHP : '110000' : FPSCR.FZ16 : '0000000000000000000';
```

Library pseudocode for aarch32/functions/memory/AArch32.CheckAlignment

```c
// AArch32.CheckAlignment()
// ========================

boolean AArch32.CheckAlignment(bits(32) address, integer alignment, AccType acctype, boolean iswrite)
if PSTATE.EL == EL0 && !ELUsingAArch32(S1TranslationRegime()) then
   A = SCTLR[].A; //use AArch64 register, when higher Exception level is using AArch64
elsif PSTATE.EL == EL2 then
   A = HSCTLR.A;
else
   A = SCTLR.A;
aligned = (address == Align(address, alignment));
atomic = acctype IN { AccType_ATOMIC, AccType_ATOMICRW,};
ordered = acctype IN { AccType.ORDERED, AccType.ORDEREDRW, AccType.LIMITEDORDERED, AccType.ORDEREDATOMIC, AccType.ORDEREDATOMICRW,};
vector = acctype == AccType.VEC;
// AccType_VEC is used for SIMD element alignment checks only
check = (atomic || ordered || vector || A == '1');
if check && !aligned then
   secondstage = FALSE;
   AArch32.Abort(address, AArch32.AlignmentFault(acctype, iswrite, secondstage));
return aligned;
```
// AArch32.MemSingle[] - non-assignment (read) form
// ---------------------------------------------------------------------
// Perform an atomic, little-endian read of 'size' bytes.

bits(size*8) AArch32.MemSingle{bits(32) address, integer size, AccType acctype, boolean wasaligned} =
assert size IN {1, 2, 4, 8, 16};
assert address == Align(address, size);

AddressDescriptor memaddrdesc;
bits(size*8) value;
iswrite = FALSE;

// MMU or MPU
memaddrdesc = AArch32.TranslateAddress(address, acctype, iswrite, wasaligned, size);
// Check for aborts or debug exceptions
if IsFault(memaddrdesc) then
    AArch32.Abort(address, memaddrdesc.fault);

// Memory array access
accdesc = CreateAccessDescriptor(acctype);
if accdesc = HaveMTEExtCreateAccessDescriptor() then
    if (!acctype)
        value = _Mem[memaddrdesc, size, accdesc];
    return value;

// AArch32.MemSingle[] - assignment (write) form
// ---------------------------------------------------------------------
// Perform an atomic, little-endian write of 'size' bytes.

AArch32.MemSingle{bits(32) address, integer size, AccType acctype, boolean wasaligned} = bits(size*8) value
assert size IN {1, 2, 4, 8, 16};
assert address == Align(address, size);

AddressDescriptor memaddrdesc;
iswrite = TRUE;

// MMU or MPU
memaddrdesc = AArch32.TranslateAddress(address, acctype, iswrite, wasaligned, size);
// Check for aborts or debug exceptions
if IsFault(memaddrdesc) then
    AArch32.Abort(address, memaddrdesc.fault);

// Effect on exclusives
if memaddrdesc.memattrs.shareable then
    ClearExclusiveByAddress(memaddrdesc.paddress, ProcessorID(), size);

// Memory array access
accdesc = CreateAccessDescriptor(acctype);
if accdesc = HaveMTEExtCreateAccessDescriptor() then
    if AccessIsTagChecked(ZeroExtend(address, 64), acctype) then
        bits(4) ptag = TransformTag(ZeroExtend(address, 64));
        if !CheckTag(memaddrdesc, ptag, iswrite) then
            TagCheckFail(ZeroExtend(address, 64), iswrite);
        value = _Mem[memaddrdesc, size, accdesc];
        return value;

// AArch32.MemSingle[] - assignment (write) form
// ---------------------------------------------------------------------
// Perform an atomic, little-endian write of 'size' bytes.

AArch32.MemSingle{bits(32) address, integer size, AccType acctype, boolean wasaligned} = bits(size*8) value
assert size IN {1, 2, 4, 8, 16};
assert address == Align(address, size);

AddressDescriptor memaddrdesc;
iswrite = TRUE;

// MMU or MPU
memaddrdesc = AArch32.TranslateAddress(address, acctype, iswrite, wasaligned, size);
// Check for aborts or debug exceptions
if IsFault(memaddrdesc) then
    AArch32.Abort(address, memaddrdesc.fault);

// Effect on exclusives
if memaddrdesc.memattrs.shareable then
    ClearExclusiveByAddress(memaddrdesc.paddress, ProcessorID(), size);

// Memory array access
accdesc = CreateAccessDescriptor(acctype);
if accdesc = HaveMTEExtCreateAccessDescriptor() then
    if AccessIsTagChecked(ZeroExtend(address, 64), acctype) then
        bits(4) ptag = TransformTag(ZeroExtend(address, 64));
        if !CheckTag(memaddrdesc, ptag, iswrite) then
            TagCheckFail(ZeroExtend(address, 64), iswrite);
    value = _Mem[memaddrdesc, size, accdesc];
    return;
Library pseudocode for aarch32/functions/memory/AddressWithAllocationTag

```c
// AddressWithAllocationTag()
// =========================
// Generate a 64-bit value containing a Logical Address Tag from a 64-bit
// virtual address and an Allocation Tag.
// If the extension is disabled, treats the Allocation Tag as '000000'.

bits(64) AddressWithAllocationTag(bits(64) address, bits(4) allocation_tag)
bits(64) result = address;
bits(4) tag = allocation_tag - ('000':address<55>);
result<59:56> = tag;
return result;
```

Library pseudocode for aarch32/functions/memory/AllocationTagFromAddress

```c
// AllocationTagFromAddress()
// ===========================
// Generate a Tag from a 64-bit value containing a Logical Address Tag.
// If access to Allocation Tags is disabled, this function returns '000000'.

bits(4) AllocationTagFromAddress(bits(64) tagged_address)
bits(4) logical_tag = tagged_address<59:56>;
bits(4) tag = logical_tag + ('000':tagged_address<55>);
return tag;
```

Library pseudocode for aarch32/functions/memory/CheckTag

```c
// CheckTag()
// =========
// Performs a Tag Check operation for a memory access and returns
// whether the check passed.

boolean CheckTag(AddressDescriptor memaddrdesc, bits(4) ptag, boolean write)
if memaddrdesc.memattrs.tagged then
    bits(64) paddress = ZeroExtend(memaddrdesc.paddress.address);
    return ptag == MemTag[paddress];
else
    return TRUE;
```

Library pseudocode for aarch32/functions/memory/Hint_PreloadData

```c
Hint_PreloadData(bits(32) address);
```

Library pseudocode for aarch32/functions/memory/Hint_PreloadDataForWrite

```c
Hint_PreloadDataForWrite(bits(32) address);
```

Library pseudocode for aarch32/functions/memory/Hint_PreloadInstr

```c
Hint_PreloadInstr(bits(32) address);
```
Library pseudocode for aarch32/functions/memory/MemA

// MemA[] - non-assignment form
// -----------------------------------

bits(8*size) MemA[bits(32) address, integer size]
    acctype = AccType_ATOMIC;
    return Mem_with_type[address, size, acctype];

// MemA[] - assignment form
// -----------------------------------

MemA[bits(32) address, integer size] = bits(8*size) value
    acctype = AccType_ATOMIC;
    Mem_with_type[address, size, acctype] = value;
    return;

Library pseudocode for aarch32/functions/memory/MemO

// MemO[] - non-assignment form
// -----------------------------------

bits(8*size) MemO[bits(32) address, integer size]
    acctype = AccType_ORDERED;
    return Mem_with_type[address, size, acctype];

// MemO[] - assignment form
// -----------------------------------

MemO[bits(32) address, integer size] = bits(8*size) value
    acctype = AccType_ORDERED;
    Mem_with_type[address, size, acctype] = value;
    return;
Library pseudocode for aarch32/functions/memory/MemTag

```
// MemTag[] - non-assignment (read) form
// -----------------------------------------------
// Load an Allocation Tag from memory.

bits(4) MemTag[bits(64) address]
    AddressDescriptor memaddrdesc;
    bits(4) value;
    iswrite = FALSE;

    memaddrdesc = AArch64.TranslateAddress(address, AccType_NORMAL, iswrite, TRUE, TAG_GRANULE);
    // Check for aborts or debug exceptions
    if IsFault(memaddrdesc) then
        AArch64.Abort(address, memaddrdesc.fault);

    // Return the granule tag if tagging is enabled...
    if AllocationTagAccessIsEnabled() then
        return MemTag[memaddrdesc];
    else
        // ...otherwise read tag as zero.
        return '0000';
```

```
// MemTag[] - assignment (write) form
// ---------------------------------------------
// Store an Allocation Tag to memory.

MemTag[bits(64) address] = bits(4) value
    AddressDescriptor memaddrdesc;
    iswrite = TRUE;

    // Stores of allocation tags must be aligned
    if address != Align(address, TAG_GRANULE) then
        boolean secondstage = FALSE;
        AArch64.Abort(address, AArch64.AlignmentFault(AccType_NORMAL, iswrite, secondstage));

    wasaligned = TRUE;
    memaddrdesc = AArch64.TranslateAddress(address, AccType_NORMAL, iswrite, wasaligned, TAG_GRANULE);

    // Check for aborts or debug exceptions
    if IsFault(memaddrdesc) then
        AArch64.Abort(address, memaddrdesc.fault);

    // Memory array access
    if AllocationTagAccessIsEnabled() then
        MemTag[memaddrdesc] = value;
```

Library pseudocode for aarch32/functions/memory/MemU

```
// MemU[] - non-assignment form
// ---------------------------------
bits(8*size) MemU[bits(32) address, integer size]
    acctype = AccType_NORMAL;
    return Mem_with_type[address, size, acctype];
```

```
// MemU[] - assignment form
// ---------------------------------
MemU[bits(32) address, integer size] = bits(8*size) value
    acctype = AccType_NORMAL;
    Mem_with_type[address, size, acctype] = value;
    return;
```
Library pseudocode for aarch32/functions/memory/MemU_unpriv

// MemU_unpriv[] - non-assignment form
// -----------------------------------------

bits(8*\text{size}) \text{MemU}_\text{unpriv}[\text{bits}(32) \text{ address, integer size}]
\text{acctype} = \text{AccType}_\text{UNPRIV};
\text{return Mem}_{\text{with type}}[\text{address, size, acctype}];

// MemU_unpriv[] - assignment form
// ---------------------------------

\text{MemU}_\text{unpriv}[\text{bits}(32) \text{ address, integer size}] = \text{bits}(8*\text{size}) \text{ value}
\text{acctype} = \text{AccType}_\text{UNPRIV};
\text{Mem}_{\text{with type}}[\text{address, size, acctype}] = \text{value};
\text{return};
// Mem_with_type[] - non-assignment (read) form
// ---------------------------------------------
// Perform a read of 'size' bytes. The access byte order is reversed for a big-endian access.
// Instruction fetches would call AArch32.MemSingle directly.

bits(size*8) Mem_with_type[bits(32) address, integer size, AccType acctype]
    assert size IN {1, 2, 4, 8, 16};
    bits(size*8) value;
    integer i;
    boolean iswrite = FALSE;

    aligned = AArch32.CheckAlignment(address, size, acctype, iswrite);
    if !aligned then
        assert size > 1;
        value<7:0> = AArch32.MemSingle[address, 1, acctype, aligned];
        // For subsequent bytes it is CONSTRAINED UNPREDICTABLE whether an unaligned Device memory
        // access will generate an Alignment Fault, as to get this far means the first byte did
        // not, so we must be changing to a new translation page.
        c = ConstrainUnpredictable(Unpredictable_DEVPAGE2);
        assert c IN {Constraint_FAULT, Constraint_NONE};
        if c == Constraint_NONE then aligned = TRUE;
        for i = 1 to size-1
            value<8*i+7:8*i> = AArch32.MemSingle[address+i, 1, acctype, aligned];
        else
            value = AArch32.MemSingle[address, size, acctype, aligned];
            if (HaveNV2Ext() && acctype == AccType_NV2REGISTER && SCTLR_EL2.EE == '1') || BigEndian() then
                value = BigEndianReverse(value);
        return value;

// Mem_with_type[] - assignment (write) form
// -----------------------------------------
// Perform a write of 'size' bytes. The byte order is reversed for a big-endian access.

Mem_with_type[bits(32) address, integer size, AccType acctype] = bits(size*8) value
    integer i;
    boolean iswrite = TRUE;
    if (HaveNV2Ext() || acctype == AccType_NV2REGISTER) = bits(size*8) value
        boolean iswrite = TRUE;
    if (SCTLR_EL2.EE == '1') || BigEndian() then
        value = BigEndianReverse(value);

    aligned = AArch32.CheckAlignment(address, size, acctype, iswrite);
    if !aligned then
        assert size > 1;
        AArch32.MemSingle[address, 1, acctype, aligned] = value<7:0>;
        // For subsequent bytes it is CONSTRAINED UNPREDICTABLE whether an unaligned Device memory
        // access will generate an Alignment Fault, as to get this far means the first byte did
        // not, so we must be changing to a new translation page.
        c = ConstrainUnpredictable(Unpredictable_DEVPAGE2);
        assert c IN {Constraint_FAULT, Constraint_NONE};
        if c == Constraint_NONE then aligned = TRUE;
        for i = 1 to size-1
            AArch32.MemSingle[address+i, 1, acctype, aligned] = value<8*i+7:8*i>;
        else
            AArch32.MemSingle[address, size, acctype, aligned] = value;
        return;
Library pseudocode for aarch32/functions/memory/TransformTag

```c
// TransformTag()
// ==============
// Apply tag transformation rules.
bits(4) TransformTag(bits(64) vaddr)
  bits(4) vtag = vaddr<59:56>;
  bits(4) tagdelta = ZeroExtend(vaddr<55>);
  bits(4) ptag = vtag + tagdelta;
  return ptag;
```

Library pseudocode for aarch32/functions/memory/boolean

```c
// boolean AccessIsTagChecked()
// ============================
// TRUE if a given access is tag-checked, FALSE otherwise.
boolean AccessIsTagChecked(bits(64) vaddr, AccType acctype)
  if PSTATE.M<4> == '1' then return FALSE;
  if EffectiveTBI(vaddr, FALSE, PSTATE.EL) == '0' then
    return FALSE;
  if EffectiveTCMA(vaddr, PSTATE.EL) == '1' && (vaddr<59:55> == '00000' || vaddr<59:55> == '11111') then
    return FALSE;
  if !AllocationTagAccessIsEnabled() then
    return FALSE;
  if acctype IN {AccType_IFETCH, AccType_PTW} then
    return FALSE;
  if acctype == AccType_NV2REGISTER then
    return FALSE;
  if PSTATE.TCO=='1' then
    return FALSE;
  if IsNonTagCheckedInstruction() then
    return FALSE;
  return TRUE;
```
// AArch32.ESBOperation()
// AArch32.ESBOperation()

// Check if routed to AArch64 state
route_to_aarch64 = PSTATE.EL == EL0 && !ELUsingAArch32(EL1);
if !route_to_aarch64 && EL2Enabled() && !ELUsingAArch32(EL2) then
    route_to_aarch64 = HCR_EL2.TGE == '1' || HCR_EL2.AMO == '1';
if !route_to_aarch64 && HaveEL(EL3) && !ELUsingAArch32(EL3) then
    route_to_aarch64 = SCR_EL3.EA == '1';
if route_to_aarch64 then
    AArch64.ESBOperation();
    return;

route_to_monitor = HaveEL(EL3) && ELUsingAArch32(EL3) && SCR.EA == '1';
route_to_hyp = EL2Enabled() && PSTATE.EL IN {EL0, EL1} && (HCR.TGE == '1' || HCR.AMO == '1');
if route_to_monitor then
target = M32_Monitor;
elsif route_to_hyp || PSTATE.M == M32_Hyp then
target = M32_Hyp;
else
target = M32_Abort;
if IsSecure() then
    mask_active = TRUE;
elsif target == M32_Monitor then
    mask_active = SCR.AW == '1' && (!HaveEL(EL2) || (HCR.TGE == '0' && HCR.AMO == '0'));
else
    mask_active = target == M32_Abort || PSTATE.M == M32_Hyp;
mask_set = PSTATE.A == '1';
(-, el) = ELFromM32(target);
intdis = Halted() || ExternalDebugInterruptsDisabled(el);
masked = intdis || (mask_active && mask_set);

// Check for a masked Physical SError pending
if IsPhysicalSErrorPending() && masked then
    syndrome32 = AArch32.PhysicalSErrorSyndrome();
    DISR = AArch32.ReportDeferredSError(syndrome32.AET, syndrome32.ExT);
    ClearPendingPhysicalSError();
    return;

// Return the SError syndrome
AArch32.SErrorSyndrome AArch32.PhysicalSErrorSyndrome();
Library pseudocode for aarch32/functions/ras/AArch32.ReportDeferredSError

```c
// AArch32.ReportDeferredSError()
// -----------------------------------------------
// Return deferred SError syndrome

bits(32) AArch32.ReportDeferredSError(bits(2) AET, bit ExT)
bits(32) target;
target<31> = '1';  // A
syndrome = Zeros(16);
if PSTATE.EL == EL2 then
    syndrome<11:10> = AET;  // AET
    syndrome<9> = ExT;  // EA
    syndrome<5:0> = '010001';  // DFSC
else
    syndrome<15:14> = AET;  // AET
    syndrome<12> = ExT;  // ExT
    syndrome<9> = TTBCR.EAE;  // LPAE
    if TTBCR.EAE == '1' then
        syndrome<5:0> = '010001';  // STATUS
        else
        syndrome<10,3:0> = '10110';  // FS
    if HaveAnyAArch64() then
        target<24:0> = ZeroExtend(syndrome);// Any RES0 fields must be set to zero
    else
        target<15:0> = syndrome;
return target;
```

Library pseudocode for aarch32/functions/ras/AArch32.SErrorSyndrome

```c
type AArch32.SErrorSyndrome is (bits(2) AET, bit ExT)
```

Library pseudocode for aarch32/functions/ras/AArch32.vESBOperation

```c
// AArch32.vESBOperation()
// ------------------------
// Perform the ESB operation for virtual SError interrupts executed in AArch32 state

AArch32.vESBOperation()
assert EL2Enabled() && PSTATE.EL IN {EL0, EL1};

// Check for EL2 using AArch64 state
if !ELUsingAArch32(EL2) then
    AArch64.vESBOperation();
return;

// If physical SError interrupts are routed to Hyp mode, and TGE is not set, then a virtual SError interrupt might be pending
vSEI_enabled = HCR.TGE == '0' && HCR.AMO == '1';
vSEI_pending = vSEI_enabled && HCR.VA == '1';
vintdis = Halted() || ExternalDebugInterruptsDisabled(EL1);
vmasked = vintdis || PSTATE.A == '1';

// Check for a masked virtual SError pending
if vSEI pending && vmskaged then
    VDISR = AArch32.ReportDeferredSError(VDFSR<15:14>, VDFSR<12>);
    HCR.VA = '0';  // Clear pending virtual SError
return;
```
// AArch32.ResetGeneralRegisters()
// -----------------------------------
AArch32.ResetGeneralRegisters()
    for i = 0 to 7
        \texttt{R[i]} = \texttt{bits(32) UNKNOWN};
    for i = 8 to 12
        \texttt{Rmode[i, M32 User]} = \texttt{bits(32) UNKNOWN};
        \texttt{Rmode[i, M32 FIQ]} = \texttt{bits(32) UNKNOWN};
    if \texttt{HaveEL(EL2)} then \texttt{Rmode[13, M32 Hyp]} = \texttt{bits(32) UNKNOWN}; // No R14_hyp
    for i = 13 to 14
        \texttt{Rmode[i, M32 User]} = \texttt{bits(32) UNKNOWN};
        \texttt{Rmode[i, M32 FIQ]} = \texttt{bits(32) UNKNOWN};
        \texttt{Rmode[i, M32 IRQ]} = \texttt{bits(32) UNKNOWN};
        \texttt{Rmode[i, M32 Svc]} = \texttt{bits(32) UNKNOWN};
        \texttt{Rmode[i, M32 Abort]} = \texttt{bits(32) UNKNOWN};
    if \texttt{HaveEL(EL3)} then \texttt{Rmode[i, M32 Monitor]} = \texttt{bits(32) UNKNOWN};
return;

// AArch32.ResetSIMDFPRegisters()
// ------------------------------
AArch32.ResetSIMDFPRegisters()
    for i = 0 to 15
        \texttt{Q[i]} = \texttt{bits(128) UNKNOWN};
return;

// AArch32.ResetSpecialRegisters()
// -------------------------------
AArch32.ResetSpecialRegisters()
    // AArch32 special registers
    \texttt{SPSR_fiq} = \texttt{bits(32) UNKNOWN};
    \texttt{SPSR_irq} = \texttt{bits(32) UNKNOWN};
    \texttt{SPSR_svc} = \texttt{bits(32) UNKNOWN};
    \texttt{SPSR_abt} = \texttt{bits(32) UNKNOWN};
    \texttt{SPSR_und} = \texttt{bits(32) UNKNOWN};
    if \texttt{HaveEL(EL2)} then
        \texttt{SPSR_hyp} = \texttt{bits(32) UNKNOWN};
        \texttt{ELR_hyp} = \texttt{bits(32) UNKNOWN};
    if \texttt{HaveEL(EL3)} then
        \texttt{SPSR_mon} = \texttt{bits(32) UNKNOWN};
    // External debug special registers
    \texttt{DLR} = \texttt{bits(32) UNKNOWN};
    \texttt{DSPSR} = \texttt{bits(32) UNKNOWN};
return;

AArch32.ResetSystemRegisters(boolean cold_reset);
Library pseudocode for aarch32/functions/registers/ALUExceptionReturn

// ALUExceptionReturn()
// -------------

ALUExceptionReturn(bits(32) address)
    if PSTATE.EL == EL2 then
        UNDEFINED;
    elsif PSTATE.M IN {M32_User, M32_System} then
        UNPREDICTABLE;  // UNDEFINED or NOP
    else
        AArch32.ExceptionReturn(address, SPSR());

Library pseudocode for aarch32/functions/registers/ALUWritePC

// ALUWritePC()
// ------------

ALUWritePC(bits(32) address)
    if CurrentInstrSet() == InstrSet_A32 then
        BXWritePC(address, address);
    else BranchType_INDIR();
    else
        BranchWritePC(address, BranchType_INDIR());

Library pseudocode for aarch32/functions/registers/BXWritePC

// BXWritePC()
// ===========

BXWritePC(bits(32) address, BXWritePC(bits(32) address)
    if address<0> == '1' then BranchType branch_type)
        SelectInstrSet(InstrSet T32);
        address<0> = '0';
    else
        SelectInstrSet(InstrSet A32);
        // For branches to an unaligned PC counter in A32 state, the processor takes the branch
        // and does one of:
        // * Forces the address to be aligned
        // * Leaves the PC unaligned, meaning the target generates a PC Alignment fault.
        if address<1> == '1' && ConstrainUnpredictableBool(Unpredictable_A32FORCEALIGNPC) then
            address<1> = '0';
        BranchTo(address, BranchType_UNKNOWN(address, branch_type));

Library pseudocode for aarch32/functions/registers/BranchWritePC

// BranchWritePC()
// ==============

BranchWritePC(bits(32) address, BranchWritePC(bits(32) address)
    if BranchType branch_type)
        if CurrentInstrSet() == InstrSet_A32 then
            address<1:0> = '00';
        else
            address<0> = '0';
        BranchTo(address, BranchType_UNKNOWN(address, branch_type));
Library pseudocode for aarch32/functions/registers/D

// D[] - non-assignment form
// =========================

bits(64) D[integer n]
assert n >= 0 && n <= 31;
base = (n MOD 2) * 64;
return _V[n DIV 2]<base+63:base>;

// D[] - assignment form
// =====================

D[integer n] = bits(64) value
assert n >= 0 && n <= 31;
base = (n MOD 2) * 64;
_V[n DIV 2]<base+63:base> = value;
return;

Library pseudocode for aarch32/functions/registers/Din

// Din[] - non-assignment form
// ===========================

bits(64) Din[integer n]
assert n >= 0 && n <= 31;
return _Dclone[n];

Library pseudocode for aarch32/functions/registers/LR

// LR - assignment form
// ====================

LR = bits(32) value
R[14] = value;
return;

// LR - non-assignment form
// ========================

bits(32) LR
return R[14];

Library pseudocode for aarch32/functions/registers/LoadWritePC

// LoadWritePC()
// =============

LoadWritePC(bits(32) address)
BXWritePC(address,(address); BranchType_INDIR);
// LookUpRIndex()
// ================

integer LookUpRIndex(integer n, bits(5) mode)
assert n >= 0 && n <= 14;
case n of // Select index by mode:  usr  fiq  irq  svc  abt  und  hyp
when 8  result = RBankSelect(mode, 8, 24, 8, 8, 8, 8, 8);
when 9  result = RBankSelect(mode, 9, 25, 9, 9, 9, 9, 9);
when 10 result = RBankSelect(mode, 10, 26, 10, 10, 10, 10, 10);
when 11 result = RBankSelect(mode, 11, 27, 11, 11, 11, 11, 11);
when 12 result = RBankSelect(mode, 12, 28, 12, 12, 12, 12, 12);
when 13 result = RBankSelect(mode, 13, 29, 17, 19, 21, 23, 15);
when 14 result = RBankSelect(mode, 14, 30, 16, 18, 20, 22, 14);
otherwise result = n;
return result;

Library pseudocode for aarch32/functions/registers/Monitor_mode_registers

bits(32) SP_mon;
b bits(32) LR_mon;

Library pseudocode for aarch32/functions/registers/PC

// PC - non-assignment form
// -------------------------

bits(32) PC
return R[15];  // This includes the offset from AArch32 state

Library pseudocode for aarch32/functions/registers/PCStoreValue

// PCStoreValue()
// ==============

bits(32) PCStoreValue()
// This function returns the PC value. On architecture versions before ARMv7, it
// is permitted to instead return PC+4, provided it does so consistently. It is
// used only to describe A32 instructions, so it returns the address of the current
// instruction plus 8 (normally) or 12 (when the alternative is permitted).
return PC;

Library pseudocode for aarch32/functions/registers/Q

// Q[] - non-assignment form
// -------------------------

bits(128) Q[integer n]
assert n >= 0 && n <= 15;
return _V[n];

// Q[] - assignment form
// ----------------------

Q[integer n] = bits(128) value
assert n >= 0 && n <= 15;
_V[n] = value;
return;
Library pseudocode for aarch32/functions/registers/Qin

```plaintext
// Qin[] - non-assignment form
// -----------------------------

bits(128) Qin[integer n]
assert n >= 0 && n <= 15;
return Din[2*n+1]:Din[2*n];
```

Library pseudocode for aarch32/functions/registers/R

```plaintext
// R[] - assignment form
// ----------------------

R[integer n] = bits(32) value
Rmode[n, PSTATE.M] = value;
return;

// R[] - non-assignment form
// -------------------------

bits(32) R[integer n]
if n == 15 then
    offset = (if CurrentInstrSet() == InstrSet_A32 then 8 else 4);
    return _PC<31:0> + offset;
else
    return Rmode[n, PSTATE.M];
```

Library pseudocode for aarch32/functions/registers/RBankSelect

```plaintext
// RBankSelect()
// --------------

integer RBankSelect(bits(5) mode, integer usr, integer fiq, integer irq,
integer svc, integer abt, integer und, integer hyp)

case mode of
    when M32_User result = usr; // User mode
    when M32_FIQ result = fiq; // FIQ mode
    when M32_IRQ result = irq; // IRQ mode
    when M32_Svc result = svc; // Supervisor mode
    when M32_Abort result = abt; // Abort mode
    when M32_Hyp result = hyp; // Hyp mode
    when M32.Undef result = und; // Undefined mode
    when M32_System result = usr; // System mode uses User mode registers
    otherwise Unreachable(); // Monitor mode

return result;
```
Library pseudocode for aarch32/functions/registers/Rmode

```c
// Rmode[] - non-assignment form
// -----------------------------------

bits(32) Rmode[integer n, bits(5) mode]
assert n >= 0 && n <= 14;

// Check for attempted use of Monitor mode in Non-secure state.
if !IsSecure() then assert mode != M32_Monitor;
assert !BadMode(mode);

if mode == M32_Monitor then
  if n == 13 then return SP_mon;
  elsif n == 14 then return LR_mon;
  else return _R[LookUpRIndex(n, mode)<31:0>];
else
  return _R[LookUpRIndex(n, mode)<31:0>];

// Rmode[] - assignment form
// -----------------------------------

Rmode[integer n, bits(5) mode] = bits(32) value
assert n >= 0 && n <= 14;

// Check for attempted use of Monitor mode in Non-secure state.
if !IsSecure() then assert mode != M32_Monitor;
assert !BadMode(mode);

if mode == M32_Monitor then
  if n == 13 then SP_mon = value;
  elsif n == 14 then LR_mon = value;
  else _R[n]<31:0> = value;
else
  // It is CONSTRAINED UNPREDICTABLE whether the upper 32 bits of the X
  // register are unchanged or set to zero. This is also tested for on
  // exception entry, as this applies to all AArch32 registers.
  if !HighestELUsingAArch32() && ConstrainUnpredictableBool(Unpredictable_ZEROUPPER) then
    _R[LookUpRIndex(n, mode)] = ZeroExtend(value);
  else
    _R[LookUpRIndex(n, mode)<31:0> = value;
  return;
```

Library pseudocode for aarch32/functions/registers/S

```c
// S[] - non-assignment form
// -----------------------------------

bits(32) S[integer n]
assert n >= 0 && n <= 31;
base = (n MOD 4) * 32;
return _V[n DIV 4]<base+31:base>;

// S[] - assignment form
// -----------------------------------

S[integer n] = bits(32) value
assert n >= 0 && n <= 31;
base = (n MOD 4) * 32;
_V[n DIV 4]<base+31:base> = value;
return;
```
Library pseudocode for aarch32/functions/registers/SP

```python
// SP - assignment form
// ====================
SP = bits(32) value
R[13] = value;
return;

// SP - non-assignment form
// ========================
bits(32) SP
return R[13];
```

Library pseudocode for aarch32/functions/registers/_Dclone

```python
array bits(64) _Dclone[0..31];
```

Library pseudocode for aarch32/functions/system/AArch32.ExceptionReturn

```python
// AArch32.ExceptionReturn()
// =========================
AArch32.ExceptionReturn(bits(32) new_pc, bits(32) spsr)

    SynchronizeContext();

    // Attempts to change to an illegal mode or state will invoke the Illegal Execution state
    // mechanism
    SetPSTATEFromPSR(spsr);
    ClearExclusiveLocal(ProcessorID());
    SendEventLocal();

    if PSTATE.IL == '1' then
        // If the exception return is illegal, PC[1:0] are UNKNOWN
        new_pc<1:0> = bits(2) UNKNOWN;
    else
        // LR[1:0] or LR[0] are treated as being 0, depending on the target instruction set state
        if PSTATE.T == '1' then
            new_pc<0> = '0';  // T32
        else
            new_pc<1:0> = '00';  // A32
        end

    BranchTo(new_pc, BranchType_ERET, BranchType_UNKNOWN);
```

Library pseudocode for aarch32/functions/system/AArch32.ExecutingATS1xPInstr

```python
// AArch32.ExecutingATS1xPInstr()
// ==============================
// Return TRUE if current instruction is AT S1CPR/WP

boolean AArch32.ExecutingATS1xPInstr()
if !HavePrivATExt() then return FALSE;

    instr = ThisInstr();
    if instr<24+:4> == '1110' && instr<8+:4> == '1110' then
        op1 = instr<21+:3>;
        CRn = instr<16+:4>;
        CRm = instr<0+:4>;
        op2 = instr<5+:3>;
        return (op1 == '000' && CRn == '0111' && CRm == '1001' && op2 IN {'000','001'});
    else
        return FALSE;
```
// AArch32.ExecutingCP10or11Instr()
// ---------------------------------------

boolean AArch32.ExecutingCP10or11Instr()
    instr = ThisInstr();
    instr_set = CurrentInstrSet();
    assert instr_set IN {InstrSet_A32, InstrSet_T32};
    if instr_set == InstrSet_A32 then
        return ((instr<27:24> == '1110' || instr<27:25> == '110') && instr<11:8> == '101x');
    else // InstrSet_T32
        return (instr<31:28> == '111x' && (instr<27:24> == '1110' || instr<27:25> == '110') && instr<11:8> == '101x');

// AArch32.ExecutingLSMInstr()
// ---------------------------
// Returns TRUE if processor is executing a Load/Store Multiple instruction

boolean AArch32.ExecutingLSMInstr()
    instr = ThisInstr();
    instr_set = CurrentInstrSet();
    assert instr_set IN {InstrSet_A32, InstrSet_T32};
    if instr_set == InstrSet_A32 then
        return (instr<28+:4> != '1111' && instr<25+:3> == '100');
    else // InstrSet_T32
        if ThisInstrLength() == 16 then
            return (instr<12+:4> == '1100');
        else
            return (instr<25+:7> == '1110100' && instr<22> == '0');

// AArch32.ITAdvance()
// -------------------

AArch32.ITAdvance()
    if PSTATE.IT<2:0> == '000' then
        PSTATE.IT = '00000000';
    else
        PSTATE.IT<4:0> = LSL(PSTATE.IT<4:0>, 1);
        return;

// AArch32.SysRegRead()
// ---------------------

AArch32.SysRegRead(integer cp_num, bits(32) instr);

// Read from a 32-bit AArch32 System register and return the register's contents.
bits(32) AArch32.SysRegRead64(integer cp_num, bits(32) instr);

// Read from a 64-bit AArch32 System register and return the register's contents.
bits(64) AArch32.SysRegRead6464(integer cp_num, bits(32) instr);
// AArch32.SysRegReadCanWriteAPSR()  
// ----------------------------------  
// Determines whether the AArch32 System register read instruction can write to APSR flags.

boolean AArch32.SysRegReadCanWriteAPSR(integer cp_num, bits(32) instr)
  assert UsingAArch32();
  assert (cp_num IN {14,15});
  assert cp_num == UInt(instr<11:8>);

  opc1 = UInt(instr<23:21>);
  opc2 = UInt(instr<7:5>);
  CRn = UInt(instr<19:16>);
  CRm = UInt(instr<3:0>);

  if cp_num == 14 && opc1 == 0 && CRn == 0 && CRm == 1 && opc2 == 0 then // DBGDSCRint
    return TRUE;
  return FALSE;

Library pseudocode for aarch32/functions/system/AArch32.SysRegWrite

// Write to a 32-bit AArch32 System register.
AArch32.SysRegWrite(integer cp_num, bits(32) instr, bits(32) val);

Library pseudocode for aarch32/functions/system/AArch32.SysRegWrite64

// Write to a 64-bit AArch32 System register.
AArch32.SysRegWrite64(integer cp_num, bits(32) instr, bits(64) val);

Library pseudocode for aarch32/functions/system/AArch32.WriteMode

// AArch32.WriteMode()
// -------------------
// Function for dealing with writes to PSTATE.M from AArch32 state only.
// This ensures that PSTATE.EL and PSTATE.SP are always valid.

AArch32.WriteMode(bits(5) mode)
  (valid,el) = ELFromM32(mode);
  assert valid;
  PSTATE.M = mode;
  PSTATE.EL = el;
  PSTATE.nRW = '1';
  PSTATE.SP = (if mode IN {M32_User, M32_System} then '0' else '1');
  return;
// AArch32.WriteModeByInstr()
// ==========================
// Function for dealing with writes to PSTATE.M from an AArch32 instruction, and ensuring that
// illegal state changes are correctly flagged in PSTATE.IL.

AArch32.WriteModeByInstr(bits(5) mode)
(valid,el) = ELFromM32(mode);

// 'valid' is set to FALSE if 'mode' is invalid for this implementation or the current value
// of SCR.NS/SCR_EL3.NS. Additionally, it is illegal for an instruction to write 'mode' to
// PSTATE.EL if it would result in any of:
// * A change to a mode that would cause entry to a higher Exception level.
if (UInt(el) > UInt(PSTATE.EL)) then
    valid = FALSE;

// * A change to or from Hyp mode.
if (PSTATE.M == M32_Hyp || mode == M32_Hyp) && PSTATE.M != mode then
    valid = FALSE;

// * When EL2 is implemented, the value of HCR.TGE is '1', a change to a Non-secure EL1 mode.
if PSTATE.M == M32_Monitor && HaveEL(EL2) && el == EL1 && SCR.NS == '1' && HCR.TGE == '1' then
    valid = FALSE;

if !valid then
    PSTATE.IL = '1';
else
    AArch32.WriteMode(mode);

Library pseudocode for aarch32/functions/system/BadMode

// BadMode()
// =========

boolean BadMode(bits(5) mode)
// Return TRUE if 'mode' encodes a mode that is not valid for this implementation
// case mode of
    when M32_Monitor
        valid = HaveAArch32EL(EL3);
    when M32_Hyp
        valid = HaveAArch32EL(EL2);
    when M32_FIQ, M32IRQ, M32Svc, M32Abort, M32Undef, M32System
        // If EL3 is implemented and using AArch32, then these modes are EL3 modes in Secure
        // state, and ELL modes in Non-secure state. If EL3 is not implemented or is using
        // AArch64, then these modes are EL1 modes.
        // Therefore it is sufficient to test this implementation supports EL1 using AArch32.
        valid = HaveAArch32EL(EL1);
    when M32_User
        valid = HaveAArch32EL(EL0);
    otherwise
        valid = FALSE;       // Passed an illegal mode value

return !valid;
// BankedRegisterAccessValid()
// -------------------------------------------
// Checks for MRS (Banked register) or MSR (Banked register) accesses to registers
// other than the SPSRs that are invalid. This includes ELR_hyp accesses.

BankedRegisterAccessValid(bits(5) SYSm, bits(5) mode)

case SYSm of
  when '000xx', '00100' // R8_usr to R12_usr
    if mode != M32_FIQ then UNPREDICTABLE;
  when '00101' // SP_usr
    if mode == M32_System then UNPREDICTABLE;
  when '00110' // LR_usr
    if mode IN {M32_Hyp, M32_System} then UNPREDICTABLE;
  when '010xx', '0110x', '01110' // R8_fiq to R12_fiq, SP_fiq, LR_fiq
    if mode == M32_FIQ then UNPREDICTABLE;
  when '1000x' // LR_irq, SP_irq
    if mode == M32_IRQ then UNPREDICTABLE;
  when '1001x' // LR_svc, SP_svc
    if mode == M32_Svc then UNPREDICTABLE;
  when '1010x' // LR_abt, SP_abt
    if mode == M32_Abort then UNPREDICTABLE;
  when '1011x' // LR_und, SP_und
    if mode == M32_Undef then UNPREDICTABLE;
  when '1110x' // LR_mon, SP_mon
    if !HaveEL(EL2) || !IsSecure() || mode == M32_Monitor then UNPREDICTABLE;
  when '11110' // ELR_hyp, only from Monitor or Hyp mode
    if !HaveEL(EL2) || !(mode IN {M32_Monitor, M32_Hyp}) then UNPREDICTABLE;
  when '11111' // SP_hyp, only from Monitor mode
    if !HaveEL(EL2) || mode != M32_Monitor then UNPREDICTABLE;
  otherwise
    UNPREDICTABLE;

return;
Library pseudocode for aarch32/functions/system/CPSRWriteByInstr

```c
// CPSRWriteByInstr()
// ================

CPSRWriteByInstr(bits(32) value, bits(4) bytemask)
{
privileged = PSTATE.EL != EL0; // PSTATE.<A,I,F,M> are not writable at EL0

// Write PSTATE from 'value', ignoring bytes masked by 'bytemask'
if bytemask<3> == '1' then
    PSTATE.<N,Z,C,V,Q> = value<31:27>; // Bits <26:24> are ignored

if bytemask<2> == '1' then
    // Bit <23> is RES0
    if privileged then
        PSTATE.PAN = value<22>;
        // Bits <21:20> are RES0
        PSTATE.GE = value<19:16>;
    if bytemask<1> == '1' then
        // Bits <15:10> are RES0
        PSTATE.E = value<9>; // PSTATE.E is writable at EL0
        if privileged then
            PSTATE.A = value<8>;
    if bytemask<0> == '1' then
        if privileged then
            PSTATE.<I,F> = value<7:6>; // Bit <5> is RES0
            // AArch32.WriteModeByInstr() sets PSTATE.IL to 1 if this is an illegal mode change.
            AArch32.WriteModeByInstr(value<4:0>);

return;
}
```

Library pseudocode for aarch32/functions/system/ConditionPassed

```c
// ConditionPassed()
// ============

boolean ConditionPassed()
{
return ConditionHolds(AArch32.CurrentCond());
}
```

Library pseudocode for aarch32/functions/system/CurrentCond

```c
bits(4) AArch32.CurrentCond();
```

Library pseudocode for aarch32/functions/system/InITBlock

```c
// InITBlock()
// =========

boolean InITBlock()
{
if CurrentInstrSet() == InstrSet_T32 then
    return PSTATE.IT<3:0> != '0000';
else
    return FALSE;
}
```

Library pseudocode for aarch32/functions/system/LastInITBlock

```c
// LastInITBlock()
// ===============

boolean LastInITBlock()
{
return (PSTATE.IT<3:0> == '1000');
}
```
Library pseudocode for aarch32/functions/system/SPSRWriteByInstr

// SPSRWriteByInstr()
// ================

SPSRWriteByInstr(bits(32) value, bits(4) bytemask)

new_spsr = SPSR[];

if bytemask<3> == '1' then
    new_spsr<31:24> = value<31:24>;  // N,Z,C,V,Q flags, IT[1:0],J bits

if bytemask<2> == '1' then

if bytemask<1> == '1' then
    new_spsr<15:8> = value<15:8>;    // IT[7:2] bits, E bit, A interrupt mask

if bytemask<0> == '1' then
    new_spsr<7:0> = value<7:0>;      // I,F interrupt masks, T bit, Mode bits

SPSR[] = new_spsr;                   // UNPREDICTABLE if User or System mode
return;

Library pseudocode for aarch32/functions/system/SPSRaccessValid

// SPSRaccessValid()
// ===============

// Checks for MRS (Banked register) or MSR (Banked register) accesses to the SPSRs
// that are UNPREDICTABLE

SPSRaccessValid(bits(5) SYSm, bits(5) mode)

case SYSm of
    when '01110'                                                   // SPSR_fiq
        if mode == M32_FIQ then UNPREDICTABLE;
    when '10000'                                                   // SPSR_irq
        if mode == M32_IRQ then UNPREDICTABLE;
    when '10010'                                                   // SPSR_svc
        if mode == M32_Svc then UNPREDICTABLE;
    when '10100'                                                   // SPSR_abt
        if mode == M32_Abt then UNPREDICTABLE;
    when '10110'                                                   // SPSR_und
        if mode == M32_Undef then UNPREDICTABLE;
    when '11100'                                                   // SPSR_mon
        if !HaveEL(EL3) || mode == M32_Monitor || !IsSecure() then UNPREDICTABLE;
    when '11110'                                                   // SPSR_hyp
        if !HaveEL(EL2) || mode != M32_Monitor then UNPREDICTABLE;
    otherwise
        UNPREDICTABLE;

return;

Library pseudocode for aarch32/functions/system/SelectInstrSet

// SelectInstrSet()
// ===============

SelectInstrSet(InstrSet iset)

assert CurrentInstrSet() IN {InstrSet_A32, InstrSet_T32};
assert iset IN {InstrSet_A32, InstrSet_T32};

PSTATE.T = if iset == InstrSet_A32 then '0' else '1';
return;
Library pseudocode for aarch32/functions/v6simd/Sat

```cpp
// Sat()
// =====

bits(N) Sat(integer i, integer N, boolean unsigned)
result = if unsigned then UnsignedSat(i, N) else SignedSat(i, N);
return result;
```

Library pseudocode for aarch32/functions/v6simd/SignedSat

```cpp
// SignedSat()
// ===========

bits(N) SignedSat(integer i, integer N)
(result, -) = SignedSatQ(i, N);
return result;
```

Library pseudocode for aarch32/functions/v6simd/UnsignedSat

```cpp
// UnsignedSat()
// =============

bits(N) UnsignedSat(integer i, integer N)
(result, -) = UnsignedSatQ(i, N);
return result;
```
// AArch32.DefaultTEXDecode
// =========================

MemoryAttributes AArch32.DefaultTEXDecode(bits(3) TEX, bit C, bit B, bit S, AccType acctype)

MemoryAttributes memattrs;

// Reserved values map to allocated values
if (TEX == '001' && C:B == '01') || (TEX == '010' && C:B != '00') || TEX == '011' then
  bits(5) texcb;
  (~, texcb) = ConstrainUnpredictableBits(Unpredictable_RESTEXCB);
  TEX = texcb<4:2>;  C = texcb<1>;  B = texcb<0>;

  case TEX:C:B of
    when '00000'
      // Device-nGnRnE
      memattrs.type = MemType_Device;
      memattrs.device = DeviceType_nGnRnE;
    when '00001', '01000'
      // Device-nGnRE
      memattrs.type = MemType_Device;
      memattrs.device = DeviceType_nGnRE;
    when '00010', '00011', '00100'
      // Write-back or Write-through Read allocate, or Non-cacheable
      memattrs.type = MemType_Normal;
      memattrs.inner = ShortConvertAttrsHints(C:B, acctype, FALSE);
      memattrs.outer = ShortConvertAttrsHints(C:B, acctype, FALSE);
      memattrs.shareable = (S == '1');
    when '00110'
      memattrs = MemoryAttributes IMPLEMENTATION_DEFINED;
    when '00111'
      // Write-back Read and Write allocate
      memattrs.type = MemType_Normal;
      memattrs.inner = ShortConvertAttrsHints('01', acctype, FALSE);
      memattrs.outer = ShortConvertAttrsHints('01', acctype, FALSE);
      memattrs.shareable = (S == '1');
    when '1xxxx'
      // Cacheable, TEX<1:0> = Outer attrs, {C,B} = Inner attrs
      memattrs.type = MemType_Normal;
      memattrs.inner = ShortConvertAttrsHints(TEX<1:0>, acctype, FALSE);
      memattrs.outer = ShortConvertAttrsHints(TEX<1:0>, acctype, FALSE);
      memattrs.shareable = (S == '1');
    otherwise
      // Reserved, handled above
      Unreachable();

  // transient bits are not supported in this format
  memattrs.inner.transient = FALSE;
  memattrs.outer.transient = FALSE;

  // distinction between inner and outer shareable is not supported in this format
  memattrs.ouershareable = memattrs.shareable;

  memattrs.tagged = FALSE;

return MemAttrDefaults(memattrs);
// AArch32.InstructionDevice()
// ===========================
// Instruction fetches from memory marked as Device but not execute-never might generate a
// Permission Fault but are otherwise treated as if from Normal Non-cacheable memory.

AddressDescriptor AArch32.InstructionDevice(AddressDescriptor addrdesc, bits(32) vaddress,
                                           bits(40) ipaddress, integer level, bits(4) domain,
                                           AccType acctype, boolean iswrite, boolean secondstage,
                                           boolean s2fs1walk)

    c = ConstrainUnpredictable(Unpredictable_INSTRDEVICE);
    assert c IN {Constraint_NONE, Constraint_FAULT};

    if c == Constraint_FAULT then
        addrdesc.fault = AArch32.PermissionFault(ipaddress, domain, level, acctype, iswrite,
                                               secondstage, s2fs1walk);
    else
        addrdesc.memattrs.type = MemType_Normal;
        addrdesc.memattrs.innerattrs = MemAttr_NC;
        addrdesc.memattrs.innerhints = MemHint_No;
        addrdesc.memattrs.outer = addrdesc.memattrs.inner;
        addrdesc.memattrs.tagged = FALSE;
        addrdesc.memattrs = MemAttrDefaults(addrdesc.memattrs);

    return addrdesc;
Library pseudocode for aarch32/translation/attrs/AArch32.RemappedTEXDecode

```plaintext
// AArch32.RemappedTEXDecode()
// --------------------------
MemoryAttributes AArch32.RemappedTEXDecode(bits(3) TEX, bit C, bit B, bit S, AccType acctype)

    MemoryAttributes memattrs;
    region = UInt(TEx<0>:C:B); // TEX<2:1> are ignored in this mapping scheme
    if region == 6 then
        memattrs = MemoryAttributes IMPLEMENTATION_DEFINED;
    else
        base = 2 * region;
        attrfield = PRRR<base+1:base>;
        if attrfield == '11' then // Reserved, maps to allocated value
            (-, attrfield) = ConstrainUnpredictableBits(Unpredictable_RESPRR);
            case attrfield of
                when '00'                  // Device-nGnRnE
                    memattrs.type = MemType_Device;
                    memattrs.device = DeviceType_nGnRnE;
                when '01'                  // Device-nGnRE
                    memattrs.type = MemType_Device;
                    memattrs.device = DeviceType_nGnRE;
                when '10'
                    memattrs.type = MemType_Normal;
                    memattrs.inner = ShortConvertAttrsHints(NMRR<base+1:base>, acctype, FALSE);
                    memattrs.outer = ShortConvertAttrsHints(NMRR<base+17:base+16>, acctype, FALSE);
                    s_bit = if S == '0' then PRRR.NS0 else PRRR.NS1;
                    memattrs.shareable = (s_bit == '1');
                    memattrs.outershareable = (s_bit == '1' && PRRR<region+24> == '0');
                when '11'
                    Unreachable();

            // transient bits are not supported in this format
            memattrs.inner.transient = FALSE;
            memattrs.outer.transient = FALSE;
            memattrs.tagged = FALSE;

            return MemAttrDefaults(memattrs);
```

Shared Pseudocode Functions

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// AArch32.S1AttrDecode()
// ==============
// Converts the Stage 1 attribute fields, using the MAIR, to orthogonal
// attributes and hints.

MemoryAttributes AArch32.S1AttrDecode(bits(2) SH, bits(3) attr, AccType acctype)

    MemoryAttributes memattrs;
    if PSTATE.EL == EL2 then
        mair = HMAIR1:HMAIR0;
    else
        mair = MAIR1:MAIR0;
    index = 8 * UInt(attr);
    attrfield = mair<index+7:index>;
    if ((attrfield<7:4> != '0000' && attrfield<7:4> != '1111' && attrfield<3:0> == '0000') ||
        (attrfield<7:4> == '0000' && attrfield<3:0> != 'xx00')) then
        // Reserved, maps to an allocated value
        (-, attrfield) = ConstrainUnpredictableBits(Unpredictable_RESMAIR);
    elsif attrfield<7:4> == '0000' then // Device
        memattrs.type = MemType_Device;
        case attrfield<3:0> of
            when '0000' memattrs.device = DeviceType_nGnRnE;
            when '0100' memattrs.device = DeviceType_nGnRE;
            when '1000' memattrs.device = DeviceType_nGRE;
            when '1100' memattrs.device = DeviceType_GRE;
            otherwise Unreachable();
        endcase
    elsif attrfield<3:0> != '0000' then // Normal
        memattrs.type = MemType_Normal;
        memattrs.outer = LongConvertAttrsHints(attrfield<7:4>, acctype);
        memattrs.inner = LongConvertAttrsHints(attrfield<3:0>, acctype);
        memattrs.shareable = SH<1> == '1';
        memattrs.outershareable = SH == '10';
    elsif HaveMTEExt() && attrfield == '11110000' then // Tagged, Normal
        memattrs.tagged = TRUE;
        memattrs.outer.attrs = MemAttr_WB;
        memattrs.inner.attrs = MemAttr_WB;
        memattrs.outer.hints = MemHint_RWA;
        memattrs.inner.hints = MemHint_RWA;
    else
        Unreachable();
    endcase

    return MemAttrDefaults(memattrs);
// AArch32.TranslateAddressS1Off()
// ------------------------------------
// Called for stage 1 translations when translation is disabled to supply a default translation.
// Note that there are additional constraints on instruction prefetching that are not described in
// this pseudocode.

TLBRecord AArch32.TranslateAddressS1Off(bits(32) vaddress, AccType acctype, boolean iswrite)
assert ELUsingAArch32(S1TranslationRegime());

TLBRecord result;

default_cacheable = (HasS2Translation() && ((if ELUsingAArch32(EL2) then HCR.DC else HCR_EL2.DC) == '1'));

if default_cacheable then
  // Use default cacheable settings
  result.addrdesc.memattrs.type = MemType_Normal;
  result.addrdesc.memattrs.inner.attrs = MemAttr_WB;       // Write-back
  result.addrdesc.memattrs.inner.hints = MemHint_RWA;
  result.addrdesc.memattrs.shareable = FALSE;
  result.addrdesc.memattrsoutershareable = FALSE;
  result.addrdesc.memattrs.tagged = HCR_EL2.DCT == '1';
elsif acctype != AccType_IFETCH then
  // Treat data as Device
  result.addrdesc.memattrs.type = MemType_Device;
  result.addrdesc.memattrs.device = DeviceType_nGnRnE;
  result.addrdesc.memattrs.inner = MemAttrHints UNKNOWN;
  result.addrdesc.memattrs.tagged = FALSE;
else
  // Instruction cacheability controlled by SCTLR/HSCTLR.I
  if PSTATE.EL == EL2 then
    cacheable = HSCTLR.I == '1';
  else
    cacheable = SCTLR.I == '1';
  if cacheable then
    result.addrdesc.memattrs.inner.attrs = MemAttr_WT;
    result.addrdesc.memattrs.inner.hints = MemHint_RA;
  else
    result.addrdesc.memattrs.inner.attrs = MemAttr_NC;
    result.addrdesc.memattrs.inner.hints = MemHint_No;
  result.addrdesc.memattrs.shareable = TRUE;
  result.addrdesc.memattrsoutershareable = TRUE;
  result.addrdesc.memattrs.tagged = FALSE;
endif

result.addrdesc.memattrs.outer = result.addrdesc.memattrs.inner;

result.perms.ap = bits(3) UNKNOWN;
result.perms.xn = '0';
result.perms.pxn = '0';
result.nG = bit UNKNOWN;
result.contiguous = boolean UNKNOWN;
result.domain = bits(4) UNKNOWN;
result.level = integer UNKNOWN;
result.blocksize = integer UNKNOWN;
result.addrdesc.paddress.address = ZeroExtend(vaddress);
result.addrdesc.paddress.NS = if IsSecure() then '0' else '1';
result.addrdesc.fault = AArch32.NoFault();
return result;
// AArch32.AccessIsPrivileged()
// ============================

boolean AArch32.AccessIsPrivileged(AccType acctype)
{
    el = PSTATE.EL;
    if el == AArch32.AccessUsesEL(acctype);
    if el == EL0 then
        ispriv = FALSE;
    elsif el != EL1 then
        ispriv = TRUE;
    else
        ispriv = (acctype != AccType_UNPRIV);
    return ispriv;
}

// AArch32.AccessUsesEL()
// ========================

// Returns the Exception Level of the regime that will manage the translation for a given access type.

bits(2) AArch32.AccessUsesEL(AccType acctype)
{
    if acctype == AccType_UNPRIV then
        return EL0;
    else
        return PSTATE.EL;
}

// AArch32.CheckDomain()
// =====================

(boolean, FaultRecord) AArch32.CheckDomain(bits(4) domain, bits(32) vaddress, integer level, AccType acctype, boolean iswrite)
{
    index = 2 * UInt(domain);
    attrfield = DACR<index+1:index>;
    if attrfield == '10' then          // Reserved, maps to an allocated value
        fault = AArch32.DomainFault(domain, level, acctype, iswrite);
    if attrfield == '00' then
        fault = AArch32.NoFault();
    else
        fault = AArch32.NoFault();
    permissioncheck = (attrfield == '01');
    return (permissioncheck, fault);
}
Library pseudocode for aarch32/translation/checks/AArch32.CheckPermission
AArch32.CheckPermission()  
// Function used for permission checking from AArch32 stage 1 translations

FaultRecord AArch32.CheckPermission(Permissions perms, bits(32) vaddress, integer level,  
bits(4) domain, bit NS, AccType accctype, boolean iswrite)

assert ELUsingAArch32(S1TranslationRegime());

if PSTATE.EL != EL2 then
    wxn = SCTLR.WXN == '1';
    if TTBCR.EAE == '1' || SCTLR.AFE == '1' || perms.ap<0> == '1' then
        priv_r = TRUE;
        priv_w = perms.ap<2> == '0';
        user_r = perms.ap<1> == '1';
        user_w = perms.ap<2:1> == '01';
    else
        priv_r = perms.ap<2:1> != '00';
        priv_w = perms.ap<2:1> == '01';
        user_r = perms.ap<1> == '1';
        user_w = FALSE;
    uwxn = SCTLR.UWXN == '1';
    ispriv = AArch32.AccessIsPrivileged(accctype);
    pan = if HavePANExt() then PSTATE.PAN else '0';
    is_ldst = !(accctype IN {AccType_DC, AccType_DC_UNPRIV, AccType_AT, AccType_IFETCH});
    is_ats1xp = (accctype == AccType_AT && AArch32.ExecutingATS1xPInstr());
    if pan == '1' && user_r && ispriv && (is_ldst || is_ats1xp) then
        priv_r = FALSE;
        priv_w = FALSE;
    user_xn = !user_r || perms.xn == '1' || (user_w && wxn);
    priv_xn = (!priv_r || perms.xn == '1' || perms.pxn == '1' || (priv_w && wxn) || (user_w && uwxn));
    if ispriv then
        (r, w, xn) = (priv_r, priv_w, priv_xn);
    else
        (r, w, xn) = (user_r, user_w, user_xn);
    else
        // Access from EL2
        wxn = HSCTLR.WXN == '1';
        r = TRUE;
        w = perms.ap<2> == '0';
        xn = perms.xn == '1' || (w && wxn);

    // Restriction on Secure instruction fetch
    if HaveEL(EL3) && IsSecure() && NS == '1' then
        secure_instr_fetch = if ELUsingAArch32(EL3) then SCR.SIF else SCR_EL3.SIF;
        if secure_instr_fetch == '1' then xn = TRUE;

    if accctype == AccType_IFETCH then
        fall = xn;
        failedread = TRUE;
    elsif accctype IN {AccType_ATOMICRW, AccType_ORDEREDRW} then
        fall = !r || !w;
        failedread = !w;
    elsif iswrite && !r && PSTATE.EL == EL1 && (accctype == AccType_DC)AccType_ORDERED_ATOMICRW)IsSecure
        fall = !r || !w;
        failedread = !r;
    then
        fall = !w;
        failedread = FALSE;
    elsif accctype == AccType_DC then
        // DC maintenance instructions operating by VA, cannot fault from stage 1 translation.
        fail = FALSE;
    elsif iswrite then

fail = !w;
failedread = FALSE;
else
    fail = !r;
    failedread = TRUE;
if fail then
    secondstage = FALSE;
s2fslwalk = FALSE;
ipaddress = bits(40) UNKNOWN;
    return AArch32.PermissionFault(ipaddress, domain, level, acctype,
        !failedread, secondstage, s2fslwalk);
else
    return AArch32>NoFault();
// AArch32.CheckS2Permission()
// --------------------------
// Function used for permission checking from AArch32 stage 2 translations

FaultRecord AArch32.CheckS2Permission(Permissions perms, bits(32) vaddress, bits(40) ipaddress, integer level, AccType acctype, boolean iswrite, boolean s2fs1walk)

assert HaveEL(EL2) && !IsSecure() && ELUsingAArch32(EL2) && HasS2Translation();

r = perms.ap<1> == '1';
w = perms.ap<2> == '1';
if HaveExtendedExecuteNeverExt() then
case perms.xn:perms.xxn of
    when '00'  xn = !r;
    when '01'  xn = !r || PSTATE.EL == EL1;
    when '10'  xn = TRUE;
    when '11'  xn = !r || PSTATE.EL == EL0;
else
    xn = !r || perms.xn == '1';
// Stage 1 walk is checked as a read, regardless of the original type
if acctype == AccType_IFETCH && !s2fs1walk then
    fail = xn;
    failedread = TRUE;
elsif (acctype IN {AccType_ATOMICRW, AccType_ORDEREDRW}) && !s2fs1walk then
    fail = !r || !w;
    failedread = FALSE;
else
    fail = !r;
    failedread = !iswrite;
    if fail then
        domain = bits(4) UNKNOWN;
        secondstage = TRUE;
        return AArch32.PermissionFault(ipaddress, domain, level, acctype, !failedread, secondstage, s2fs1walk);
    else
        return AArch32.NoFault();
elsif acctype == AccType_DC && !s2fs1walk then
    // DC maintenance instructions operating by VA, do not generate Permission faults
    // from stage 2 translation, other than from stage 1 translation table walk.
    fail = FALSE;
elsif iswrite && !s2fs1walk then
    fail = !w;
    failedread = FALSE;
else
    fail = !r;
    failedread = !iswrite;

if fail then
    domain = bits(4) UNKNOWN;
    secondstage = TRUE;
    return AccType_ORDEREDDATOMICRW)) && !s2fs1walk then
    fail = !r || !w;
    failedread = !r;
elsif acctype == AccType_DC && !s2fs1walk then
    // DC maintenance instructions operating by VA, do not generate Permission faults
    // from stage 2 translation, other than from stage 1 translation table walk.
    fail = FALSE;
elsif iswrite && !s2fs1walk then
    fail = !w;
    failedread = FALSE;
else
    fail = !r;
    failedread = !iswrite;

if fail then
    domain = bits(4) UNKNOWN;
    secondstage = TRUE;
    return AArch32.PermissionFault(ipaddress, domain, level, acctype, !failedread, secondstage, s2fs1walk);
else
    return AArch32.NoFault();
// AArch32.CheckBreakpoint()
// Called before executing the instruction of length "size" bytes at "vaddress" in an AArch32
// translation regime.
// The breakpoint can in fact be evaluated well ahead of execution, for example, at instruction
// fetch. This is the simple sequential execution of the program.

FaultRecord AArch32.CheckBreakpoint(bits(32) vaddress, integer size)
assert ELUsingAArch32(61TranslationRegime());
assert size IN {2,4};

match = FALSE;
mismatch = FALSE;
for i = 0 to UInt(DBGDIDR.BRPs)
    (match_i, mismatch_i) = AArch32.BreakpointMatch(i, vaddress, size);
    match = match || match_i;
    mismatch = mismatch || mismatch_i;
if match && HaltOnBreakpointOrWatchpoint() then
    reason = DebugHalt_Breakpoint;
    Halt(reason);
elsif (match || mismatch) && DBGDSCRext.MDBGen == '1' && AArch32.GenerateDebugExceptions() then
    acctype = AccType_IFETCH;
    iswrite = FALSE;
    debugmoe = DebugException_Breakpoint;
    return AArch32.DebugFault(acctype, iswrite, debugmoe);
else
    return AArch32.NoFault();

Library pseudocode for aarch32/translation/debug/AArch32.CheckDebug

// AArch32.CheckDebug()
// Called on each access to check for a debug exception or entry to Debug state.

FaultRecord AArch32.CheckDebug(bits(32) vaddress, AccType acctype, boolean iswrite, integer size)

FaultRecord fault = AArch32.NoFault();
d_side = (acctype != AccType_IFETCH);
generate_exception = AArch32.GenerateDebugExceptions() && DBGDSCRext.MDBGen == '1';
halt = HaltOnBreakpointOrWatchpoint();
// Relative priority of Vector Catch and Breakpoint exceptions not defined in the architecture
vector_catch_first = ConstrainUnpredictableBool(Unpredictable_BPVECTORCATCHPRI);
if !d_side && vector_catch_first && generate_exception then
    fault = AArch32.CheckVectorCatch(vaddress, size);
if fault.type == Fault_None && (generate_exception || halt) then
    if d_side then
        fault = AArch32.CheckWatchpoint(vaddress, acctype, iswrite, size);
    else
        fault = AArch32.CheckBreakpoint(vaddress, size);
if fault.type == Fault_None && !d_side && !vector_catch_first && generate_exception then
    return AArch32.CheckVectorCatch(vaddress, size);
return fault;
// AArch32.CheckVectorCatch()
// ---------------
// Called before executing the instruction of length "size" bytes at "vaddress" in an AArch32
// translation regime.
// Vector Catch can in fact be evaluated well ahead of execution, for example, at instruction
// fetch. This is the simple sequential execution of the program.

FaultRecord AArch32.CheckVectorCatch(bits(32) vaddress, integer size)
assert ELUsingAArch32(S1TranslationRegime());
match = AArch32.VCRMatch(vaddress);
if size == 4 && !match && AArch32.VCRMatch(vaddress + 2) then
    match = ConstrainUnpredictableBool(Unpredictable_VCMATCHHALF);
if match && DBGDSCRext.MDBGen == '1' && AArch32.GenerateDebugExceptions() then
    acctype = AccType_IFETCH;
iswrite = FALSE;
ddebugmoe = DebugException_VectorCatch;
return AArch32.DebugFault(acctype, iswrite, debugmoe);
else
    return AArch32.NoFault();

Library pseudocode for aarch32/translation/debug/AArch32.CheckWatchpoint

// AArch32.CheckWatchpoint()
// -------------------
// Called before accessing the memory location of "size" bytes at "address".

FaultRecord AArch32.CheckWatchpoint(bits(32) vaddress, AccType acctype, boolean iswrite, integer size)
assert ELUsingAArch32(AccType acctype);
match = FALSE;
ispriv = AArch32.AccessIsPrivileged(acctype);
for i = 0 to UInt(DBGDIDR.WRPs)
    match = match || AArch32.WatchpointMatch(i, vaddress, size, ispriv, iswrite);
if match && HaltonBreakpointOrWatchpoint() then
    reason = DebugHalt_Watchpoint;
    return AArch32.DebugFault(acctype, iswrite, debugmoe);
else
    return AArch32.NoFault();

Library pseudocode for aarch32/translation/faults/AArch32.AccessFlagFault

// AArch32.AccessFlagFault()
// ----------------------

FaultRecord AArch32.AccessFlagFault(bits(40) ipaddress, bits(4) domain, integer level, AccType acctype, boolean iswrite, boolean secondstage, boolean s2fs1walk)
extflag = bit UNKNOWN;
ddebugmoe = bits(4) UNKNOWN;
errtype = bits(2) UNKNOWN;
return AArch32.CreateFaultRecord(Fault_AccessFlag, ipaddress, domain, level, acctype, iswrite, extflag, debugmoe, errrtype, secondstage, s2fs1walk);
// AArch32.AddressSizeFault()
// ------------------------------------------
FaultRecord AArch32.AddressSizeFault(bits(40) ipaddress, bits(4) domain, integer level,
    AccType acctype, boolean iswrite, boolean secondstage,
    boolean s2fs1walk)

    extflag = bit UNKNOWN;
    debugmoe = bits(4) UNKNOWN;
    errortype = bits(2) UNKNOWN;
    return AArch32.CreateFaultRecord(Fault_AddressSize, ipaddress, domain, level, acctype, iswrite,
    extflag, debugmoe, errortype, secondstage, s2fs1walk);

// AArch32.AlignmentFault()
// ------------------------
FaultRecord AArch32.AlignmentFault(AccType acctype, boolean iswrite, boolean secondstage)

    ipaddress = bits(40) UNKNOWN;
    domain = bits(4) UNKNOWN;
    level = integer UNKNOWN;
    extflag = bit UNKNOWN;
    debugmoe = bits(4) UNKNOWN;
    errortype = bits(2) UNKNOWN;
    s2fs1walk = boolean UNKNOWN;
    return AArch32.CreateFaultRecord(Fault_Alignment, ipaddress, domain, level, acctype, iswrite,
    extflag, debugmoe, errortype, secondstage, s2fs1walk);

// AArch32.AsynchExternalAbort()
// ------------------------------
// Wrapper function for asynchronous external aborts
FaultRecord AArch32.AsynchExternalAbort(boolean parity, bits(2) errortype, bit extflag)

    type = if parity then Fault_AsyncParity else Fault_AsyncExternal;
    ipaddress = bits(40) UNKNOWN;
    domain = bits(4) UNKNOWN;
    level = integer UNKNOWN;
    acctype = AccType_NORMAL;
    iswrite = boolean UNKNOWN;
    debugmoe = bits(4) UNKNOWN;
    secondstage = FALSE;
    s2fs1walk = FALSE;
    return AArch32.CreateFaultRecord(type, ipaddress, domain, level, acctype, iswrite, extflag,
    debugmoe, errortype, secondstage, s2fs1walk);
// AArch32.DebugFault()
// ================
FaultRecord AArch32.DebugFault(AccType acctype, boolean iswrite, bits(4) debugmoe)

    ipaddress = bits(40) UNKNOWN;
domain = bits(4) UNKNOWN;
errortype = bits(2) UNKNOWN;
level = integer UNKNOWN;
extflag = bit UNKNOWN;
secondstage = FALSE;
s2fs1walk = FALSE;

    return AArch32.CreateFaultRecord(Fault_Debug, ipaddress, domain, level, acctype, iswrite, extflag, debugmoe, errortype, secondstage, s2fs1walk);

// AArch32.DomainFault()
// ===============
FaultRecord AArch32.DomainFault(bits(4) domain, integer level, AccType acctype, boolean iswrite)

    ipaddress = bits(40) UNKNOWN;
extflag = bit UNKNOWN;
debugmoe = bits(4) UNKNOWN;
errortype = bits(2) UNKNOWN;
secondstage = FALSE;
s2fs1walk = FALSE;

    return AArch32.CreateFaultRecord(Fault_Domain, ipaddress, domain, level, acctype, iswrite, extflag, debugmoe, errortype, secondstage, s2fs1walk);

// AArch32.NoFault()
// ============
FaultRecord AArch32.NoFault()

    ipaddress = bits(40) UNKNOWN;
domain = bits(4) UNKNOWN;
level = integer UNKNOWN;
acctype = AccType_NORMAL;
iswrite = boolean UNKNOWN;
extflag = bit UNKNOWN;
debugmoe = bits(4) UNKNOWN;
errortype = bits(2) UNKNOWN;
secondstage = FALSE;
s2fs1walk = FALSE;

    return AArch32.CreateFaultRecord(Fault_None, ipaddress, domain, level, acctype, iswrite, extflag, debugmoe, errortype, secondstage, s2fs1walk);
Library pseudocode for aarch32/translation/faults/AArch32.PermissionFault

```c
// AArch32.PermissionFault()
// =========================
FaultRecord AArch32.PermissionFault(bits(40) ipaddress, bits(4) domain, integer level,
            AccType acctype, boolean iswrite, boolean secondstage,
            boolean s2fs1walk)
    extflag = bit UNKNOWN;
    debugmoe = bits(4) UNKNOWN;
    errortype = bits(2) UNKNOWN;
    return AArch32.CreateFaultRecord(Fault Permission, ipaddress, domain, level, acctype, iswrite,
                                     extflag, debugmoe, errortype, secondstage, s2fs1walk);
```

Library pseudocode for aarch32/translation/faults/AArch32.TranslationFault

```c
// AArch32.TranslationFault()
// ==========================
FaultRecord AArch32.TranslationFault(bits(40) ipaddress, bits(4) domain, integer level,
            AccType acctype, boolean iswrite, boolean secondstage,
            boolean s2fs1walk)
    extflag = bit UNKNOWN;
    debugmoe = bits(4) UNKNOWN;
    errortype = bits(2) UNKNOWN;
    return AArch32.CreateFaultRecord(Fault Translation, ipaddress, domain, level, acctype, iswrite,
                                      extflag, debugmoe, errortype, secondstage, s2fs1walk);
```
// AArch32.FirstStageTranslate()
// ---------------------------------
// Perform a stage 1 translation walk. The function used by Address Translation operations is
// similar except it uses the translation regime specified for the instruction.

AddressDescriptor AArch32.FirstStageTranslate(bits(32) vaddress, AccType acctype, boolean iswrite, 
    boolean wasaligned, integer size)

if PSTATE.EL == EL2 then
    s1_enabled = HSCTRL.M == '1';
elsif EL2Enabled() then
    tge = (if ELUsingAArch32(EL2) then HCR.TGE else HCR_EL2.TGE);
    dc = (if ELUsingAArch32(EL2) then HCR.DC else HCR_EL2.DC);
    s1_enabled = tge == '0' && dc == '0' && SCTLR.M == '1';
else
    s1_enabled = SCTLR.M == '1';

ipaddress = bits(40) UNKNOWN;
secondstage = FALSE;
s2fs1walk = FALSE;

if s1_enabled then // First stage enabled
    use_long_descriptor_format = PSTATE.EL == EL2 || TTBCR.EAE == '1';
    if use_long_descriptor_format then
        S1 = AArch32.TranslationTableWalkLD(ipaddress, vaddress, acctype, iswrite, secondstage, 
            s2fs1walk, size);
        permissioncheck = TRUE;  domaincheck = FALSE;
    else
        S1 = AArch32.TranslationTableWalkSD(vaddress, acctype, iswrite, size);
        permissioncheck = TRUE;  domaincheck = TRUE;
    else
        S1 = AArch32.TranslateAddressS1Off(vaddress, acctype, iswrite);
        permissioncheck = FALSE;  domaincheck = FALSE;
    fi
fi

if UsingAAArch32() && HaveTrapLoadStoreMultipleDeviceExt() && AArch32.ExecutingLSMInstr() then
    if S1.addrdesc.memattrs.type == MemType_Device && S1.addrdesc.memattrs.device != DeviceType_GRE then
        nTLSMD = if S1TranslationRegime() == EL2 then HSCTRL.nTLSMD else SCTLR.nTLSMD;
        if nTLSMD == '0' then
            S1.addrdesc.fault = AArch32.AlignmentFault(acctype, iswrite, secondstage);
        fi
    fi
fi

// Check for unaligned data accesses to Device memory
if (!wasaligned && acctype != AccType_IFETCH || (acctype == AccType_DCZVA)) && S1.addrdesc.memattrs.type == MemType_Device && !IsFault(S1.addrdesc) then
    S1.addrdesc.fault = AArch32.AlignmentFault(acctype, iswrite, secondstage);
fi

if !IsFault(S1.addrdesc) && domaincheck then
    (permissioncheck, abort) = AArch32.CheckDomain(S1.domain, vaddress, S1.level, acctype, 
        iswrite);
    S1.addrdesc.fault = abort;
fi

if !IsFault(S1.addrdesc) && permissioncheck then
    S1.addrdesc.fault = AArch32.CheckPermission(S1.perms, vaddress, S1.level, 
        S1.domain, S1.addrdesc.paddress.NS, acctype, iswrite);
fi

// Check for instruction fetches from Device memory not marked as execute-never. If there has
// not been a Permission Fault then the memory is not marked execute-never.
if (!IsFault(S1.addrdesc) && S1.addrdesc.memattrs.type == MemType_Device && acctype == AccType_IFETCH) then
    S1.addrdesc = AArch32.InstructionDevice(S1.addrdesc, vaddress, ipaddress, S1.level, 
        S1.domain, acctype, iswrite, secondstage, s2fs1walk);
fi

return S1.addrdesc;
// AArch32.FullTranslate()
// =======================
// Perform both stage 1 and stage 2 translation walks for the current translation regime. The
// function used by Address Translation operations is similar except it uses the translation
// regime specified for the instruction.

AddressDescriptor AArch32.FullTranslate(bits(32) vaddress, AccType acctype, boolean iswrite,
  boolean wasaligned, integer size)
// First Stage Translation
S1 = AArch32.FirstStageTranslate(vaddress, acctype, iswrite, wasaligned, size);
if !IsFault(S1) && !HaveNV2Ext() && acctype == AccType_NV2REGISTER && HasS2Translation() then
  s2fs1walk = FALSE;
  result = AArch32.SecondStageTranslate(S1, vaddress, acctype, iswrite, wasaligned, s2fs1walk, size);
else
  result = S1;
return result;
// AArch32.SecondStageTranslate()
// ---------------------------------------------
// Perform a stage 2 translation walk. The function used by Address Translation operations is
// similar except it uses the translation regime specified for the instruction.

AddressDescriptor AArch32.SecondStageTranslate(AddressDescriptor S1, bits(32) vaddress,
                                                AccType acctype, boolean iswrite, boolean wasaligned,
                                                boolean s2fs1walk, integer size)

    assert HasS2Translation();
    assert IsZero(S1.paddress.address<47:40>);
    hwupdatewalk = FALSE;
if !ELUsingAArch32(EL2) then
    return AArch64.SecondStageTranslate(S1, ZeroExtend(vaddress, 64), acctype, iswrite,
                                          wasaligned, s2fs1walk, size, hwupdatewalk);

s2_enabled = HCR.VM == '1' || HCR.DC == '1';
secondstage = TRUE;
if s2_enabled then // Second stage enabled
    ipaddress = S1.paddress.address<39:0>;
    S2 = AArch32.TranslationTableWalkLD(ipaddress, vaddress, acctype, iswrite, secondstage,
                                          s2fs1walk, size);

    // Check for unaligned data accesses to Device memory
    if (!wasaligned && acctype != AccType_IFETCH) || (acctype == AccType_DCZVA) &&
        S2.addrdesc.memattrs.type == MemType_Device && !IsFault(S2.addrdesc) then
        S2.addrdesc.fault = AArch32.AlignmentFault(acctype, iswrite, secondstage);

    // Check for permissions on Stage2 translations
    if !IsFault(S2.addrdesc) then
        S2.addrdesc.fault = AArch32.CheckS2Permission(S2.perms, vaddress, ipaddress, S2.level,
                                                      acctype, iswrite, s2fs1walk);

    // Check for instruction fetches from Device memory not marked as execute-never. As there
    // has not been a Permission Fault then the memory is not marked execute-never.
    if !s2fs1walk && !IsFault(S2.addrdesc) && S2.addrdesc.memattrs.type == MemType_Device &&
        acctype == AccType_IFETCH) then
        domain = bits(4) UNKNOWN;
        S2.addrdesc = AArch32.InstructionDevice(S2.addrdesc, vaddress, ipaddress, S2.level,
                                                domain, acctype, iswrite,
                                                secondstage, s2fs1walk);

    // Check for protected table walk
    if (s2fs1walk && !IsFault(S2.addrdesc) && HCR.PTW == '1' &&
        S2.addrdesc.memattrs.type == MemType_Device) then
        domain = bits(4) UNKNOWN;
        S2.addrdesc.fault = AArch32.PermissionFault(ipaddress, domain, S2.level, acctype,
                                                    iswrite, secondstage, s2fs1walk);

    result = CombineS1S2Desc(S1, S2.addrdesc);
    else
        result = S1;

return result;
// AArch32.SecondStageWalk()
// -----------------------------------------------
// Perform a stage 2 translation on a stage 1 translation page table walk access.

AddressDescriptor AArch32.SecondStageWalk(AddressDescriptor S1, bits(32) vaddress, AccType acctype, boolean iswrite, integer size)

  assert HasS2Translation();

  s2fs1walk = TRUE;
  wasaligned = TRUE;
  return AArch32.SecondStageTranslate(S1, vaddress, acctype, iswrite, wasaligned, s2fs1walk, size);

Library pseudocode for aarch32/translation/translation/AArch32.TranslateAddress

// AArch32.TranslateAddress()
// ------------------------------
// Main entry point for translating an address

AddressDescriptor AArch32.TranslateAddress(bits(32) vaddress, AccType acctype, boolean iswrite, boolean wasaligned, integer size)

  if !ELUsingAArch32(S1TranslationRegime()) then
    return AArch64.TranslateAddress(ZeroExtend(vaddress, 64), acctype, iswrite, wasaligned, size);
  result = AArch32.FullTranslate(vaddress, acctype, iswrite, wasaligned, size);

  if !(acctype IN {AccType_PTW, AccType_IC, AccType_AT}) && !IsFault(result) then
    result.fault = AArch32.CheckDebug(vaddress, acctype, iswrite, size);

  // Update virtual address for abort functions
  result.vaddress = ZeroExtend(vaddress);

  return result;
AArch32.TranslationTableWalkLD

Returns a result of a translation table walk using the Long-descriptor format

Implementations might cache information from memory in any number of non-coherent TLB caching structures, and so avoid memory accesses that have been expressed in this pseudocode. The use of such TLBs is not expressed in this pseudocode.

TLBRecord AArch32.TranslationTableWalkLD(bits(40) ipaddress, bits(32) vaddress,
                                          AccType acctype, boolean iswrite, boolean secondstage,
                                          boolean s2fstwalk, integer size)

if !secondstage then
    assert ELUsingAArch32(S1TranslationRegime());
else
    assert HaveEL(EL2) && !IsSecure() && ELUsingAArch32(EL2) && HasS2Translation();

TLBRecord result;
AddressDescriptor descaddr;
bits(64) baseregister;
browseraddr; // Input Address is 'vaddress' for stage 1, 'ipaddress' for stage 2

domain = bits(4) UNKNOWN;
descaddr.memattrs.type = MemType_Normal;

// Fixed parameters for the page table walk:
// grainsize = Log2(Size of Table)         - Size of Table is 4KB in AArch32
// stride = Log2(Address per Level)        - Bits of address consumed at each level
constant integer grainsize = 12;                    // Log2(4KB page size)
constant integer stride = grainsize - 3;            // Log2(page size / 8 bytes)

// Derived parameters for the page table walk:
// inputsize = Log2(Size of Input Address) - Input Address size in bits
// level = Level to start walk from
// This means that the number of levels after start level = 3-level

if !secondstage then
    // First stage translation
    inputaddr = ZeroExtend(vaddress);
el = EL(S1TranslationRegime());
if el = AArch32.AccessUsesEL(acctype);
if el = EL2 then
    inputsize = 32 - UInt(HTCR.T0SZ);
    basefound = inputsize == 32 || IsZero(inputaddr<31:inputsize>);
    disabled = FALSE;
    baseregister = HTTBR;
    descaddr.memattrs = WalkAttrDecode(HTCR.SH0, HTCR.ORGN0, HTCR.IRGN0, secondstage);
    reversedescriptors = HSCTLR.EE == '1';
    lookupsecure = FALSE;
    singlepriv = TRUE;
    hierattrsdisabled = AArch32.HaveHPDExt() && HTCR.HPD == '1';
else
    basefound = FALSE;
    disabled = FALSE;
t0size = UInt(TTBCR.T0SZ);
if t0size == 0 || IsZero(inputaddr<31:(32-t0size)>) then
    inputsize = 32 - t0size;
    basefound = TRUE;
    disabled = TTBCR.EPD0 == '1';
    baseregister = TTBR0;
    descaddr.memattrs = WalkAttrDecode(TTBCR.SH0, TTBCR.ORGN0, TTBCR.IRGN0, secondstage);
    hierattrsdisabled = AArch32.HaveHPDExt() && TTBCR.T2E == '1' && TTBCR2.HPD0 == '1';
t1size = UInt(TTBCR.T1SZ);
if (t1size == 0 && !basefound) || (t1size > 0 && IsOnes(inputaddr<31:(32-t1size)>) then
    inputsize = 32 - t1size;
    basefound = TRUE;
    disabled = TTBCR.EPD1 == '1';
    baseregister = TTBR1;
    descaddr.memattrs = WalkAttrDecode(TTBCR.SH1, TTBCR.ORGN1, TTBCR.IRGN1, secondstage);
    hierattrsdisabled = AArch32.HaveHPDExt() && TTBCR.T2E == '1' && TTBCR2.HPD1 == '1';
reversedescriptors = SCTLR.EE == '1';
lookupsecure = IsSecure();
singlepriv = FALSE;
// The starting level is the number of strides needed to consume the input address
level = 4 - RoundUp(Real(inputsize - grainsize) / Real(stride));

else
// Second stage translation
inputaddr = ipaddress;
inputsize = 32 - SInt(VTCR.TOSZ);
// VTCR.S must match VTCR.TOSZ[3]
if VTCR.S != VTCR.TOSZ<3> then
(-, inputsize) = ConstrainUnpredictableInteger(32-7, 32+8, Unpredictable_RESVTCR);
basefound = inputsize == 40 || IsZero(inputaddr<39:inputsize>);
disabled = FALSE;
descaddr.memattrs = WalkAttrDecode(VTCR.IRGN0, VTCR.ORGN0, VTCR.SH0, secondstage);
reversedescriptors = HSCTLR.EE == '1';
singlepriv = TRUE;
lookupsecure = FALSE;
baseregister = VTTBR;
startlevel = UInt(VTCR.SL0);
level = 2 - startlevel;
if level <= 0 then basefound = FALSE;
// Number of entries in the starting level table =
// (Size of Input Address)/((Address per level)^(Num levels remaining)*(Size of Table))
startsizecheck = inputsize - ((3 - level)*stride + grainsize); // Log2(Num of entries)
// Check for starting level table with fewer than 2 entries or longer than 16 pages.
// Lower bound check is:  startsizecheck < Log2(2 entries)
// That is, VTCR.SL0 == '00' and SInt(VTCR.TOSZ) > 1, Size of Input Address < 2^31 bytes
// Upper bound check is:  startsizecheck > Log2(pagesize/8*16)
// That is, VTCR.SL0 == '01' and SInt(VTCR.TOSZ) < -2, Size of Input Address > 2^34 bytes
if startsizecheck < 1 || startsizecheck > stride + 4 then basefound = FALSE;
if !basefound || disabled then
level = 1;           // AArch64 reports this as a level 0 fault
result.addrdesc.fault = AArch32.TranslationFault(ipaddress, domain, level, acctype, iswrite, secondstage, s2fs1walk);
return result;
if !IsZero(baseregister<47:40>) then
level = 0;
result.addrdesc.fault = AArch32.AddressSizeFault(ipaddress, domain, level, acctype, iswrite, secondstage, s2fs1walk);
return result;

// Bottom bound of the Base address is:
// Log2(8 bytes per entry)+Log2(Number of entries in starting level table)
// Number of entries in starting level table =
// (Size of Input Address)/((Address per level)^(Num levels remaining)*(Size of Table))
baselowerbound = 3 + inputsize - ((3-level)*stride + grainsize); // Log2(Num of entries*8)
basedaddress = baseregister<39:baselowerbound>:Zeros(baselowerbound);
ns_table = if lookupsecure then '0' else '1';
ap_table = '00';
xn_table = '0';
pxn_table = '0';
addrselecttop = inputsize - 1;
repeat
addrselectbottom = (3-level)*stride + grainsize;
bits(40) index = ZeroExtend(inputaddr<addrselecttop:addrselectbottom>:'000');
descaddr.paddress.address = ZeroExtend(basedaddress OR index);
descaddr.paddress.NS = ns_table;
// If there are two stages of translation, then the first stage table walk addresses
// are themselves subject to translation
if secondstage || HasS2Translation() || (HaveNV2Ext() && acctype == AccType_NV2REGISTER) then
descaddr2 = descaddr;
else
descaddr2 = AArch32.SecondStageWalk(descaddr, vaddress, acctype, iswrite, 8);
// Check for a fault on the stage 2 walk
if IsFault(descaddr2) then
    result.addrdesc.fault = descaddr2.fault;
    return result;

// Update virtual address for abort functions
descaddr2.vaddress = ZeroExtend(vaddress);

accdesc = CreateAccessDescriptorPTW(acctype, secondstage, s2fs1walk, level);
desc = _Mem[descaddr2, 8, accdesc];
if reversedescriptors then desc = BigEndianReverse(desc);
if desc<0> == '0' || (desc<1:0> == '01' && level == 3) then
    // Fault (00), Reserved (10), or Block (01) at level 3.
    result.addrdesc.fault = AArch32.TranslationFault(ipaddress, doma
ap = desc<7:6>:'1';                                      // Bits[7:6] of the block/page descriptor
contiguousbit = desc<52>;                               // AttrIndx and NS bit in stage 1
memattr = desc<5:2>;                                     // Domains not used
result.domain = bits(4) UNKNOWN;
result.level = level;
result.blocksize = 2^((3-level)*stride + grainsize);

// Stage 1 translation regimes also inherit attributes from the tables
if !secondstage then
    result.domains.xx = xn OR xn_table;
    result.domains.ap<2> = ap<2> OR ap_table<1>;          // Force read-only
    // PXN, nG and AP[1] apply only in EL1&0 stage 1 translation regimes
    if !singlepriv then
        result.domains.ap<1> = ap<1> AND NOT(ap_table<0>);  // Force privileged only
        result.domains.pxn = pxn OR pxn_table;
    // Pages from Non-secure tables are marked non-global in Secure EL1&0
    if IsSecure() then
        result.domains.nG = nG OR ns_table;
    else
        result.domains.nG = nG;
    else
        result.domains.ap<1> = '1';
        result.domains.pxn = '0';
        result.domains.nG = '0';
result.OP = desc<50>;                                    // Stage 1 block or pages might be guarded

else
    result.domains.ap<1> = ap<1>;                        // PXN, nG and AP[1] apply only in EL1&0 stage 1 translation regimes
    result.domains.xn = xn;
    if HaveExtendedExecuteNeverExt() then result.domains.xxn = desc<53>;
    result.domains.pxn = '0';
    result.domains.nG = '0';
    if s2fs1walk then
        result.addrdesc.memattrs = S2AttrDecode(sh, memattr, AccType_PTW);
    else
        result.addrdesc.memattrs = S2AttrDecode(sh, memattr, acctype);
result.addrdesc.paddress.NS = '1';
result.addrdesc.paddress.address = ZeroExtend(outputaddress);
result.addrdesc.fault = AArch32.NoFault();
result.contiguous = contiguousbit == '1';
if HaveCommonNotPrivateTransExt() then result.CnP = baseregister<0>;
return result;
AArch32.TranslationTableWalkSD()
 returns a result of a translation table walk using the Short-descriptor format

Implementations might cache information from memory in any number of non-coherent TLB
 caching structures, and so avoid memory accesses that have been expressed in this
 pseudocode. The use of such TLBs is not expressed in this pseudocode.

TLBRecord AArch32.TranslationTableWalkSD(bits(32) vaddress, AccType acctype, boolean iswrite,
 integer size)

assert ELUsingAArch32 (S1TranslationRegime());

// This is only called when address translation is enabled
TLBRecord result;
AddressDescriptor l1descaddr;
AddressDescriptor l2descaddr;
bits(40) outputaddress;

// Variables for Abort functions
ipaddress = bits(40) UNKNOWN;
secondstage = FALSE;
s2fs1walk = FALSE;
NS = bit UNKNOWN;

// Default setting of the domain
domain = bits(4) UNKNOWN;

// Determine correct Translation Table Base Register to use.
bits(64) ttbr;
n = UInt (TTBCR.N);
if n == 0 || IsZero (vaddress<31:(32-n)>)
    ttbr = TTBR0;
    disabled = (TTBCR.PD0 == '1');
else
    ttbr = TTBR1;
    disabled = (TTBCR.PD1 == '1');
n = 0; // TTBR1 translation always works like N=0 TTBR0 translation

// Check this Translation Table Base Register is not disabled.
if disabled then
    level = 1;
    result.addrdesc.fault = AArch32.TranslationFault (ipaddress, domain, level, acctype, iswrite,
    secondstage, s2fs1walk);

return result;

// Obtain descriptor from initial lookup.
l1descaddr.paddress.address = ZeroExtend (ttbr<31:14-n>:vaddress<31-n:20>:'00');
l1descaddr.paddress.NS = if IsSecure () then '0' else '1';
IRGN = ttbr<0>:ttbr<6>; // TTBR.IRGN
RGN = ttbr<4:3>; // TTBR.RGN
SH = ttbr<1>:ttbr<5>; // TTBR.S:TTBR.NOS
l1descaddr.memattrs = WalkAttrDecode (SH, RGN, IRGN, secondstage);

// if !HaveEL(EL2) || (IsSecure () && !IsSecureEL2Enabled()) then
// if only 1 stage of translation
l1descaddr2 = l1descaddr;
else
    l1descaddr2 = AArch32.SecondStageWalk (l1descaddr, vaddress, acctype, iswrite, 4);
// Check for a fault on the stage 2 walk
if IsFault (l1descaddr2) then
    result.addrdesc.fault = l1descaddr2.fault;
    return result;

// Update virtual address for abort functions
l1descaddr2.vaddress = ZeroExtend (vaddress);

accdesc = CreateAccessDescriptorPTW (acctype, secondstage, s2fs1walk, level);
l1desc = _Mem[l1descaddr2, 4, accdesc];
if SCTLR.EE == '1' then l1desc = BigEndianReverse (l1desc);
// Process descriptor from initial lookup.

  case l1desc<1:0> of
    when '00' // Fault, Reserved
      level = 1;
      result.addrdesc.fault = AArch32.TranslationFault(ipaddress, domain, level, acctype, iswrite, secondstage, s2fs1walk);
      return result;
    when '01' // Large page or Small page
      domain = l1desc<8:5>;
      level = 2;
      pxn = l1desc<2>;
      NS = l1desc<3>;
      // Obtain descriptor from level 2 lookup.
      l2descaddr.paddress.address = ZeroExtend(l1desc<31:10>:vaddress<19:12>:'00');
      l2descaddr.paddress.NS = if IsSecure() then '0' else '1';
      l2descaddr.memattrs = l1descaddr.memattrs;
      if !HaveEL(EL2) || (IsSecure() && !IsSecureEL2Enabled()) then
        // if only 1 stage of translation
        l2descaddr2 = l2descaddr;
      else
        l2descaddr2 = AArch32.SecondStageWalk(l2descaddr, vaddress, acctype, iswrite, 4);
        // Check for a fault on the stage 2 walk
        if IsFault(l2descaddr2) then
          result.addrdesc.fault = l2descaddr2.fault;
          return result;
      // Update virtual address for abort functions
      l2descaddr2.vaddress = ZeroExtend(vaddress);
      accdesc = CreateAccessDescriptorPTW(acctype, secondstage, s2fs1walk, level);
      l2desc = _Mem[l2descaddr2, 4, accdesc];
      if SCTLR.EE == '1' then l2desc = BigEndianReverse(l2desc);
      // Process descriptor from level 2 lookup.
      if l2desc<1:0> == '00' then
        result.addrdesc.fault = AArch32.TranslationFault(ipaddress, domain, level, acctype, iswrite, secondstage, s2fs1walk);
        return result;
      nG = l2desc<11>;
      S = l2desc<10>;
      ap = l2desc<9,5:4>;
      if SCTLR.AFE == '1' && l2desc<4> == '0' then
        // ARMv8 VMSAv8-32 does not support hardware management of the Access flag.
        result.addrdesc.fault = AArch32.AccessFlagFault(ipaddress, domain, level, acctype, iswrite, secondstage, s2fs1walk);
        return result;
      if l2desc<1> == '0' then // Large page
        xn = l2desc<15>;
        tex = l2desc<14:12>;
        c = l2desc<3>;
        b = l2desc<2>;
        blocksize = 64;
        outputaddress = ZeroExtend(l2desc<31:16>:vaddress<15:0>);
      else // Small page
        tex = l2desc<8:6>;
        c = l2desc<3>;
        b = l2desc<2>;
        xn = l2desc<0>;
        blocksize = 4;
        outputaddress = ZeroExtend(l2desc<31:12>:vaddress<11:0>);
      when '1x' // Section or Supersection
        Shared Pseudocode Functions Page 1708
NS = l1desc<19>;
nG = l1desc<17>;
S = l1desc<16>;
ap = l1desc<15,11:10>;
tex = l1desc<14:12>;
xn = l1desc<4>;
c = l1desc<3>;
b = l1desc<2>;
pxn = l1desc<0>;
level = 1;

if SCTLR.AFE == '1' && l1desc<10> == '0' then // ARMv8 VMSAv8-32 does not support hardware management of the Access flag.
    result.addrdesc.fault = AArch32.AccessFlagFault(ipaddress, domain, level, acctype, iswrite, secondstage, s2fs1walk);
    return result;

if l1desc<18> == '0' then // Section
domain = l1desc<8:5>;
blocksize = 1024;
outputaddress = ZeroExtend(l1desc<31:20>:vaddress<19:0>);
else // Supersection
domain = '0000';
blocksize = 16384;
outputaddress = l1desc<8:5>:l1desc<23:20>:l1desc<31:24>:vaddress<23:0>;

// Decode the TEX, C, B and S bits to produce the TLBRecord's memory attributes
if SCTLR.TRE == '0' then
    if RemapRegsHaveResetValues() then
        result.addrdesc.memattrs = AArch32.DefaultTEXDecode(tex, c, b, S, acctype);
    else
        result.addrdesc.memattrs = MemoryAttributes IMPLEMENTATION_DEFINED;
    else
        result.addrdesc.memattrs = AArch32.RemappedTEXDecode(tex, c, b, S, acctype);

// Set the rest of the TLBRecord, try to add it to the TLB, and return it.
result.perms.ap = ap;
result.perms.xn = xn;
result.perms.pxn = pxn;
result.nG = nG;
result.domain = domain;
result.level = level;
result.blocksize = blocksize;
result.addrdesc.paddress.address = ZeroExtend(outputaddress);
result.addrdesc.paddress.NS = if IsSecure() then NS else '1';
result.addrdesc.fault = AArch32.NoFault();
return result;

Library pseudocode for aarch32/translation/walk/RemapRegsHaveResetValues

boolean RemapRegsHaveResetValues();
// AArch64.BreakpointMatch()
// -----------------------------------
// Breakpoint matching in an AArch64 translation regime.

boolean AArch64.BreakpointMatch(integer n, bits(64) vaddress, AccType acctype, integer size)
assert !ELUsingAArch32(SlTranslationRegime());
assert n <= UInt(ID_AA64DFR0_EL1.BRPs);

enabled = DBGBCR_EL1[n].E == '1';
ispriv = PSTATE.EL != EL0;
linked = DBGBCR_EL1[n].BT == '0x01';
isbreakpnt = TRUE;
linked_to = FALSE;

state_match = AArch64.StateMatch(DBGBCR_EL1[n].SSC, DBGBCR_EL1[n].HMC, DBGBCR_EL1[n].PMC,
                                    linked, DBGBCR_EL1[n].LBN, isbreakpnt, acctype, ispriv);
value_match = AArch64.BreakpointValueMatch(n, vaddress, linked_to);

if HaveAnyAArch32() && size == 4 then // Check second halfword
    // If the breakpoint address and BAS of an Address breakpoint match the address of the
    // second halfword of an instruction, but not the address of the first halfword, it is
    // CONSTRAINED UNPREDICTABLE whether or not this breakpoint generates a Breakpoint debug
    // event.
    match_i = AArch64.BreakpointValueMatch(n, vaddress + 2, linked_to);
    if !value_match && match_i then
        value_match = ConstrainUnpredictableBool(Unpredictable_BPMATCHHALF);

if vaddress<> == '1' && DBGBCR_EL1[n].BAS == '1111' then
    // The above notwithstanding, if DBGBCR_EL1[n].BAS == '1111', then it is CONSTRAINED
    // UNPREDICTABLE whether or not a Breakpoint debug event is generated for an instruction
    // at the address DBGVR_EL1[n]+2.
    if value_match then value_match = ConstrainUnpredictableBool(Unpredictable_BPMATCHHALF);

match = value_match && state_match && enabled;
return match;
Library pseudocode for aarch64/debug/breakpoint/AArch64.BreakpointValueMatch
boolean AArch64.BreakpointValueMatch(integer n, bits(64) vaddress, boolean linked_to)

// "n" is the identity of the breakpoint unit to match against.
// "vaddress" is the current instruction address, ignored if linked_to is TRUE and for Context
// matching breakpoints.
// "linked_to" is TRUE if this is a call from StateMatch for linking.

// If a non-existent breakpoint then it is CONSTRAINED UNPREDICTABLE whether this gives
// no match or the breakpoint is mapped to another UNKNOWN implemented breakpoint.
if n > UInt(ID_AA64DFR0_EL1.BRPs) then
    (c, n) = ConstrainUnpredictableInteger(0, UInt(ID_AA64DFR0_EL1.BRPs), Unpredictable_BPNOTIMPL);
    assert c IN {Constraint_DISABLED, Constraint_UNKNOWN};
    if c == Constraint_DISABLED then return FALSE;

// If this breakpoint is not enabled, it cannot generate a match. (This could also happen on a
// call from StateMatch for linking).
if DBGBCR_EL1[n].E == '0' then return FALSE;

context_aware = (n >= UInt(ID_AA64DFR0_EL1.BRPs) - UInt(ID_AA64DFR0_EL1.CTX_CMPs));

// If BT is set to a reserved type, behaves either as disabled or as a not-reserved type.
type = DBGBCR_EL1[n].BT;

if ((type IN {'011x', '11xx'}) && !HaveVirtHostExt()) ||              // Context matching
    (type != '0x0x' && !context_aware) ||                         // Context matching
    (type == '1xxx' && !HaveEL(EL2))) then                        // EL2 extension
    (c, type) = ConstrainUnpredictableBits(Unpredictable_RESBPTYPE);
    assert c IN {Constraint_DISABLED, Constraint_UNKNOWN};
    if c == Constraint_DISABLED then return FALSE;

// Otherwise the value returned by ConstrainUnpredictableBits must be a not-reserved value
// Determine what to compare against.
match_addr = (type == '0x0x');
match_vmid = (type == '10xx');
match_cid = (type == '001x');
match_cid1 = (type IN { '101x', 'x11x'});
match_cid2 = (type == '11xx');
linked = (type == 'xxx1');

// This is a call from StateMatch, return FALSE if the breakpoint is not programmed for a
// VMID and/or context ID match, or if not context-aware. The above assertions mean that the
// code can just test for match_addr == TRUE to confirm all these things.
if linked_to && (!linked || match_addr) then return FALSE;

// If called from BreakpointMatch return FALSE for Linked context ID and/or VMID matches.
if !linked_to && linked && !match_addr then return FALSE;

// Do the comparison.
if match_addr then
    byte = UInt(vaddress<1:0>);
    if HaveAnyAArch32() then
        // T32 instructions can be executed at EL0 in an AArch64 translation regime.
        assert byte IN {0,2}; // "vaddress" is halfword aligned
        byte_select_match = (DBGBCR_EL1[n].BAS<byte> == '1');
    else
        assert byte == 0; // "vaddress" is word aligned
        byte_select_match = TRUE;
        top = AddrTop(vaddress, TRUE, PSTATE.EL);
        BVR_match = vaddress<top:2> == DBGBVR_EL1[n]<top:2> && byte_select_match;
    elsif match_cid then
        if IsInHost() then
            BVR_match = (CONTEXTIDR_EL2 == DBGBVR_EL1[n]<31:0>);
        else
            BVR_match = (PSTATE.EL IN {EL0,EL1} && CONTEXTIDR_EL1 == DBGBVR_EL1[n]<31:0>);
        end
        elsif match_cid1 then
            BVR_match = (PSTATE.EL IN {EL0,EL1} && !IsInHost() && CONTEXTIDR_EL1 == DBGBVR_EL1[n]<31:0>);
        end
    end
else
    BVR_match = (DBGBCR_EL1[n].BT == '0') && match_addr;
end
if match_vmid then
    if !Have16bitVMID() || VTCR_EL2.VS == '0' then
        vmid = ZeroExtend(VTTBR_EL2.VMID<7:0>, 16);
        bvr_vmid = ZeroExtend(DBGVR_EL1[n]<39:32>, 16);
    else
        vmid = VTTBR_EL2.VMID;
        bvr_vmid = DBGVR_EL1[n]<47:32>;
    BXVR_match = (EL2Enabled() && PSTATE.EL IN {ELO, EL1} &&
                  !IsInHost() &&
                  vmid == bvr_vmid);
elsif match_cid2 then
    BXVR_match = (!IsSecure() && HaveVirtHostExt() &&
                  DBGVR_EL1[n]<63:32> == CONTEXTIDR_EL2);

bvr_match_valid = (match_addr || match_cid || match_cid1);
bxvr_match_valid = (match_vmid || match_cid2);
match = (!bxvr_match_valid || BXVR_match) && (!bvr_match_valid || BVR_match);
return match;
// AArch64.StateMatch()
// -------------------
// Determine whether a breakpoint or watchpoint is enabled in the current mode and state.

boolean AArch64.StateMatch(bits(2) SSC, bit HMC, bits(2) PxC, boolean linked, bits(4) LBN, 
boolean isbreakpnt, AccType acctype, boolean ispriv)

// "SSC", "HMC", "PxC" are the control fields from the DBGBCR[n] or DBGWCR[n] register.
// "linked" is TRUE if this is a linked breakpoint/watchpoint type.
// "LBN" is the linked breakpoint number from the DBGBCR[n] or DBGWCR[n] register.
// "isbreakpnt" is TRUE for breakpoints, FALSE for watchpoints.
// "ispriv" is valid for watchpoints, and selects between privileged and unprivileged accesses.

// If parameters are set to a reserved type, behaves as either disabled or a defined type
if ((HMC:SSC:PxC) IN {'011xx','100x0','101x0','11010','11101','1111x'}) ||       // Reserved
(HMC == '0' && PxC == '00' && (!isbreakpnt || !HaveAArch32EL(EL1))) ||    // Usr/Svc/Sys
(SSC IN {'01','10'} && !HaveEL(EL3)) ||                                   // No EL3
((HMC:SSC != '000' && HMC:SSC != '111' && !HaveEL(EL3) && !HaveEL(EL2)) || // No EL3/EL2
(HMC:SSC:PxC == '11100' && !HaveEL(EL2))) then                            // No EL2
(c<0>, <HMC,SSC,PxC>) = ConstrainUnpredictableBits(Unpredictable_RESBPFPCTRL);
assert c IN {Constraint_DISABLED, Constraint_UNKNOWN};
if c == Constraint_DISABLED then return FALSE;

// Otherwise the value returned by ConstrainUnpredictableBits must be a not-reserved value
EL3_match = HaveEL(EL3) && HMC == '1' && SSC<0> == '0';
EL2_match = HaveEL(EL2) && HMC == '1';
EL1_match = PxC<0> == '1';
EL0_match = PxC<1> == '1';

el = if HaveNV2Ext() && acctype == AccType_NV2REGISTER then EL2 else PSTATE.EL;
if !ispriv && !isbreakpnt then
  priv_match = EL0_match;
else
  case el of
    when EL3 priv_match = EL3_match;
    when EL2 priv_match = EL2_match;
    when EL1 priv_match = EL1_match;
    when EL0 priv_match = EL0_match;
  endcase
  security_state_match = TRUE;         // Both
  if '01' security_state_match = !IsSecure(); // Non-secure only
  when '10' security_state_match = IsSecure(); // Secure only
  when '11' security_state_match = TRUE; // Both

if linked then
  // "LBN" must be an enabled context-aware breakpoint unit. If it is not context-aware then
  // it is CONSTRAINED UNPREDICTABLE whether this gives no match, or LBN is mapped to some
  // UNKNOWN breakpoint that is context-aware.
  lbn = UInt(LBN);
  first_ctx_cmp = UInt(ID_AA64DFR0_EL1.BRPs) - UInt(ID_AA64DFR0_EL1.CTX_CMPs));
  last_ctx_cmp = UInt(ID_AA64DFR0_EL1.BRPs);
  if (lbn < first_ctx_cmp || lbn > last_ctx_cmp) then
    (c<0>, lbn) = ConstrainUnpredictableInteger(first_ctx_cmp, last_ctx_cmp, Unpredictable_BPNOTCTRL);
    assert c IN {Constraint_DISABLED, Constraint_NONE, Constraint_UNKNOWN};
  endcase
  when Constraint_DISABLED return FALSE; // Disabled
  when Constraint_NONE linked = FALSE; // No linking
  // Otherwise ConstrainUnpredictableInteger returned a context-aware breakpoint

if linked then
  vaddress = bits(64) UNKNOWN;
  linked_to = TRUE;
  linked_match = AArch64.BreakpointValueMatch(lbn, vaddress, linked_to);

return priv_match && security_state_match && (!linked || linked_match);
Library pseudocode for aarch64/debug/enables/AArch64.GenerateDebugExceptions

```c
// AArch64.GenerateDebugExceptions()
// --------------------------------

boolean AArch64.GenerateDebugExceptions()
return AArch64.GenerateDebugExceptionsFrom(PSTATE_EL, IsSecure(), PSTATE_D);
```

Library pseudocode for aarch64/debug/enables/AArch64.GenerateDebugExceptionsFrom

```c
// AArch64.GenerateDebugExceptionsFrom()
// -------------------------------------

boolean AArch64.GenerateDebugExceptionsFrom(bits(2) from, boolean secure, bit mask)
if OSLSR_EL1.OSLK == '1' || DoubleLockStatus() || Halted() then
return FALSE;

route_to_el2 = HaveEL2() && !secure && (HCR_EL2.TGE == '1' || MDCR_EL2.TDE == '1');
target = (if route_to_el2 then EL2 else EL1);
enabled = !HaveEL3() || !secure || MDCR_EL3.SDD == '0';
if from == target then
enabled = enabled && MDSCR_EL1.KDE == '1' && mask == '0';
else
enabled = enabled && UInt(target) > UInt(from);
return enabled;
```

Library pseudocode for aarch64/debug/pmu/AArch64.CheckForPMUOverflow

```c
// AArch64.CheckForPMUOverflow()
// -----------------------------
// Signal Performance Monitors overflow IRQ and CTI overflow events

boolean AArch64.CheckForPMUOverflow()

pmuirq = PMCR_EL0.E == '1' && PMINTENSET_EL1<31> == '1' && PMOVSET_EL0<31> == '1';
for n = 0 to UInt(PMCR_EL0.N) - 1
if HaveEL2() then
    E = (if n < UInt(MDCR_EL2.HPMN) then PMCR_EL0.E else MDCR_EL2.HPME);
else
    E = PMCR_EL0.E;
if E == '1' && PMINTENSET_EL1<n> == '1' && PMOVSET_EL0<n> == '1' then pmuirq = TRUE;
SetInterruptRequestLevel(InterruptID_PMUIRQ, if pmuirq then HIGH else LOW);
CTI_SetEventLevel(CrossTriggerIn_PMUOverflow, if pmuirq then HIGH else LOW);
// The request remains set until the condition is cleared. (For example, an interrupt handler
// or cross-triggered event handler clears the overflow status flag by writing to PMOVSCRL_EL0.)
return pmuirq;
```
// AArch64.CountEvents()
// =====================
// Return TRUE if counter "n" should count its event. For the cycle counter, n == 31.

boolean AArch64.CountEvents(integer n)
assert n == 31 || n < UInt(PMCR_EL0.N);

// Event counting is disabled in Debug state
d = Halted();

// In Non-secure state, some counters are reserved for EL2
if HaveEL(EL2) then
    E = if n < UInt(MDCR_EL2.HPMN) || n == 31 then PMCR_EL0.E else MDCR_EL2.HPME;
else
    E = PMCR_EL0.E;
enabled = E == '1' && PMCNTENSET_EL0<n> == '1';

if !IsSecure()
// Event counting in Non-secure state is allowed unless all of:
// * EL2 and the HPMD Extension are implemented
// * Executing at EL2
// * MDCR_EL2.HPMD == 1
if HaveHPMDExt() && PSTATE.EL == EL2 && (n < UInt(MDCR_EL2.HPMN) || n == 31) then
    prohibited = (MDCR_EL2.HPMD == '1');
else
    prohibited = FALSE;
else
// Event counting in Secure state is prohibited unless any one of:
// * EL3 is not implemented
// * EL3 is using AArch64 and MDCR_EL3.SPME == 1
prohibited = HaveEL(EL3) && MDCR_EL3.SPME == '0';

// The IMPLEMENTATION DEFINED authentication interface might override software controls
if prohibited && !HaveNoSecurePMUDisableOverride() then
    prohibited = !ExternalSecureNoninvasiveDebugEnabled();

// For the cycle counter, PMCR_EL0.DP enables counting when otherwise prohibited
if prohibited && n == 31 then prohibited = (PMCR_EL0.DP == '1');

// Event counting can be filtered by the {P, U, NSK, NSU, NSH, M} bits
filter = if n == 31 then PMCCFILTR else PNEVTYPER[n];
P = filter<31>;
U = filter<30>;
NSK = if HaveEL(EL3) then filter<29> else '0';
NSU = if HaveEL(EL3) then filter<28> else '0';
NSH = if HaveEL(EL2) then filter<27> else '0';
M = if HaveEL(EL3) then filter<26> else '0';

case PSTATE.EL of
    when EL0 filtered = if IsSecure() then U == '1' else U != NSU;
    when EL1 filtered = if IsSecure() then P == '1' else P != NSK;
    when EL2 filtered = (NSH == '0');
    when EL3 filtered = (M != P);
return !d && enabled && !prohibited && !filtered;
Library pseudocode for aarch64/debug/statisticalprofiling/CheckProfilingBufferAccess

```c
// CheckProfilingBufferAccess()
// ============================
SysRegAccess CheckProfilingBufferAccess()
    if !HaveStatisticalProfiling() || PSTATE.EL == EL0 || UsingAArch32() then
        return SysRegAccess_UNDEFINED;
    if EL2Enabled() && PSTATE.EL == EL1 && MDCR_EL2.E2PB<0> != '1' then
        return SysRegAccess_TrapToEL2;
    if HaveEL(EL3) && PSTATE.EL != EL3 && MDCR_EL3.NSPB != SCR_EL3.NS:'1' then
        return SysRegAccess_TrapToEL3;
    return SysRegAccess_OK;
```

Library pseudocode for aarch64/debug/statisticalprofiling/CheckStatisticalProfilingAccess

```c
// CheckStatisticalProfilingAccess()
// =================================
SysRegAccess CheckStatisticalProfilingAccess()
    if !HaveStatisticalProfiling() || PSTATE.EL == EL0 || UsingAArch32() then
        return SysRegAccess_UNDEFINED;
    if EL2Enabled() && PSTATE.EL == EL1 && MDCR_EL2.TPMS == '1' then
        return SysRegAccess_TrapToEL2;
    if HaveEL(EL3) && PSTATE.EL != EL3 && MDCR_EL3.NSPB != SCR_EL3.NS:'1' then
        return SysRegAccess_TrapToEL3;
    return SysRegAccess_OK;
```

Library pseudocode for aarch64/debug/statisticalprofiling/CollectContextIDR1

```c
// CollectContextIDR1()
// ====================
boolean CollectContextIDR1()
    if !StatisticalProfilingEnabled() then return FALSE;
    if PSTATE.EL == EL2 then return FALSE;
    if EL2Enabled() && HCR_EL2.TGE == '1' then return FALSE;
    return PMSCR_EL1.CX == '1';
```

Library pseudocode for aarch64/debug/statisticalprofiling/CollectContextIDR2

```c
// CollectContextIDR2()
// ====================
boolean CollectContextIDR2()
    if !StatisticalProfilingEnabled() then return FALSE;
    if EL2Enabled() then return FALSE;
    return PMSCR_EL2.CX == '1';
```

Library pseudocode for aarch64/debug/statisticalprofiling/CollectPhysicalAddress

```c
// CollectPhysicalAddress()
// ========================
boolean CollectPhysicalAddress()
    if !StatisticalProfilingEnabled() then return FALSE;
    (secure, el) = ProfilingBufferOwner();
    if !secure && HaveEL(EL2) then
        return PMSCR_EL2.PA == '1' && (el == EL2 || PMSCR_EL1.PA == '1');
    else
        return PMSCR_EL1.PA == '1';
```
// CollectRecord()
// ===============

boolean CollectRecord(bits(64) events, integer total_latency, 
                      OpType optype)
assert StatisticalProfilingEnabled();
if PMSFCR_EL1.PE == '1' then
  e = events<63:48,31:24,15:12,7,5,3,1>;
  m = PMSEVFR_EL1<63:48,31:24,15:12,7,5,3,1>;
  // Check for UNPREDICTABLE case
  if IsZero(PMSEVFR_EL1) && ConstrainUnpredictableBool(Unpredictable_ZEROPMSEVFR) then return FALSE;
  if !IsZero((e AND m) AND m) then return FALSE;
if PMSFCR_EL1.PT == '1' then
  // Check for UNPREDICTABLE case
  if IsZero(PMSFCR_EL1.<B,LD,ST>) && ConstrainUnpredictableBool(Unpredictable_NOOPTYPES) then
    return FALSE;
  case optype of
    when OpType_Branch if PMSFCR_EL1.B == '0' then return FALSE;
    when OpType_Load if PMSFCR_EL1.LD == '0' then return FALSE;
    when OpType_Store if PMSFCR_EL1.ST == '0' then return FALSE;
    when OpType_LoadAtomic if PMSFCR_EL1.<LD,ST> == '00' then return FALSE;
    otherwise return FALSE;
if PMSFCR_EL1.FL == '1' then
  if IsZero(PMSLATFR_EL1.MINLAT) && ConstrainUnpredictableBool(Unpredictable_ZEROMINLATENCY) then // UNPREDICTABLE case
    return FALSE;
  if total_latency < UInt(PMSLATFR_EL1.MINLAT) then return FALSE;
return TRUE;

// CollectTimeStamp()
// ==================

TimeStamp CollectTimeStamp()
if !StatisticalProfilingEnabled() then return TimeStamp_None;
(sector, el) = ProfilingBufferOwner();
if el == EL2 then
  if PMSCR_EL2.TS == '0' then return TimeStamp_None;
else
  if PMSCR_EL1.TS == '0' then return TimeStamp_None;
if EL2Enabled() then
  pct = PMSCR_EL2.PCT == '1' && (el == EL2 || PMSCR_EL1.PCT == '1');
else
  pct = PMSCR_EL1.PCT == '1';
return (if pct then TimeStamp_Physical else TimeStamp_Virtual);

// OpType

enumeration OpType {
  OpType_Load,                       // Any memory-read operation other than atomics, compare-and-swap, and swap
  OpType_Store,                      // Any memory-write operation, including atomics without return
  OpType_LoadAtomic,                 // Atomics with return, compare-and-swap and swap
  OpType_Branch,                     // Software write to the PC
  OpType_Other;                      // Any other class of operation
};

// ProfilingBufferEnabled
// ========================

boolean ProfilingBufferEnabled()
if !HaveStatisticalProfiling() then return FALSE;
(sector, el) = ProfilingBufferOwner();
non_secure_bit = if sector then '0' else '1';
return (!ELUsingAArch32(el) && non_secure_bit == SCR_EL3.NS &&
          PMBLIMITR_EL1.E == '1' && PMBSR_EL1.S == '0');
// ProfilingBufferOwner()
// ================

(boolean, bits(2)) ProfilingBufferOwner()
    secure = if HaveEL(EL3) then (MDCR_EL3.NSPB<1> == '0') else IsSecure();
el = if !secure && HaveEL(EL2) && MDCR_EL2.E2PB == '00' then EL2 else EL1;
return (secure, el);

// Barrier to ensure that all existing profiling data has been formatted, and profiling buffer
// addresses have been translated such that writes to the profiling buffer have been initiated.
// A following DSB completes when writes to the profiling buffer have completed.
ProfilingSynchronizationBarrier();

// StatisticalProfilingEnabled()
// =============================

boolean StatisticalProfilingEnabled()
    if !HaveStatisticalProfiling() || UsingAArch32() || !ProfilingBufferEnabled() then return FALSE;
in_host = EL2Enabled() && HCR_EL2.TGE == '1';
(secure, el) = ProfilingBufferOwner();
if UInt(el) < UInt(PSTATE.EL) || secure != IsSecure() || (in_host && el == EL1) then return FALSE;
case PSTATE.EL of
    when EL3 Unreachable();
    when EL2 spe_bit = PMSCR_EL2.E2SPE;
    when EL1 spe_bit = PMSCR_EL1.E1SPE;
    when EL0 spe_bit = (if in_host then PMSCR_EL2.E0HSPE else PMSCR_EL1.E0SPE);
return spe_bit == '1';

// SysRegAccess

enumeration SysRegAccess { SysRegAccess_OK,
                      SysRegAccess_UNDEFINED,
                      SysRegAccess_TrapToEL1,
                      SysRegAccess_TrapToEL2,
                      SysRegAccess_TrapToEL3 };

// TimeStamp

enumeration TimeStamp { TimeStamp_None,
                      TimeStamp_Virtual,
                      TimeStamp_Physical };

// AArch64.TakeExceptionInDebugState()
// ----------------------------------
// Take an exception in Debug state to an Exception Level using AArch64.

AArch64.TakeExceptionInDebugState(bits(2) target_el, ExceptionRecord exception)
assert HaveEL(target_el) && !ELUsingAArch32(target_el) && UInt(target_el) >= Uint(PSTATE.EL);
sync_errors = !PSTATE.EL1 && HaveIESB() && SCTLR[].IESB == '1';
if HaveDoubleFaultExt() then
  sync_errors = sync_errors || (SCR_EL3.EA == '1' && SCR_EL3.NMEA == '1' && PSTATE.EL == EL3);
if !ConstrainUnpredictableBool(Unpredictable_IESBinDebug) then
  sync_errors = FALSE;
if sync_errors && InsertIESBBeforeException(target_el) then
  SynchronizeErrors();

SynchronizeContext();

// If coming from AArch32 state, the top parts of the X[] registers might be set to zero
from_32 = UsingAArch32();
if from_32 then AArch64.MaybeZeroRegisterUppers();
MaybeZeroSVEUppers(target_el);
AArch64.ReportException(exception, target_el);

PSTATE.EL = target_el; PSTATE.nRW = '0'; PSTATE.SP = '1';
SPSR[] = bits(32) UNKNOWN;
ELR[] = bits(64) UNKNOWN;

// PSTATE.{SS,D,A,I,F} are not observable and ignored in Debug state, so behave as if UNKNOWN.
PSTATE.CPSR.D = bits(5) UNKNOWN;
DLR_EL0 = bits(64) UNKNOWN;
DSPSR_EL0 = bits(32) UNKNOWN;
PSTATE.I = '0';
if from_32 then // Coming from AArch32
  PSTATE.IT = '00000000'; PSTATE.T = '0'; // PSTATE.J is RES0
if HaveSSBSExt() then PSTATE.SCBS = bits(1) UNKNOWN;
// PSTATE.{SS,D,A,I,F} are not observable and ignored in Debug state, so behave as if UNKNOWN.
PSTATE.CPSR.F = bits(5) UNKNOWN;
DLR_EL0 = bits(64) UNKNOWN;
DSPSR_EL0 = bits(32) UNKNOWN;
if HaveBTIExt() then
  if exception.type == Exception_Breakpoint then
    DSPSR_EL0<11:10> = PSTATE.BTYPE;
  else
    DSPSR_EL0<11:10> = if ConstrainUnpredictableBool(Unpredictable_ZEROBTYPE) then '00' else PSTATE.BTYPE;
  PSTATE.BTYPE = '00';

PSTATE.I = '0';
if from_32 then // Coming from AArch32
  PSTATE.IT = '00000000'; PSTATE.T = '0'; // PSTATE.J is RES0
if HavePANExt() && (PSTATE.EL == EL1 || (PSTATE.EL == EL2 && ELIsInHost(EL0))) && SCTLR[].SPAN == '1';
if ESCR.ERR == '1'; HaveMTEExtUpdateEDSCRFields() then PSTATE.TCO = '1';
();                        // Update ESCR processor state flags.

EDSCR.ERR = '1'; // SCTLR[].IESB might be ignored in Debug state.
if sync_errors then
  SynchronizeErrors();
EndOfInstruction();
// AArch64.WatchpointByteMatch()
// ----------------------------------------

boolean AArch64.WatchpointByteMatch(integer n, AccType acctype, bits(64) vaddress)

    el = if HaveNV2Ext() && acctype == AccType_NV2REGISTER then EL2 else PSTATE.EL;
    top = AddrTop(vaddress, FALSE, el);
    bottom = if DBGWVR_EL1[n]<2> == '1' then 2 else 3; // Word or doubleword
    byte_select_match = (DBGWCR_EL1[n].BAS<UInt(vaddress<bottom-1:0>)> != '0');
    mask = UInt(DBGWCR_EL1[n].MASK);
    // If DBGWCR_EL1[n].MASK is non-zero value and DBGWCR_EL1[n].BAS is not set to '11111111', or
    // DBGWCR_EL1[n].BAS specifies a non-contiguous set of bytes behavior is CONSTRAINED
    // UNPREDICTABLE.
    if mask > 0 && !IsOnes(DBGWCR_EL1[n].BAS) then
        byte_select_match = ConstrainUnpredictableBool(Unpredictable_WPMASKANDBAS);
    else
        LSB = (DBGWCR_EL1[n].BAS AND NOT(DBGWCR_EL1[n].BAS - 1));  MSB = (DBGWCR_EL1[n].BAS + LSB);
        if !IsZero(MSB AND (MSB - 1)) then                     // Not contiguous
            byte_select_match = ConstrainUnpredictableBool(Unpredictable_WPBASCONTIGUOUS);
        bottom = 3;                                        // For the whole doubleword
    // If the address mask is set to a reserved value, the behavior is CONSTRAINED UNPREDICTABLE.
    if mask > 0 && mask <= 2 then
        (c, mask) = ConstrainUnpredictableInteger(3, 31, Unpredictable_RESWPMASK);
        assert c IN {Constraint_DISABLED, Constraint_NONE, Constraint_UNKNOWN};
        case c of
            when Constraint_DISABLED return FALSE;            // Disabled
            when Constraint_NONE mask = 0;                // No masking
            else // Otherwise the value returned by ConstrainUnpredictableInteger is a not-reserved value
                if mask > bottom then
                    WVR_match = (vaddress<top:mask> == DBGWVR_EL1[n]<top:mask>);
                    // If masked bits of DBGWVR_EL1[n] are not zero, the behavior is CONSTRAINED UNPREDICTABLE.
                    if WVR_match && !IsZero(DBGWVR_EL1[n]<mask-1:bottom>) then
                        WVR_match = ConstrainUnpredictableBool(Unpredictable_WPMASKEDBITS);
                    else
                        WVR_match = vaddress<top:bottom> == DBGWVR_EL1[n]<top:bottom>;
                    return WVR_match && byte_select_match;
                break
            endcase
        end;
    else
        WVR_match = (vaddress<top:mask> == DBGWVR_EL1[n]<top:mask>);
        // If masked bits of DBGWVR_EL1[n] are not zero, the behavior is CONSTRAINED UNPREDICTABLE.
        if WVR_match && !IsZero(DBGWVR_EL1[n]<mask-1:bottom>) then
            WVR_match = ConstrainUnpredictableBool(Unpredictable_WPMASKEDBITS);
        else
            WVR_match = vaddress<top:bottom> == DBGWVR_EL1[n]<top:bottom>;
        return WVR_match && byte_select_match;
    end;

Shared Pseudocode Functions
// AArch64.WatchpointMatch\{
// Watchpoint matching in an AArch64 translation regime.

boolean AArch64.WatchpointMatch(integer n, bits(64) vaddress, integer size, boolean ispriv, AccType acctype, boolean iswrite)
    assert !ELUsingAArch32(S1TranslationRegime());
    assert n <= UInt(ID_AA64DPFR0_EL1.WRPs);

    // "ispriv" is FALSE for LDTR/STTR instructions executed at EL1 and all
    // load/stores at EL0, TRUE for all other load/stores. "iswrite" is TRUE for stores, FALSE for
    // loads.
    enabled = DBGWCR_EL1[n].E == '1';
    linked = DBGWCR_EL1[n].WT == '1';
    isbreakpnt = FALSE;

    state_match = AArch64.StateMatch(DBGWCR_EL1[n].SSC, DBGWCR_EL1[n].HMC, DBGWCR_EL1[n].PAC, linked, DBGWCR_EL1[n].LBN, isbreakpnt, acctype, ispriv);

    ls_match = (DBGWCR_EL1[n].LSC<(if iswrite then 1 else 0)> == '1');

    value_match = FALSE;
    for byte = 0 to size - 1
        value_match = value_match || AArch64.WatchpointByteMatch(n, acctype, vaddress + byte);

    return value_match && state_match && ls_match && enabled;

// AArch64.Abort\{
// Abort and Debug exception handling in an AArch64 translation regime.

AArch64.Abort(bits(64) vaddress, FaultRecord fault)
    if IsDebugException(fault) then
        if fault.acctype == AccType_IFETCH then
            if UsingAArch32() && fault.debugmoe == DebugException_VectorCatch then
                AArch64.VectorCatchException(fault);
            else
                AArch64.BreakpointException(fault);
        else
            AArch64.InstructionAbort(vaddress, fault);
        end
    elsif fault.acctype == AccType_IFETCH then
        AArch64.WatchpointException(vaddress, fault);
    else
        AArch64.DataAbort(vaddress, fault);
    end
Library pseudocode for aarch64/exceptions/aborts/AArch64.AbortSyndrome

```cpp
// AArch64.AbortSyndrome()
// --------------------------
// Creates an exception syndrome record for Abort and Watchpoint exceptions
// from an AArch64 translation regime.

ExceptionRecord AArch64.AbortSyndrome(Exception type, FaultRecord fault, bits(64) vaddress)
    exception = ExceptionSyndrome(type);
    d_side = type IN {Exception_DataAbort, Exception_NV2DataAbort, Exception_Watchpoint};
    exception.syndrome = AArch64.FaultSyndrome(d_side, fault);
    if IPAValid(fault) then
        exception.ipavalid = TRUE;
        exception.NS = fault.ipaddress.NS;
        exception.ipaddress = fault.ipaddress.address;
    else
        exception.ipavalid = FALSE;
    return exception;
```

Library pseudocode for aarch64/exceptions/aborts/AArch64.CheckPCAlignment

```cpp
// AArch64.CheckPCAlignment()
// --------------------------
AArch64.CheckPCAlignment()
    bits(64) pc = ThisInstrAddr();
    if pc<1:0> != '00' then
        AArch64.PCAlignmentFault();
```

Library pseudocode for aarch64/exceptions/aborts/AArch64.DataAbort

```cpp
// AArch64.DataAbort()
// -------------------
AArch64.DataAbort(bits(64) vaddress, FaultRecord fault)
    route_to_el3 = HaveEL(EL3) && SCR_EL3.EA == '1' && IsExternalAbort(fault);
    route_to_el2 = (EL2Enabled() && PSTATE.EL IN {EL0, EL1} && (HCR_EL2.TGE == '1' ||
        (HaveRASExt() && HCR_EL2.TEA == '1' && IsExternalAbort(fault)) ||
        (HaveNV2Ext() && fault.acctype == AccType_NV2REGISTER) ||
        IsSecondStage(fault)));
    bits(64) preferred_exception_return = ThisInstrAddr();
    if vect_offset = 0x0;
    if HaveDoubleFaultExt() && (PSTATE.EL == EL3 || route_to_el3) &&
        IsExternalAbort(fault) && SCR_EL3.EASE == '1') then
        vect_offset = 0x180;
    else
        vect_offset = 0x0;
    if HaveNV2Ext() && fault.acctype == AccType_NV2REGISTER then
        exception = AArch64.AbortSyndrome(Exception_NV2DataAbort, fault, vaddress);
    else
        exception = AArch64.AbortSyndrome(Exception_DataAbort, fault, vaddress);
    if PSTATE.EL == EL3 || route_to_el3 then
        AArch64.TakeException(EL3, exception, preferred_exception_return, vect_offset);
    elsif PSTATE.EL == EL2 || route_to_el2 then
        AArch64.TakeException(EL2, exception, preferred_exception_return, vect_offset);
    else
        AArch64.TakeException(EL1, exception, preferred_exception_return, vect_offset);
```
// AArch64.InstructionAbort()
// ----------------------------------

AArch64.InstructionAbort(bits(64) vaddress, FaultRecord fault)
  // External aborts on instruction fetch must be taken synchronously
  // if route_to_el3 = HaveDoubleFaultExt() then assert fault.type != Fault_AsyncExternal;
  if route_to_el3 = HaveEL(EL3) && SCR_EL3.EA == '1' && IsExternalAbort(fault);
  route_to_el2 = (EL2Enabled() && PSTATE_EL IN (EL0,EL1)) &&
    (HCR_EL2.TGE == '1' || IsSecondStage(fault)) ||
    (HaveRASExt() && HCR_EL2.TEA == '1' && IsExternalAbort(fault));

  bits(64) preferred_exception_return = ThisInstrAddr();
  vect_offset = 0x0;

  exception = AArch64.AbortSyndrome(Exception_InstructionAbort, fault, vaddress);

  if PSTATE.EL == EL3 || route_to_el3 then
    AArch64.TakeException(EL3, exception, preferred_exception_return, vect_offset);
  elsif PSTATE.EL == EL2 || route_to_el2 then
    AArch64.TakeException(EL2, exception, preferred_exception_return, vect_offset);
  else
    AArch64.TakeException(EL1, exception, preferred_exception_return, vect_offset);

Library pseudocode for aarch64/exceptions/aborts/AArch64.PCAlignmentFault

// AArch64.PCAlignmentFault()
// -----------------------------
// Called on unaligned program counter in AArch64 state.

AArch64.PCAlignmentFault()

  bits(64) preferred_exception_return = ThisInstrAddr();
  vect_offset = 0x0;

  exception = ExceptionSyndrome(Exception_PCAlignment);
  exception.vaddress = ThisInstrAddr();

  if UInt(PSTATE.EL) > UInt(EL1) then
    AArch64.TakeException(PSTATE.EL, exception, preferred_exception_return, vect_offset);
  elsif EL2Enabled() && HCR_EL2.TGE == '1' then
    AArch64.TakeException(EL2, exception, preferred_exception_return, vect_offset);
  else
    AArch64.TakeException(EL1, exception, preferred_exception_return, vect_offset);

Library pseudocode for aarch64/exceptions/aborts/AArch64.SPAlignmentFault

// AArch64.SPAlignmentFault()
// -----------------------------
// Called on an unaligned stack pointer in AArch64 state.

AArch64.SPAlignmentFault()

  bits(64) preferred_exception_return = ThisInstrAddr();
  vect_offset = 0x0;

  exception = ExceptionSyndrome(Exception_SPAlignment);

  if UInt(PSTATE.EL) > UInt(EL1) then
    AArch64.TakeException(PSTATE.EL, exception, preferred_exception_return, vect_offset);
  elsif EL2Enabled() && HCR_EL2.TGE == '1' then
    AArch64.TakeException(EL2, exception, preferred_exception_return, vect_offset);
  else
    AArch64.TakeException(EL1, exception, preferred_exception_return, vect_offset);
// BranchTargetException
// ===============
// Raise branch target exception.
AArch64.BranchTargetException(bits(52) vaddress)

    route_to_el2 = EL2Enabled() && PSTATE.EL == EL0 && HCR_EL2.TGE == '1';
    bits(64) preferred_exception_return = ThisInstrAddr();
    vect_offset = 0x0;

    exception = ExceptionSyndrome(Exception_BranchTarget);
    exception.syndrome<1:0> = PSTATE.BTYPE;
    exception.syndrome<24:2> = Zeros(); // RES0

    if UInt(PSTATE.EL) > UInt(EL1) then
        AArch64.TakeException(PSTATE.EL, exception, preferred_exception_return, vect_offset);
    elsif route_to_el2 then
        AArch64.TakeException(EL2, exception, preferred_exception_return, vect_offset);
    else
        AArch64.TakeException(EL1, exception, preferred_exception_return, vect_offset);

// EffectiveTCF()
// ===============
// Returns the TCF field applied to Tag Check Fails in the given Exception Level
Bits(2) EffectiveTCF(bits(2) el)

    if el == EL3 then
        tcf = SCTLR_EL3.TCF;
    elsif el == EL2 then
        tcf = SCTLR_EL2.TCF;
    elsif el == EL1 then
        tcf = SCTLR_EL1.TCF;
    elsif el == EL0 && HCR_EL2.<E2H,TGE> == '11' then
        tcf = SCTLR_EL2.TCF0;
    elsif el == EL0 && HCR_EL2.<E2H,TGE> != '11' then
        tcf = SCTLR_EL1.TCF0;

    return tcf;

// RecordTagCheckFail()
// =====================
// Records a tag fail exception into the appropriate TCFR_ELx
ReportTagCheckFail(bits(2) el, bit ttbr)

    if el == EL3 then
        assert ttbr == '0';
        TFSR_EL3.TF0 = '1';
    elsif el == EL2 then
        if ttbr == '0' then
            TFSR_EL2.TF0 = '1';
        else
            TFSR_EL2.TF1 = '1';
    elsif el == EL1 then
        if ttbr == '0' then
            TFSR_EL1.TF0 = '1';
        else
            TFSR_EL1.TF1 = '1';
    elsif el == EL0 then
        if ttbr == '0' then
            TFSR_E0_EL1.TF0 = '1';
        else
            TFSR_E0_EL1.TF1 = '1';
// TagCheckFail()
// Handle a tag check fail condition
TagCheckFail(bits(64) vaddress, boolean iswrite)
    bits(2) tcf = EffectiveTCF(PSTATE.EL);
    if tcf == '01' then
        TagCheckFault(vaddress, iswrite);
    elsif tcf == '10' then
        ReportTagCheckFail(PSTATE.EL, vaddress<55>);

// TagCheckFault()
// Raise a tag check fail exception.
TagCheckFault(bits(64) va, boolean write)
    bits(2) target_el;
    bits(64) preferred_exception_return = ThisInstrAddr();
    integer vect_offset = 0x00;
    if PSTATE.EL == EL0 then
        target_el = if HCR_EL2.TGE == 0 then
            EL1 else
            EL2;
    else
        target_el = PSTATE.EL;
    exception = ExceptionSyndrome(Exception_DataAbort);
    exception.syndrome<5:0> = '010001';
    if write then
        exception.syndrome<6> = '1';
        exception.vaddress = va;
    AArch64.TakeException(target_el, exception, preferred_exception_return, vect_offset);

// AArch64.TakePhysicalFIQException()
// AArch64.TakePhysicalFIQException()
AArch64.TakePhysicalFIQException()
    route_to_el3 = HaveEL(EL3) && SCR_EL3.FIQ == '1';
    route_to_el2 = (EL2Enabled() && PSTATE.EL IN {EL0,EL1} &&
        (HCR_EL2.TGE == '1' || HCR_EL2.FMO == '1'));
    bits(64) preferred_exception_return = ThisInstrAddr();
    vect_offset = 0x100;
    exception = ExceptionSyndrome(Exception_FIQ);
    if route_to_el3 then
        AArch64.TakeException(EL3, exception, preferred_exception_return, vect_offset);
    elsif PSTATE.EL == EL2 && route_to_el2 then
        assert PSTATE.EL != EL3;
        AArch64.TakeException(EL2, exception, preferred_exception_return, vect_offset);
    else
        assert PSTATE.EL IN {EL0,EL1};
        AArch64.TakeException(EL1, exception, preferred_exception_return, vect_offset);
Library pseudocode for aarch64/exceptions/asynch/AArch64.TakePhysicalIRQException

// AArch64.TakePhysicalIRQException()
// ----------------------------------
// Take an enabled physical IRQ exception.

AArch64.TakePhysicalIRQException()

route_to_el3 = HaveEL(EL3) && SCR_EL3.IRQ == '1';
route_to_el2 = (EL2Enabled() && PSTATE.EL IN {EL0,EL1}) &&
(HCR_EL2.TGE == '1' || HCR_EL2.IMO == '1'));
bits(64) preferred_exception_return = ThisInstrAddr();
vect_offset = 0x80;

exception = ExceptionSyndrome(Exception_IRQ);
if route_to_el3 then
  AArch64.TakeException(EL3, exception, preferred_exception_return, vect_offset);
elsif PSTATE.EL == EL2 || route_to_el2 then
  assert PSTATE.EL != EL3;
  AArch64.TakeException(EL2, exception, preferred_exception_return, vect_offset);
else
  assert PSTATE.EL IN {EL0,EL1};
  AArch64.TakeException(EL1, exception, preferred_exception_return, vect_offset);

Library pseudocode for aarch64/exceptions/asynch/AArch64.TakePhysicalSErrorException

// AArch64.TakePhysicalSErrorException()
// ------------------------------------
// AArch64.TakePhysicalSErrorException(boolean impdef_syndrome, bits(24) syndrome)

AArch64.TakePhysicalSErrorException(

route_to_el3 = HaveEL(EL3) && SCR_EL3.EA == '1';
route_to_el2 = (EL2Enabled() && PSTATE.EL IN {EL0,EL1}) &&
(HCR_EL2.TGE == '1' || (!IsInHost() && HCR_EL2.AMO == '1')));
bits(64) preferred_exception_return = ThisInstrAddr();
vect_offset = 0x180;

exception = ExceptionSyndrome(Exception_SError);
exception.syndrome<24> = if impdef_syndrome then '1' else '0';
exception.syndrome<23:0> = syndrome;
ClearPendingPhysicalSError();
if PSTATE.EL == EL3 || route_to_el3 then
  AArch64.TakeException(EL3, exception, preferred_exception_return, vect_offset);
elsif PSTATE.EL == EL2 || route_to_el2 then
  AArch64.TakeException(EL2, exception, preferred_exception_return, vect_offset);
else
  AArch64.TakeException(EL1, exception, preferred_exception_return, vect_offset);

Library pseudocode for aarch64/exceptions/asynch/AArch64.TakeVirtualFIQException

// AArch64.TakeVirtualFIQException()
// ----------------------------------

AArch64.TakeVirtualFIQException()

assert EL2Enabled() && PSTATE.EL IN {EL0,EL1};
assert HCR_EL2.TGE == '0' && HCR_EL2.FMO == '1'; // Virtual IRQ enabled if TGE==0 and FMO==1
bits(64) preferred_exception_return = ThisInstrAddr();
vect_offset = 0x100;

exception = ExceptionSyndrome(Exception_FIQ);
AArch64.TakeException(EL1, exception, preferred_exception_return, vect_offset);
// AArch64.TakeVirtualIRQException()
// =================================

AArch64.TakeVirtualIRQException()
assert EL2Enabled() && PSTATE.EL IN {EL0, EL1};
assert HCR_EL2.TGE == '0' && HCR_EL2.IMO == '1'; // Virtual IRQ enabled if TGE==0 and IMO==1

bits(64) preferred_exception_return = ThisInstrAddr();
vect_offset = 0x80;

exception = ExceptionSyndrome(Exception_IRQ);
AArch64.TakeException(EL1, exception, preferred_exception_return, vect_offset);

// AArch64.TakeVirtualSErrorException()
// ====================================

AArch64.TakeVirtualSErrorException(boolean impdef_syndrome, bits(24) syndrome)
assert EL2Enabled() && PSTATE.EL IN {EL0, EL1};
assert HCR_EL2.TGE == '0' && HCR_EL2.AMO == '1'; // Virtual SError enabled if TGE==0 and AMO==1

bits(64) preferred_exception_return = ThisInstrAddr();
vect_offset = 0x180;

exception = ExceptionSyndrome(Exception_SError);
if HaveRASExt() then
  exception.syndrome<24> = VESR_EL2.IDS;
  exception.syndrome<23:0> = VESR_EL2.ISS;
else
  exception.syndrome<24> = if impdef_syndrome then '1' else '0';
  if impdef_syndrome then exception.syndrome<23:0> = syndrome;

ClearPendingVirtualSError();
AArch64.TakeException(EL1, exception, preferred_exception_return, vect_offset);

// AArch64.BreakpointException()
// =============================

AArch64.BreakpointException(FaultRecord fault)
assert PSTATE.EL != EL3;

route_to_el2 = (EL2Enabled() && PSTATE.EL IN {EL0, EL1} &&
  (HCR_EL2.TGE == '1' || MDCR_EL2.TDE == '1'));

bits(64) preferred_exception_return = ThisInstrAddr();
vect_offset = 0x0;

vaddress = bits(64) UNKNOWN;
exception = AArch64.AbortSyndrome(Exception_Breakpoint, fault, vaddress);

if PSTATE.EL == EL2 || route_to_el2 then
  AArch64.TakeException(EL2, exception, preferred_exception_return, vect_offset);
else
  AArch64.TakeException(EL1, exception, preferred_exception_return, vect_offset);
Library pseudocode for aarch64/exceptions/debug/AArch64.SoftwareBreakpoint

```c
// AArch64.SoftwareBreakpoint()
// -------------------------------------

AArch64.SoftwareBreakpoint(bits(16) immediate)

route_to_el2 = (EL2Enabled() && PSTATE.EL IN (EL0,EL1) &&
  (HCR_EL2.TGE == '1' || MDCR_EL2.TDE == '1'));

bits(64) preferred_exception_return = ThisInstrAddr();
vect_offset = 0x0;

exception = ExceptionSyndrome(Exception_SoftwareBreakpoint);
exception.syndrome<15:0> = immediate;
if UInt(PSTATE.EL) > UInt(EL1) then
  AArch64.TakeException(PSTATE.EL, exception, preferred_exception_return, vect_offset);
else if route_to_el2 then
  AArch64.TakeException(EL2, exception, preferred_exception_return, vect_offset);
else
  AArch64.TakeException(EL1, exception, preferred_exception_return, vect_offset);
```

Library pseudocode for aarch64/exceptions/debug/AArch64.SoftwareStepException

```c
// AArch64.SoftwareStepException()
// -----------------------------------

AArch64.SoftwareStepException()

assert PSTATE.EL != EL3;

route_to_el2 = (EL2Enabled() && PSTATE.EL IN (EL0,EL1) &&
  (HCR_EL2.TGE == '1' || MDCR_EL2.TDE == '1'));

bits(64) preferred_exception_return = ThisInstrAddr();
vect_offset = 0x0;

exception = ExceptionSyndrome(Exception_SoftwareStep);
if SoftwareStep_DidNotStep() then
  exception.syndrome<24> = '0';
else
  exception.syndrome<24> = '1';
  exception.syndrome<6> = if SoftwareStep_SteppedEX() then '1' else '0';
if PSTATE.EL == EL2 || route_to_el2 then
  AArch64.TakeException(EL2, exception, preferred_exception_return, vect_offset);
else
  AArch64.TakeException(EL1, exception, preferred_exception_return, vect_offset);
```

Library pseudocode for aarch64/exceptions/debug/AArch64.VectorCatchException

```c
// AArch64.VectorCatchException()
// ----------------------------------

AArch64.VectorCatchException(FaultRecord fault)

assert PSTATE.EL != EL2;
assert EL2Enabled() && (HCR_EL2.TGE == '1' || MDCR_EL2.TDE == '1');

bits(64) preferred_exception_return = ThisInstrAddr();
vect_offset = 0x0;

vaddress = bits(64) UNKNOWN;
exception = AArch64.AbortSyndrome(Exception_VectorCatch, fault, vaddress);
AArch64.TakeException(EL2, exception, preferred_exception_return, vect_offset);
```
// AArch64.WatchpointException()
// =============================
AArch64.WatchpointException(bits(64) vaddress, FaultRecord fault)
assert PSTATE.EL != EL3;

route_to_el2 = (EL2Enabled() && PSTATE.EL IN (EL0, EL1) &&
(HCR_EL2.TGE == '1' || MDCR_EL2.TDE == '1'));

bits(64) preferred_exception_return = ThisInstrAddr();
vect_offset = 0x0;

exception = AArch64.AbortSyndrome(Exception_Watchpoint, fault, vaddress);
if PSTATE.EL == EL2 || route_to_el2 then
  AArch64.TakeException(EL2, exception, preferred_exception_return, vect_offset);
else
  AArch64.TakeException(EL1, exception, preferred_exception_return, vect_offset);
// AArch64.ExceptionClass()
// Returns the Exception Class and Instruction Length fields for reported in ESR

(integer, bit) AArch64.ExceptionClass(Exception type, bits(2) target_el)

il = if ThisInstrLength() == 32 then '1' else '0';
from_32 = UsingAArch32();
assert from_32 || il == '1'; // AArch64 instructions always 32-bit

case type of
  when Exception_Uncategorized ec = 0x00; il = '1';
  when Exception_WFxTrap ec = 0x01;
  when Exception_CP15RTTrap ec = 0x03; assert from_32;
  when Exception_CP15RRTTrap ec = 0x04; assert from_32;
  when Exception_CP14RTTrap ec = 0x05; assert from_32;
  when Exception_CP14DTRTTrap ec = 0x06; assert from_32;
  when Exception_AdvSIMDFPAccessTrap ec = 0x07;
  when Exception_FPIDTrap ec = 0x08;
  when Exception_PACTrap ec = 0x09;
  when Exception_CP14RRTTrap ec = 0x0C; assert from_32;
  when Exception_BranchTarget ec = 0x0D;
  when Exception_IllegalState ec = 0x0E; il = '1';
  when Exception_SupervisorCall ec = 0x11;
  when Exception_HypervisorCall ec = 0x12;
  when Exception_MonitorCall ec = 0x13;
  when Exception_SystemRegisterTrap ec = 0x18; assert !from_32;
  when Exception_SVEAccessTrap ec = 0x19; assert !from_32;
  when Exception_ERetTrap ec = 0x1A;
  when Exception_InstructionAbort ec = 0x20; il = '1';
  when Exception_PCAIignment ec = 0x22; il = '1';
  when Exception_DataAbort ec = 0x24;
  when Exception_NV2DataAbort ec = 0x25;
  when Exception_PAIIgment ec = 0x26; il = '1'; assert !from_32;
  when Exception_FPTrappedException ec = 0x28;
  when Exception_PError ec = 0x2F; il = '1';
  when Exception_Breakpoint ec = 0x30; il = '1';
  when Exception_SoftwareStep ec = 0x32; il = '1';
  when Exception_Watchpoint ec = 0x34; il = '1';
  when Exception_SoftwareBreakpoint ec = 0x38;
  when Exception_VectorCatch ec = 0x3A; il = '1'; assert from_32;
  otherwise Unreachable();

if ec IN {0x20, 0x24, 0x30, 0x32, 0x34} \&\& target_el == PSTATE.EL then
  ec = ec + 1;

if ec IN {0x11, 0x12, 0x13, 0x28, 0x38} \&\& !from_32 then
  ec = ec + 4;

return (ec, il);
// AArch64.ReportException()  
// =========================  
// Report syndrome information for exception taken to AArch64 state.

AArch64.ReportException(ExceptionRecord exception, bits(2) target_el)

  Exception type = exception.type;

  (ec, il) = AArch64.ExceptionClass(type, target_el);
  iss = exception.syndrome;

  // IL is not valid for Data Abort exceptions without valid instruction syndrome information
  if ec IN {0x24,0x25} & iss<24> == '0' then
      il = '1';

  ESR[target_el] = ec<5:0>:il:iss;

  if type IN {Exception InstructionAbort, Exception PCAlignment, Exception DataAbort, Exception NV2DataAbort, Exception Watchpoint} then
      FAR[target_el] = exception.vaddress;
  else
      FAR[target_el] = bits(64) UNKNOWN;

  if target_el == EL2 then
      if exception.ipavalid then
          HPFAR_EL2<43:4> = exception.ipaddress<51:12>;
          if HaveSecureEL2Ext() then
              if IsSecureEL2Enabled() then
                  HPFAR_EL2.NS = exception.NS;
              else
                  HPFAR_EL2.NS = '0';
          else
              HPFAR_EL2<43:4> = bits(40) UNKNOWN;
  return;

Library pseudocode for aarch64/exceptions/exceptions/AArch64.ResetControlRegisters

// Resets System registers and memory-mapped control registers that have architecturally-defined
// reset values to those values.
AArch64.ResetControlRegisters(boolean cold_reset);
// AArch64.TakeReset()
// ================
// Reset into AArch64 state

AArch64.TakeReset(boolean cold_reset)
    assert !HighestELUsingAArch32();

    // Enter the highest implemented Exception level in AArch64 state
    PSTATE.nRW = '0';
    if HaveEL(EL3) then
        PSTATE.EL = EL3;
    elsif HaveEL(EL2) then
        PSTATE.EL = EL2;
    else
        PSTATE.EL = EL1;

    // Reset the system registers and other system components
    AArch64.ResetControlRegisters(cold_reset);

    // Reset all other PSTATE fields
    PSTATE.SP = '1'; // Select stack pointer
    PSTATE.<D,A,I,F> = '1111'; // All asynchronous exceptions masked
    PSTATE.SS = '0'; // Clear software step bit
    PSTATE.DIT = '0'; // PSTATE.DIT is reset to 0 when resetting into AArch64
    PSTATE.IL = '0'; // Clear Illegal Execution state bit

    // All registers, bits and fields not reset by the above pseudocode or by the BranchTo() call
    // below are UNKNOWN bitstrings after reset. In particular, the return information registers
    // ELR_ELx and SPSR_ELx have UNKNOWN values, so that it
    // is impossible to return from a reset in an architecturally defined way.
    AArch64.ResetGeneralRegisters();
    AArch64.ResetSIMDFPRegisters();
    AArch64.ResetSpecialRegisters();
    ResetExternalDebugRegisters(cold_reset);

    bits(64) rv; // IMPLEMENTATION DEFINED reset vector

    if HaveEL(EL3) then
        rv = RVBAR_EL3;
    elsif HaveEL(EL2) then
        rv = RVBAR_EL2;
    else
        rv = RVBAR_EL1;

    // The reset vector must be correctly aligned
    assert IsZero(rv<63:PAMax()>) && IsZero(rv<1:0>);

    BranchTo(rv, BranchType_RESET, BranchType_UNKNOWN);
// AArch64.FPTrappedException()
// ============================
AArch64.FPTrappedException(boolean is_ase, integer element, bits(8) accumulated_exceptions)
exception = ExceptionSyndrome(Exception_FPTrappedException);
    if is_ase then
        if boolean IMPLEMENTATION_DEFINED "vector instructions set TFV to 1" then
            exception.syndrome<23> = '1';                      // TFV
        else
            exception.syndrome<23> = '0';                      // TFV
        else
            exception.syndrome<23> = '1';                      // TFV
        exception.syndrome<10:8> = bits(3) UNKNOWN;          // VECITR
        if exception.syndrome<23> == '1' then
            exception.syndrome<7,4:0> = accumulated_exceptions<7,4:0>; // IDF,IXF,UFF,OFF,DZF,IOF
        else
            exception.syndrome<7,4:0> = bits(6) UNKNOWN;        // TFV
        if is_ase then exception.syndrome<10:8> = element<2:0>; // VECITR
        exception.syndrome<7,4:0> = accumulated_exceptions<7,4:0>; // IDF,IXF,UFF,OFF,DZF,IOF
    route_to_el2 = EL2Enabled() && HCR_EL2.TGE == '1';
    bits(64) preferred_exception_return = ThisInstrAddr();
    vect_offset = 0x0;
    if UInt(PSTATE.EL) > UInt(EL1) then
        AArch64.TakeException(PSTATE.EL, exception, preferred_exception_return, vect_offset);
    elsif route_to_el2 then
        AArch64.TakeException(EL2, exception, preferred_exception_return, vect_offset);
    else
        AArch64.TakeException(EL1, exception, preferred_exception_return, vect_offset);

// AArch64.CallHypervisor()
// ========================
// Performs a HVC call
AArch64.CallHypervisor(bits(16) immediate)
assert HaveEL(EL2);
    if UsingAArch32() then AArch32.ITAdvance();
    SSAdvance();
    bits(64) preferred_exception_return = NextInstrAddr();
    vect_offset = 0x0;
    exception = ExceptionSyndrome(Exception_HypervisorCall);
    exception.syndrome<15:0> = immediate;
    if PSTATE.EL == EL3 then
        AArch64.TakeException(EL3, exception, preferred_exception_return, vect_offset);
    else
        AArch64.TakeException(EL2, exception, preferred_exception_return, vect_offset);
// AArch64.CallSecureMonitor()
// ------------------------

AArch64.CallSecureMonitor(bits(16) immediate)
assert HaveEL(EL3) && !UsingAArch32(EL3);
if UsingAArch32() then AArch32.ITAdvance();
SSAdvance();

bits(64) preferred_exception_return = NextInstrAddr();
vect_offset = 0x0;

exception = ExceptionSyndrome(Exception_MonitorCall);
exception.syndrome<15:0> = immediate;
AArch64.TakeException(EL3, exception, preferred_exception_return, vect_offset);

Library pseudocode for aarch64/exceptions/syscalls/AArch64.CallSupervisor

// AArch64.CallSupervisor()
// ------------------------

// Calls the Supervisor

AArch64.CallSupervisor(bits(16) immediate)

if UsingAAArch32() then AArch32.ITAdvance();
SSAdvance();

route_to_el2 = EL2Enabled() && PSTATE.EL == EL0 && HCR_EL2.TGE == '1';

bits(64) preferred_exception_return = NextInstrAddr();
vect_offset = 0x0;

exception = ExceptionSyndrome(Exception_SupervisorCall);
exception.syndrome<15:0> = immediate;

if UInt(PSTATE.EL) > UInt(EL1) then
  AArch64.TakeException(PSTATE.EL, exception, preferred_exception_return, vect_offset);
elsif route_to_el2 then
  AArch64.TakeException(EL2, exception, preferred_exception_return, vect_offset);
else
  AArch64.TakeException(EL1, exception, preferred_exception_return, vect_offset);
AArch64.TakeException() takes an exception to an Exception Level using AArch64.

```c
AArch64.TakeException(bits(2) target_el, ExceptionRecord exception,
    bits(64) preferred_exception_return, integer vect_offset)
assert HaveEL(target_el) && !ELUsingAArch32(target_el) && Uint(target_el) >= Uint(PSTATE.EL);

sync_errors = LSTATE.EL; HaveIESB() && SCTLR[].IESB == '1';
if HaveDoubleFaultExt() then
    sync_errors = sync_errors || (SCR_EL3.EA == '1' && SCR_EL3.NMEA == '1' && PSTATE.EL == EL3);
if sync_errors && InsertIESBBeforeException(target_el) then
    SynchronizeErrors();
    iesb_req = FALSE;
    sync_errors = FALSE;
    TakeUnmaskedPhysicalSErrorInterrupts(iesb_req);
SynchronizeContext();
```

If coming from AArch32 state, the top parts of the X[] registers might be set to zero from_32 = UsingAArch32(); if from_32 then AArch64.MaybeZeroRegisterUppers(); MaybeZeroSVEUppers(target_el);

```c
if Uint(target_el) > Uint(PSTATE.EL) then
    boolean lower_32;
    if target_el == EL3 then
        if EL2Enabled() then
            lower_32 = ELUsingAArch32(EL2);
        else
            lower_32 = ELUsingAArch32(EL1);
    elsif IsInHost() && PSTATE.EL == EL0 && target_el == EL2 then
        lower_32 = ELUsingAArch32(EL0);
    else
        lower_32 = ELUsingAArch32(target_el - 1);
    vect_offset = vect_offset + (if lower_32 then 0x600 else 0x400);
    elsif PSTATE.SP == '1' then
        vect_offset = vect_offset + 0x200;
    spsr = GetPSRFromPSTATE();
    if PSTATE.EL == EL1 && target_el == EL1 && HaveNVExt() && EL2Enabled() && HCR_EL2.<NV, NV1> == '10' then
        spsr<3:2> = '10';
    if HaveUAOExt() then PSTATE.UAO = '0';
    if ![exception.type IN {Exception_IRQ, Exception_FIQ}] then
        AArch64.ReportException(exception, target_el);
    PSTATE.EL = target_el; PSTATE.nRW = '0'; PSTATE.SP = '1';
    if PSTATE.EL == target_el; PSTATE.nRW == '0'; PSTATE.SP == '1'; HaveBTIExt() then
        if ![exception.type IN {Exception_ERROR, Exception_IRQ, Exception_FIQ, Exception_SSoftwareStep, Exception_PCAlignment, Exception_InstructionAbort, Exception_SoftwareBreakpoint, Exception_IllegalState, Exception_Branch}]
            spsr_btype = PSTATE.BTYPE;
        else
            spsr_btype = if ConstrainUnpredictableBool(Unpredictable_ZEROBTYPE) then '00' else PSTATE.BTYPE;
        spsr<11:10> = spsr_btype;
    SPSR[] = spsr;
    ELR[] = preferred_exception_return;
    PSTATE.SS = '1';
    PSTATE.CD,A,1,F = '1111';
    PSTATE.IL = '0';
    if from_32 then // Coming from AArch32
        PSTATE.IT = '00000000'; PSTATE.T = '0'; // PSTATE.I is RES0
    if HaveSSBSExt() then PSTATE.SSBS = SCTLR[].DSSBS;

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```
if HaveBTIExt() then PSTATE.BTYPE = '00';
PSTATE.SS = '0';
PSTATE.<D,A,I,F> = '1111';
PSTATE.IL = '0';
if from_32 then // Coming from AArch32
  PSTATE.IT = '00000000'; PSTATE.T = '0'; // PSTATE.J is RES0
if HavePANExt() && (PSTATE.EL == EL1 || (PSTATE.EL == EL2 && ELIsInHost(EL0)) && SCTLR[].SPAN == '1') && 
PSTATE.PAN = '1';
if HaveMTEExt() then PSTATE.TCO = '1';
BranchTo(VBAR[]<63:11>:vect_offset<10:0>, BranchType_EXCEPTION);

if HaveRASExt() && 
  if sync_errors then if IESB == '1' then 
    SynchronizeErrors();
  iesb_req = TRUE;
  TakeUnmaskedPhysicalSErrorInterrupts(iesb_req);

EndOfInstruction();

Library pseudocode for aarch64/exceptions/traps/AArch64.AArch32SystemAccessTrap

// AArch64.AArch32SystemAccessTrap()
// ===============================
// Trapped AArch32 System register access other than due to CPTR_EL2 or CPACR_EL1.
AArch64.AArch32SystemAccessTrap(bits(2) target_el, bits(32) aarch32_instr)
assert HaveEL(target_el) && target_el != EL0 && UInt(target_el) >= UInt(PSTATE.EL);
bits(64) preferred_exception_return = ThisInstrAddr();
vect_offset = 0x0;

exception = AArch64.AArch32SystemAccessTrapSyndrome(aarch32_instr);
if target_el == EL1 && EL2Enabled() && HCR_EL2.TGE == '1' then 
  AArch64.TakeException(EL2, exception, preferred_exception_return, vect_offset);
else
  AArch64.TakeException(target_el, exception, preferred_exception_return, vect_offset);
// AArch64.AArch32SystemAccessTrapSyndrome()
// ---------------------------------------------------------------
// Return the syndrome information for traps on AArch32 MCR, MCRR, MRC, MRRC, and VMRS instructions,
// other than traps that are due to HCPTR or CPACR.

ExceptionRecord AArch64.AArch32SystemAccessTrapSyndrome(bits(32) instr)
    ExceptionRecord exception;
    cpnum = UInt(instr[11:8]);

    bits(20) iss = Zeros();
        // MRC/MCR
        case cpnum of
            when 10 exception = ExceptionSyndrome(Exception_FPIDTrap);
            when 14 exception = ExceptionSyndrome(Exception_CP14RTTrap);
            when 15 exception = ExceptionSyndrome(Exception_CP15RTTrap);
            otherwise Unreachable();
    end case

    iss[19:17] = instr[7:5];  // opc2
    iss[16:14] = instr[23:21];  // opc1
    iss[13:10] = instr[19:16];  // CRn
    if instr[20] == '1' && instr[15:12] == '1111' then // MRC, Rt==15
        iss[9:5] = '11111';
    elsif instr[20] == '0' && instr[15:12] == '1111' then // MCR, Rt==15
        iss[9:5] = bits(5) UNKNOWN;
    else
        iss[9:5] = LookUpRIndex(UInt(instr[15:12]), PSTATE.M)<4:0>;
    end case

    iss[19:16] = instr[7:4];  // opc1
    if instr[19:16] == '1111' then // Rt2==15
        iss[14:10] = bits(5) UNKNOWN;
    else
        iss[14:10] = LookUpRIndex(UInt(instr[19:16]), PSTATE.M)<4:0>;
    end case

    if instr[15:12] == '1111' then // Rt==15
        iss[9:5] = bits(5) UNKNOWN;
    else
        iss[9:5] = LookUpRIndex(UInt(instr[15:12]), PSTATE.M)<4:0>;
    end if

    iss[4:1] = instr[3:0];  // CRm
    if instr[19:16] == '1111' then // Rn==15, LDC(Literal addressing)/STC
        iss[9:5] = bits(5) UNKNOWN;
    else
        iss[9:5] = LookUpRIndex(UInt(instr[19:16]), PSTATE.M)<4:0>;
    end if

    assert cpnum == 14;
    exception = ExceptionSyndrome(Exception_CP14DTTrap);

    iss[19:12] = instr[7:0];  // imm8
    iss[4] = instr[23];  // U
    if instr[19:16] == '1111' then // Rn==15, LDC(Literal addressing)/STC
        iss[9:5] = bits(5) UNKNOWN;
    else
        iss[9:5] = LookUpRIndex(UInt(instr[19:16]), PSTATE.M)<4:0>;
    end if

    iss[3] = '1';
    else
        Unreachable();
    end case

    iss[0] = instr[20];  // Direction

    exception.syndrome<24:20> = ConditionSyndrome();
    exception.syndrome<19:0> = iss;

    return exception;
AArch64.AdvSIMDFPAccessTrap(bits(2) target_el)
bits(64) preferred_exception_return = ThisInstrAddr();
vect_offset = 0x0;

route_to_el2 = (target_el == EL1 && EL2Enabled() && HCR_EL2.TGE == '1');

if route_to_el2 then
    exception = ExceptionSyndrome(Exception_Uncategorized);
    AArch64.TakeException(EL2, exception, preferred_exception_return, vect_offset);
else
    exception = ExceptionSyndrome(Exception_AdvSIMDFPAccessTrap);
    exception.syndrome<24:20> = ConditionSyndrome();
    AArch64.TakeException(target_el, exception, preferred_exception_return, vect_offset);
return;
// AArch64.CheckAArch32SystemAccess()
// ==================================
// Check AArch32 System register access instruction for enables and disables

AArch64.CheckAArch32SystemAccess(bits(32) instr)
    cp_num = UInt(instr<11:8>);
    assert cp_num IN {14,15};
    // Decode the AArch32 System register access instruction
    if instr<31:28> != '1111' && instr<27:24> == '1110' && instr<4> == '1' then  // MRC/MCR
        cp_num = 14;
        opc1 = UInt(instr<23:21>);
        opc2 = UInt(instr<7:5>);
        CRn  = UInt(instr<19:16>);
        CRm  = UInt(instr<3:0>);
    elsif instr<31:28> != '1111' && instr<27:21> == '1100010' then                   // MRRC/MCRR
        cp_num = 15;
        opc1 = UInt(instr<7:4>);
        CRm  = UInt(instr<3:0>);
    elsif instr<31:28> != '1111' && instr<27:25> == '110' && instr<22> == '0' then   // LDC/STC
        cp_num = 15;
        opc1 = 0;
        CRn  = UInt(instr<15:12>);
    else
        allocated = FALSE;

    // Coarse-grain decode into CP14 or CP15 encoding space. Each of the CPxxxInstrDecode functions
    // returns TRUE if the instruction is allocated at the current Exception level, FALSE otherwise.
    if cp_num == 14 then
        // LDC and STC only supported for c5 in CP14 encoding space
        if cpdt && CRn != 5 then
            allocated = FALSE;
        else
            // Coarse-grained decode of CP14 based on opc1 field
            case opc1 of
                when 0 allocated = CP14DebugInstrDecode(instr);
                when 1 allocated = CP14TraceInstrDecode(instr);
                when 7 allocated = CP14JazelleInstrDecode(instr);    // JIDR only
                otherwise allocated = FALSE;          // All other values are unallocated
            endcase
        end
    elsif cp_num == 15 then
        // LDC and STC not supported in CP15 encoding space
        if !cpdt then
            allocated = FALSE;
        else
            allocated = CP15InstrDecode(instr);
        end

    // Coarse-grain traps to EL2 have a higher priority than exceptions generated because
    // the access instruction is UNDEFINED
    if AArch64.CheckCP15InstrCoarseTraps(CRn, nreg, CRm) then
        // For a coarse-grain trap, if it is IMPLEMENTATION DEFINED whether an access from
        // User mode is UNDEFINED when the trap is disabled, then it is
        // IMPLEMENTATION DEFINED whether the same access is UNDEFINED or generates a trap
        // when the trap is enabled.
        if PSTATE.EL == EL0 && EL2Enabled() && !allocated then
            // For a coarse-grain trap, if it is IMPLEMENTATION DEFINED whether an access from
            // User mode is UNDEFINED when the trap is disabled, then it is
            // IMPLEMENTATION DEFINED whether the same access is UNDEFINED or generates a trap
            // when the trap is enabled.
            if boolean IMPLEMENTATION_DEFINED "UNDEF unallocated CP15 access at
            EL0" then
                UNDEFINED;
                AArch64.AArch32SystemAccessTrap(EL2, instr);
            end
            allocated = FALSE;
        end
    end
    if !allocated then
        UNDEFINED;

    // If the instruction is not UNDEFINED, it might be disabled or trapped to a higher EL.
    AArch64.CheckAArch32SystemAccessTraps(instr);

    return;
// Library pseudocode for aarch64/exceptions/traps/AArch64.CheckAArch32SystemAccessEL1Traps()
// -----------------------------------------
// Check for configurable disables or traps to EL1 or EL2 of an AArch32 System register
// access instruction.

AArch64.CheckAArch32SystemAccessEL1Traps(bits(32) instr)
    assert PSTATE.EL == EL0;
    trap = FALSE;

    // Decode the AArch32 System register access instruction
    (op, cp_num, CRn, CRm, opc2, write) = AArch32.DecodeSysRegAccess(instr);

    if cp_num == 14 then
        if ((op == SystemAccessType_RT && opc1 == 0 && CRn == 0 && CRm == 5 && opc2 == 0) ||
            (op == SystemAccessType_DT && CRn == 5 && opc2 == 0)) then
            trap = !Halted() && MDSCR_EL1.TDCC == '1';
        elsif opc1 == 0 then
            trap = MDSCR_EL1.TDCC == '1';
        elsif opc1 == 1 then
            trap = CPACR[].TTA == '1';
        elsif cp_num == 15 then
            if ((op == SystemAccessType_RT && opc1 == 0 && CRn == 9 && CRm == 12 && opc2 == 0) ||
                (op == SystemAccessType_RT && opc1 == 0 && CRn == 9 && CRm == 12 && opc2 == 1) ||
                (op == SystemAccessType_RT && opc1 == 0 && CRn == 9 && CRm == 12 && opc2 == 2) ||
                (op == SystemAccessType_RT && opc1 == 0 && CRn == 9 && CRm == 12 && opc2 == 3) ||
                (op == SystemAccessType_RT && opc1 == 0 && CRn == 14 && CRm == 12 && opc2 == 6) ||
                (op == SystemAccessType_RT && opc1 == 0 && CRn == 14 && CRm == 12 && opc2 == 7) ||
                (op == SystemAccessType_RT && opc1 == 0 && CRn == 14 && CRm == 13 && opc2 == 1) ||
                (op == SystemAccessType_RT && opc1 == 0 && CRn == 14 && CRm == 14 && opc2 == 3) ||
                (op == SystemAccessType_RT && opc1 == 0 && CRn == 14 && CRm == 12 && opc2 == 4) then
                trap = PMUSERENR_EL0.EN == '0';
            elsif op == SystemAccessType_RT && opc1 == 0 && CRn == 14 && CRm == 12 && opc2 == 5 then
                trap = PMUSERENR_EL0.EN == '0' && PMUSERENR_EL0.ER == '0';
            elsif op == SystemAccessType_RT && opc1 == 0 && CRn == 14 && CRm == 12 && opc2 == 6 then
                trap = PMUSERENR_EL0.EN == '0' && PMUSERENR_EL0.ER == '0';
            elsif op == SystemAccessType_RT && opc1 == 0 && CRn == 14 && CRm == 2 && opc2 IN {0,1,2} then
                trap = CNTKCTL[].ELOPTEN == '0';
            elsif op == SystemAccessType_RT && opc1 == 0 && CRn == 2 && CRm == 0 && opc2 == 0 then
                trap = CNTKCTL[].ELOPTEN == '0' && CNTKCTL[].ELOVCENT == '0';
            elsif op == SystemAccessType_RRT && opc1 == 1 && CRm == 14 then
                trap = CNTKCTL[].ELOVCENT == '0';
            end
            if trap then
                AArch64.AArch32SystemAccessTrap(EL1, instr);
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// AArch64.CheckAArch32SystemAccessEL2Traps()
// -----------------------------------------------
// Check for configurable traps to EL2 of an AArch32 System register access instruction.

AArch64.CheckAArch32SystemAccessEL2Traps(bits(32) instr)
assert EL2Enabled() && PSTATE.EIN {EL0, EL1, EL2};

trap = FALSE;
// Decode the AArch32 System register access instruction
(op, cp_num, opc1, CRn, CRm, opc2, write) = AArch32.DecodeSysRegAccess(Instr);
if cp_num == 14 && PSTATE.EIN {EL0, EL1} then
    if ((op == SystemAccessType_RT && opc1 == 0 && CRn == 1 && CRm == 0 && opc2 == 0) ||  // DBGDRAR
        (op == SystemAccessType_RRT && opc1 == 0 && CRm == 1) ||                         // DBGDRAR (MRRC)
        (op == SystemAccessType_RT && opc1 == 0 && CRn == 2 && CRm == 0 && opc2 == 0) || // DBGDSAR
        (op == SystemAccessType_RRT && opc1 == 0 && CRm == 2)) then                      // DBGDSAR (MRRC)
        trap = MDCR_EL2.TDRA == '1' || MDCR_EL2.TDE == '1' || HCR_EL2.TGE == '1';
elsif ((op == SystemAccessType_RT && opc1 == 0 && CRn == 1 && CRm == 0 && opc2 == 4) || // DBGOSLAR
        (op == SystemAccessType_RT && opc1 == 0 && CRn == 1 && CRm == 1 && opc2 == 4) ||    // DBGOSLSR
        (op == SystemAccessType_RT && opc1 == 0 && CRn == 1 && CRm == 3 && opc2 == 4) ||    // DBGOSDLR
        (op == SystemAccessType_RT && opc1 == 0 && CRn == 1 && CRm == 4 && opc2 == 4)) then // DBGPRCR
        trap = MDCR_EL2.TDOSA == '1' || MDCR_EL2.TDE == '1' || HCR_EL2.TGE == '1';
elsif opc1 == 0 && (!Halted() || !(op == SystemAccessType_RT && CRn == 0 && CRm == 5 && opc2 == 0)) then
        trap = MDCR_EL2.TDA == '1' || MDCR_EL2.TDE == '1' || HCR_EL2.TGE == '1';
elsif opc1 == 1 then
        trap = CPTR_EL2.TTA == '1';
elsif op == SystemAccessType_RT && opc1 == 7 && CRn == 0 && CRm == 0 && opc2 == 0 then  // JIDR
        trap = HCR_EL2.TID0 == '1';
elsif cp_num == 15 && PSTATE.EIN {EL0, EL1} then
    if opc1 == 1 then
        trap = CPTR_EL2.TTA == '1';
elsif op == SystemAccessType_RT && opc1 == 7 & CRn == 0 & CRm == 0 & opc2 == 0 then // JIDR
    trap = HCR_EL2.TID0 == '1';
elsif cp_num == 16 && PSTATE.EIN {EL0, EL1} then
    if opc1 == 1 then
        trap = CPTR_EL2.TTA == '1';
elsif cp_num == 15 && PSTATE.EIN {EL0, EL1} then
    if ((op == SystemAccessType_RT && opc1 == 0 && CRn == 1 && CRm == 0 && opc2 == 0) ||  // SCTLR
        (op == SystemAccessType_RT && opc1 == 0 && CRn == 2 && CRm == 0 && opc2 == 0) ||  // TTBR0
        (op == SystemAccessType_RT && opc1 == 0 && CRn == 2 && CRm == 0 && opc2 == 2) ||  // TTBR1
        (op == SystemAccessType_RT && opc1 == 0 && CRn == 3 && CRm == 0 && opc2 == 0) ||  // DACR
        (op == SystemAccessType_RT && opc1 == 0 && CRn == 6 && CRm == 0 && opc2 == 0) ||  // DPAR
        (op == SystemAccessType_RT && opc1 == 0 && CRn == 5 && CRm == 0 && opc2 == 0) ||  // AFISR
        (op == SystemAccessType_RT && opc1 == 0 && CRn == 10 && CRm == 0 && opc2 == 0) ||  // PRIMR/MUSR
        (op == SystemAccessType_RT && opc1 == 0 && CRn == 10 && CRm == 0 && opc2 == 0) ||  // NRMR/MRSR
        (op == SystemAccessType_RT && opc1 == 0 && CRn == 10 && CRm == 2 && opc2 == 0) ||  // AMASR
        (op == SystemAccessType_RT && opc1 == 0 && CRn == 10 && CRm == 0 && opc2 == 2) ||  // AMACR
        (op == SystemAccessType_RT && opc1 == 0 && CRn == 13 && CRm == 2 && opc2 == 1) then // CONTEXTIDR
        trap = if write then HCR_EL2.TVM == '1' else HCR_EL2.TKVM == '1';
elsif op == SystemAccessType_RT && opc1 == 0 && CRn == 8 then                         // TLBI
    trap = write & HCR_EL2.TTLB == '1';
elsif ((op == SystemAccessType_RT && opc1 == 0 && CRn == 7 && CRm == 6 && opc2 == 2) || // DCI
    (op == SystemAccessType_RT && opc1 == 0 && CRn == 7 && CRm == 10 && opc2 == 2) || // DCI
    (op == SystemAccessType_RT && opc1 == 0 && CRn == 7 && CRm == 14 && opc2 == 2)) then // DCI
    trap = write & HCR_EL2.TSSW == '1';
elsif ((op == SystemAccessType_RT && opc1 == 0 && CRn == 7 && CRm == 6 && opc2 == 1) || // DCI
    (op == SystemAccessType_RT && opc1 == 0 && CRn == 7 && CRm == 10 && opc2 == 1) || // DCI
    (op == SystemAccessType_RT && opc1 == 0 && CRn == 7 && CRm == 14 && opc2 == 1)) then // DCI
    trap = write & HCR_EL2.TFPCC == '1';
elsif ((op == SystemAccessType_RT && opc1 == 0 && CRn == 7 && CRm == 5 && opc2 == 1)) then // DCOTMVAU
  trap = write && HCR_EL2.TPU == '1';
elsif ((op == SystemAccessType_RT && opc1 == 0 && CRn == 7 && CRm == 5 && opc2 == 0)) then // DICALLU
  trap = HCR_EL2.TACR == '1';
elsif ((op == SystemAccessType_RT && opc1 == 0 && CRn == 7 && CRm == 1 && opc2 == 0)) then // DICAILLIS
  trap = HCR_EL2.TID1 == '1';
elsif ((op == SystemAccessType_RT && opc1 == 0 && CRn == 7 && CRm == 11 && opc2 == 1)) then // DCCMVAU
  trap = write && HCR_EL2.TPU == '1';
elsif ((op == SystemAccessType_RT && opc1 == 0 && CRn == 1 && CRm == 0 && opc2 == 1)) then // ACTLR
  trap = HCR_EL2.TID1 == '1';
elsif ((op == SystemAccessType_RT && opc1 == 0 && CRn == 1 && CRm == 0 && opc2 == 3)) then // ACTLR2
  trap = HCR_EL2.TID1 == '1';
elsif ((op == SystemAccessType_RT && opc1 == 0 && CRn == 0 && CRm == 0 && opc2 == 2)) then // TCMTR
  trap = HCR_EL2.TID1 == '1';
elsif ((op == SystemAccessType_RT && opc1 == 0 && CRn == 0 && CRm == 0 && opc2 == 3)) then // TLBTR
  trap = HCR_EL2.TID1 == '1';
elsif ((op == SystemAccessType_RT && opc1 == 0 && CRn == 0 && CRm == 0 && opc2 == 6)) then // REVIDR
  trap = HCR_EL2.TID1 == '1';
elsif ((op == SystemAccessType_RT && opc1 == 0 && CRn == 0 && CRm == 0 && opc2 == 7)) then // AIDR
  trap = HCR_EL2.TID1 == '1';
elsif ((op == SystemAccessType_RT && opc1 == 0 && CRn == 0 && CRm == 1)) then // ID_1
  trap = HCR_EL2.TID1 == '1';
elsif ((op == SystemAccessType_RT && opc1 == 0 && CRn == 0 && CRm == 2 && opc2 <= 7)) then // ID_2
  trap = HCR_EL2.TID1 == '1';
elsif ((op == SystemAccessType_RT && opc1 == 0 && CRn == 0 && CRm >= 3 && opc2 <= 1)) then // Reserved
  trap = HCR_EL2.TID1 == '1';
elsif ((op == SystemAccessType_RT && opc1 == 0 && CRn == 0 && CRm == 3 && opc2 == 2)) then // Reserved
  trap = HCR_EL2.TID1 == '1';
elsif ((op == SystemAccessType_RT && opc1 == 0 && CRn == 0 && CRm == 5 && opc2 IN {4,5})) then // Reserved
  trap = HCR_EL2.TID1 == '1';
elsif op == SystemAccessType_RT && opc1 == 0 && CRn == 1 && CRm == 0 && opc2 == 2 then // CPACR
  trap = CPTR_EL2.TCPAC == '1';
elsif op == SystemAccessType_RT && opc1 == 0 && CRn == 9 && CRm == 12 && opc2 == 0 then // PMCR
  trap = MDCR_EL2.TPACR == '1' || MDCR_EL2.TPM == '1';
elsif ((op == SystemAccessType_RT && opc1 == 0 && CRn == 14 && CRm >= 8) ||
  (op == SystemAccessType_RT && opc1 == 0 && CRn == 9 && CRm IN {12,13,14}) ||
  (op == SystemAccessType_RT && opc1 == 0 && CRm == 9))) then // PMCCNTR (MRRC/MCCR)
  trap = MDCR_EL2.TPM == '1';
elsif op == SystemAccessType_RT && opc1 == 0 && CRn == 14 && CRm == 2 && opc2 IN {0,1,2} then // CNTPCT
  trap = CNTHCTL_EL2.EL1PTEN == '0';
elsif ((op == SystemAccessType_RT && opc1 == 0 && CRn == 1 && CRm == 1 && opc2 == 0) ||
  (op == SystemAccessType_RT && opc1 == 0 && CRn == 1 && CRm == 2) ||
  (op == SystemAccessType_RT && opc1 == 0 && CRn == 12 && CRm == 1)) then // MTBT
  trap = CNTHCTL_EL2.EL1PCEN == '0';
elsif ((op == SystemAccessType_RT && opc1 == 0 && CRn == 1 && CRm == 3 && opc2 == 0)) then // MTBV
  trap = CNTHCTL_EL2.EL1PCEN == '0';
elsif ((op == SystemAccessType_RT && opc1 == 0 && CRn == 14 && CRm == 2 && opc2 IN {0,1,2}) then
  if !HaveVirtHostExt() || HCR_EL2.E2H == '0' then
    trap = CNTHCTL_EL2.EL1PCEN == '0';
  else
    trap = CNTHCTL_EL2.EL1PCEN == '0';
elsif op == SystemAccessType_RT && opc1 == 0 && CRn == 14 && CRm == 2 && opc2 IN {0,1,2} then
  if !HaveVirtHostExt() || HCR_EL2.E2H == '0' then
    trap = CNTHCTL_EL2.EL1PCEN == '0';
else
  trap = CNTHCTL_EL2.EL1PCEN == '0';
elsif ((op == SystemAccessType_RT && opc1 == 0 && CRn == 14 && CRm == 2 && opc2 == 0) ||
  (op == SystemAccessType_RT && opc1 == 0 && CRn == 14 && CRm == 2 && opc2 == 2) ||
  (op == SystemAccessType_RT && opc1 == 0 && CRn == 14 && CRm == 2 && opc2 == 1) ||
  (op == SystemAccessType_RT && opc1 == 0 && CRn == 14 && CRm == 2 && opc2 == 0)) then // AMT
  trap = IsSecureEL2Enabled() && PSTATE.EL == EL1 && IsSecure() && ELUsingAArch32(EL1);
  if trap then
    AArch64.AArch32SystemAccessTrap(EL2, instr);
AArch64.CheckAArch32SystemAccessTraps(bits(32) instr)

assert HaveEL(EL3) && PSTATE.EL != EL3;

// Decode the AArch32 System register access instruction
(op, cp_num, opc1, CRn, CRm, opc2, write) = AArch32.DecodeSysRegAccess(instr);

trap = FALSE;
if cp_num == 14 then
  if (op == SystemAccessType_RT && opc1 == 0 && CRn == 1 && CRm == 0 && opc2 == 4 && !write)
    then trap = MDCR_EL3.TDOSA == '1';
  elsif opc1 == 0 && (!Halted() || !op == SystemAccessType_RT && CRn == 0 && CRm == 5 && opc2 == 0)
    then trap = MDCR_EL3.TDA == '1';
  elsif opc1 == 1 then
    trap = CPTR_EL3.TTA == '1';
elsif cp_num == 15 then
  if (op == SystemAccessType_RT && opc1 == 0 && CRn == 1 && CRm == 0 && opc2 == 2)
    then trap = MDCR_EL3.TCPAC == '1';
  elsif ((op == SystemAccessType_RT && opc1 == 0 && CRn == 14 && CRm >= 8) ||
    (op == SystemAccessType_RT && opc1 == 0 && CRn == 9 && CRm IN {12,13,14}) ||
    (op == SystemAccessType_RT && opc1 == 0 && CRn == 7 && CRm == 8 && opc2 >= 4))
    then trap = MDCR_EL3.TPM == '1';
if trap then
  AArch64.AArch32SystemAccessTrap(EL3, instr);

Shared Pseudocode Functions
## AArch64.CheckCP15InstrCoarseTraps

```plaintext
boolean AArch64.CheckCP15InstrCoarseTraps(integer CRn, integer nreg, integer CRm)
```

// Check for coarse-grained Hyp traps
if EL2Enabled() && PSTATE.EL IN {EL0, EL1} then
  // Check for MCR, MRC, MCRR and MRRC disabled by HSTR_EL2<CRn/CRm>
  major = if nreg == 1 then CRn else CRm;
  if !IsInHost() && !(major IN {4,14}) && HSTR_EL2<major> == '1' then
    return TRUE;

// Check for MRC and MCR disabled by HCR_EL2.TIDCP
if (HCR_EL2.TIDCP == '1' && nreg == 1 &&
    ((CRn == 9 && CRm IN {0,1,2, 5,6,7,8 }) ||
     (CRn == 10 && CRm IN {0,1, 4,     8   }) ||
     (CRn == 11 && CRm IN {0,1,2,3,4,5,6,7,8,15}))) then
  return TRUE;

return FALSE;
```

## AArch64.CheckFPAdvSIMDEnabled

```plaintext
// Check against CPACR[]
AArch64.CheckFPAdvSIMDEnabled()
```

if PSTATE.EL IN {EL0, EL1} && !IsInHost() then
  // Check if access disabled in CPACR_EL1
  case CPACR[].FPEN of
    when 'x0' disabled = TRUE;
    when '01' disabled = PSTATE.EL == EL0;
    when '11' disabled = FALSE;
  if disabled then AArch64.AdvSIMDFPAccessTrap(EL1);
  AArch64.CheckFPAdvSIMDTrap(); // Also check against CPTR_EL2 and CPTR_EL3
```

## AArch64.CheckFPAdvSIMDTrap

```plaintext
// Check against CPTR_EL2 and CPTR_EL3.
AArch64.CheckFPAdvSIMDTrap()
```

if EL2Enabled() then
  // Check if access disabled in CPTR_EL2
  if HaveVirtHostExt() && HCR_EL2.E2H == '1' then
    case CPTR_EL2.FPEN of
      when 'x0' disabled = !(PSTATE.EL == EL1 && HCR_EL2.TGE == '1');
      when '01' disabled = (PSTATE.EL == EL0 && HCR_EL2.TGE == '1');
      when '11' disabled = FALSE;
    if disabled then AArch64.AdvSIMDFPAccessTrap(EL2);
  else
    if CPTR_EL2.TFP == '1' then AArch64.AdvSIMDFPAccessTrap(EL2);

if HaveEL(EL3) then
  // Check if access disabled in CPTR_EL3
  if CPTR_EL3.TFP == '1' then AArch64.AdvSIMDFPAccessTrap(EL3);

return;
// AArch64.CheckForERetTrap()
// ----------------------------------
// Check for trap on ERET, ERETTA, ERETAB instruction

AArch64.CheckForERetTrap(boolean eret_with_pac, boolean pac_uses_key_a)

// Non-secure EL1 execution of ERET, ERETTA, ERETAB when HCR_EL2.NV bit is set, is trapped to EL2
route_to_el2 = HaveNVExt() && EL2Enabled() && PSTATE.EL == EL1 && HCR_EL2.NV == '1';

if route_to_el2 then
    ExceptionRecord exception;
    bits(64) preferred_exception_return = ThisInstrAddr();
    vect_offset = 0x0;
    exception = ExceptionSyndrome(Exception_ERetTrap);
    if !eret_with_pac then                             // ERET
        exception.syndrome<1> = '0';
        exception.syndrome<0> = '0';                   // RES0
    else
        exception.syndrome<1> = '1';
        if pac_uses_key_a then                         // ERETTA
            exception.syndrome<0> = '0';
        else                                           // ERETAB
            exception.syndrome<0> = '1';
    AArch64.TakeException(EL2, exception, preferred_exception_return, vect_offset);

Library pseudocode for aarch64/exceptions/traps/AArch64.CheckForSMCUndefOrTrap

// AArch64.CheckForSMCUndefOrTrap()
// -----------------------------------
// Check for UNDEFINED or trap on SMC instruction

AArch64.CheckForSMCUndefOrTrap(bits(16) imm)

route_to_el2 = EL2Enabled() && PSTATE.EL == EL1 && HCR_EL2.TSC == '1';

if PSTATE.EL == EL0 then UNDEFINED;
if !route_to_el2 then
    UnallocatedEncoding();
else
    if HaveEL(EL3) then
        if EL2Enabled() && PSTATE.EL == EL1 then
            if HaveNVExt() && HCR_EL2.NV == '1' && HCR_EL2.TSC == '1' then
                route_to_el2 = TRUE;
            else
                UnallocatedEncoding();
        else
            UnallocatedEncoding() && HCR_EL2.NV == '1' && HCR_EL2.TSC == '1' then
                route_to_el2 = TRUE;
            else
                UNDEFINED;
        else
            UNDEFINED;
    else
        route_to_el2 = EL2Enabled() && PSTATE.EL == EL1 && HCR_EL2.TSC == '1';
        if route_to_el2 then
            bits(64) preferred_exception_return = ThisInstrAddr();
            vect_offset = 0x0;
            exception = ExceptionSyndrome(Exception_MonitorCall);
            exception.syndrome<15:0> = imm;
            AArch64.TakeException(EL2, exception, preferred_exception_return, vect_offset);
// AArch64.CheckForWFxTrap()
// ------------------------
// Check for trap on WFE or WFI instruction

AArch64.CheckForWFxTrap(bits(2) target_el, boolean is_wfe)
assert HaveEL(target_el);
case target_el of
when EL1 trap = (if is_wfe then SCTLR[].nTWE else SCTLR[].nTWI) == '0';
when EL2 trap = (if is_wfe then HCR_EL2.TWE else HCR_EL2.TWI) == '1';
when EL3 trap = (if is_wfe then SCR_EL3.TWE else SCR_EL3.TWI) == '1';
if trap then
AArch64.WFxTrap(target_el, is_wfe);

// AArch64.CheckIllegalState()
// ---------------------------
// Check PSTATE.IL bit and generate Illegal Execution state exception if set.

AArch64.CheckIllegalState()
if PSTATE.IL == '1' then
route_to_el2 = EL2Enabled() && PSTATE.EL == EL0 && HCR_EL2.TGE == '1';
bits(64) preferred_exception_return = ThisInstrAddr();
vect_offset = 0x0;
exception = ExceptionSyndrome(Exception_IllegalState);
if UInt(PSTATE.EL) > UInt(EL1) then
AArch64.TakeException(PSTATE.EL, exception, preferred_exception_return, vect_offset);
elsif route_to_el2 then
AArch64.TakeException(EL2, exception, preferred_exception_return, vect_offset);
else
AArch64.TakeException(EL1, exception, preferred_exception_return, vect_offset);

// AArch64.MonitorModeTrap()
// --------------------------
// Trapped use of Monitor mode features in a Secure EL1 AArch32 mode

AArch64.MonitorModeTrap()
bits(64) preferred_exception_return = ThisInstrAddr();
vect_offset = 0x0;
exception = ExceptionSyndrome(Exception_Uncategorized);
if IsSecureEL2Enabled() then
AArch64.TakeException(EL2, exception, preferred_exception_return, vect_offset);
AArch64.TakeException(EL1, exception, preferred_exception_return, vect_offset);
Library pseudocode for aarch64/exceptions/traps/AArch64.SystemRegisterTrap

```c
// AArch64.SystemRegisterTrap()
// ----------------------------------------
// Trapped system register access other than due to CPTR_EL2 and CPACR_EL1

AArch64.SystemRegisterTrap(bits(2) target_el, bits(2) op0, bits(3) op2, bits(3) op1, bits(4) crn,
                          bits(5) rt, bits(4) crm, bit dir)
    assert UInt(target_el) >= UInt(PSTATE.EL);
    bits(64) preferred_exception_return = ThisInstrAddr();
    vect_offset = 0x0;

    exception = ExceptionSyndrome(Exception_SystemRegisterTrap);
    exception.syndrome<21:20> = op0;
    exception.syndrome<19:17> = op2;
    exception.syndrome<16:14> = crn;
    exception.syndrome<13:10> = rt;
    exception.syndrome<13:10> = crn;
    exception.syndrome<13:10> = crm;
    exception.syndrome<0> = dir;

    if target_el == EL1 && EL2Enabled() && HCR_EL2.TGE == '1' then
        AArch64.TakeException(EL2, exception, preferred_exception_return, vect_offset);
    else
        AArch64.TakeException(target_el, exception, preferred_exception_return, vect_offset);
```

Library pseudocode for aarch64/exceptions/traps/AArch64.UndefinedFault

```c
// AArch64.UndefinedFault()
// -------------------------

AArch64.UndefinedFault()
    route_to_el2 = EL2Enabled() && PSTATE.EL == EL0 && HCR_EL2.TGE == '1';
    bits(64) preferred_exception_return = ThisInstrAddr();
    vect_offset = 0x0;

    exception = ExceptionSyndrome(Exception_Uncategorized);

    if UInt(PSTATE.EL) > UInt(EL1) then
        AArch64.TakeException(PSTATE.EL, exception, preferred_exception_return, vect_offset);
    elsif route_to_el2 then
        AArch64.TakeException(EL2, exception, preferred_exception_return, vect_offset);
    else
        AArch64.TakeException(EL1, exception, preferred_exception_return, vect_offset);
```

Library pseudocode for aarch64/exceptions/traps/AArch64.WFxTrap

```c
// AArch64.WFxTrap()
// -----------------

AArch64.WFxTrap(bits(2) target_el, boolean is_wfe)
    assert UInt(target_el) > UInt(PSTATE.EL);
    bits(64) preferred_exception_return = ThisInstrAddr();
    vect_offset = 0x0;

    exception = ExceptionSyndrome(Exception_WFxTrap);
    exception.syndrome<24:20> = ConditionSyndrome();
    exception.syndrome<0> = if is_wfe then '1' else '0';

    if target_el == EL1 && EL2Enabled() && HCR_EL2.TGE == '1' then
        AArch64.TakeException(EL2, exception, preferred_exception_return, vect_offset);
    else
        AArch64.TakeException(target_el, exception, preferred_exception_return, vect_offset);
```
// CheckFPAdvSIMDEnabled64()
// =========================
// AArch64 instruction wrapper

CheckFPAdvSIMDEnabled64()
  AArch64.CheckFPAdvSIMDEnabled();

// AArch64.CreateFaultRecord()
// ---------------------------

FaultRecord AArch64.CreateFaultRecord(Fault type, bits(52) ipaddress, bit NS,
  integer level, AccType acctype, boolean write, bit extflag,
  bits(2) errortype, boolean secondstage, boolean s2fslwalk)

  FaultRecord fault;
  fault.type = type;
  fault.domain = bits(4) UNKNOWN;        // Not used from AArch64
  fault.debugmoe = bits(4) UNKNOWN;       // Not used from AArch64
  fault.errortype = errortype;
  fault.ipaddress.NS = NS;
  fault.ipaddress.address = ipaddress;
  fault.level = level;
  fault.acctype = acctype;
  fault.write = write;
  fault.extflag = extflag;
  fault.secondstage = secondstage;
  fault.s2fslwalk = s2fslwalk;

  return fault;

// AArch64.FaultSyndrome()
// -----------------------

// Creates an exception syndrome value for Abort and Watchpoint exceptions taken to
// an Exception Level using AArch64.

bits(25) AArch64.FaultSyndrome(boolean d_side, FaultRecord fault)

  assert fault.type != Fault_None;

  bits(25) iss = Zeros();
  if HaveRASExt() && IsExternalSyncAbort(fault) then iss<12:11> = fault.errortype; // SET
  if d_side then
    if IsSecondStage(fault) && !fault.s2fslwalk then iss<24:14> = LSInstructionSyndrome();
    if HaveNV2Ext() && fault.acctype == AccType_NV2REGISTER then
      iss<13> = '1';   // Value of '1' indicates fault is generated by use of VNCR_EL2
    if fault.acctype IN {AccType_DC, AccType_DC_UNPRIV, AccType_IC, AccType_AT} then
      iss<8> = '1';  iss<6> = '1';
    else
      iss<6> = if fault.write then '1' else '0';
    if IsExternalAbort(fault) then iss<9> = fault.extflag;
    iss<7> = if fault.s2fslwalk then '1' else '0';
    iss<5:0> = EncodeLDFSC(fault.type, fault.level);

  return iss;
// AArch64.ExclusiveMonitorsPass()
// =============================================

// Return TRUE if the Exclusives monitors for the current PE include all of the addresses
// associated with the virtual address region of size bytes starting at address.
// The immediately following memory write must be to the same addresses.

boolean AArch64.ExclusiveMonitorsPass(bits(64) address, integer size)

    // It is IMPLEMENTATION DEFINED whether the detection of memory aborts happens
    // before or after the check on the local Exclusives monitor. As a result a failure
    // of the local monitor can occur on some implementations even if the memory
    // access would give an memory abort.

    acctype = AccType_ATOMIC;
    iswrite = TRUE;
    aligned = (address == Align(address, size));

    if !aligned then
        secondstage = FALSE;
        AArch64.Abort(address, AArch64.AlignmentFault(acctype, iswrite, secondstage));

    passed = AArch64.IsExclusiveVA(address, ProcessorID(), size);
    if !passed then
        return FALSE;

    memaddrdesc = AArch64.TranslateAddress(address, acctype, iswrite, aligned, size);

    // Check for aborts or debug exceptions
    if IsFault(memaddrdesc) then
        AArch64.Abort(address, memaddrdesc.fault);

    passed = IsExclusiveLocal(memaddrdesc.paddress, ProcessorID(), size);
    if passed then
        ClearExclusiveLocal(ProcessorID());
        if memaddrdesc.memattrs.shareable then
            passed = IsExclusiveGlobal(memaddrdesc.paddress, ProcessorID(), size);

    return passed;

Library pseudocode for aarch64/functions/exclusive/AArch64.IsExclusiveVA

// An optional IMPLEMENTATION DEFINED test for an exclusive access to a virtual
// address region of size bytes starting at address.
//
// It is permitted (but not required) for this function to return FALSE and
// cause a store exclusive to fail if the virtual address region is not
// totally included within the region recorded by MarkExclusiveVA().
//
// It is always safe to return TRUE which will check the physical address only.

boolean AArch64.IsExclusiveVA(bits(64) address, integer processorid, integer size);

Library pseudocode for aarch64/functions/exclusive/AArch64.MarkExclusiveVA

// Optionally record an exclusive access to the virtual address region of size bytes
// starting at address for processorid.
AArch64.MarkExclusiveVA(bits(64) address, integer processorid, integer size);
Library pseudocode for aarch64/functions/exclusive/AArch64.SetExclusiveMonitors

```c
// AArch64.SetExclusiveMonitors()
// =================-------------

// Sets the Exclusives monitors for the current PE to record the addresses associated
// with the virtual address region of size bytes starting at address.

AArch64.SetExclusiveMonitors(bits(64) address, integer size)

    acctype = AccType_ATOMIC;
    iswrite = FALSE;
    aligned = (address == Align(address, size));
    memaddrdesc = AArch64.TranslateAddress(address, acctype, iswrite, aligned, size);
    // Check for aborts or debug exceptions
    if IsFault(memaddrdesc) then
        return;
    
    if memaddrdesc.memattrs.shareable then
        MarkExclusiveGlobal(memaddrdesc.paddress, ProcessorID(), size);
        MarkExclusiveLocal(memaddrdesc.paddress, ProcessorID(), size);
        AArch64.MarkExclusiveVA(address, ProcessorID(), size);
```

Library pseudocode for aarch64/functions/fusedrstep/FPRSqrtStepFused

```c
// FPRSqrtStepFused()
// ----------------

bits(N) FPRSqrtStepFused(bits(N) op1, bits(N) op2)

assert N IN {16, 32, 64};

bits(N) result;

op1 = FPNeg(op1);
(type1,sign1,value1) = FPUnpack(op1, FPCR);
(type2,sign2,value2) = FPUnpack(op2, FPCR);
(done,result) = FPProcessNaNs(type1, type2, op1, op2, FPCR);
if !done then
    inf1 = (type1 == FPType_Infinity);
    inf2 = (type2 == FPType_Infinity);
    zero1 = (type1 == FPType_Zero);
    zero2 = (type2 == FPType_Zero);
    if (inf1 && zero2) || (zero1 && inf2) then
        result = FPOnePointFive('0');
    elsif inf1 || inf2 then
        result = FPInfinity(sign1 EOR sign2);  
    else
        // Fully fused multiply-add and halve
        result_value = (3.0 + (value1 * value2)) / 2.0;
        if result_value == 0.0 then
            // Sign of exact zero result depends on rounding mode
            sign = if FPRoundingMode(FPCR) == FPRounding_NEGINF then '1' else '0';
            result = FPZero(sign);
        else
            result = FPRound(result_value, FPCR);
        return result;
```
Library pseudocode for aarch64/functions/fusedrstep/FPRecipStepFused

```c
// FPRecipStepFused()
// ==================

bits(N) FPRecipStepFused(bits(N) op1, bits(N) op2)
    assert N IN {16, 32, 64};
    bits(N) result;
    op1 = FPNeg(op1);
    (type1,sign1,value1) = FPUnpack(op1, FPCR);
    (type2,sign2,value2) = FPUnpack(op2, FPCR);
    (done,result) = FPProcessNaNs(type1, type2, op1, op2, FPCR);
    if !done then
        inf1 = (type1 == FPType_Infinity);
        inf2 = (type2 == FPType_Infinity);
        zero1 = (type1 == FPType_Zero);
        zero2 = (type2 == FPType_Zero);
        if (inf1 && zero2) || (zero1 && inf2) then
            result = FPTwo('0');
        elsif inf1 || inf2 then
            result = FPInfinity(sign1 EOR sign2);
        else
            // Fully fused multiply-add
            result_value = 2.0 + (value1 * value2);
            if result_value == 0.0 then
                // Sign of exact zero result depends on rounding mode
                sign = if FPRoundingMode(FPCR) == FPRounding_NEGINF then '1' else '0';
                result = FPZero(sign);
            else
                result = FPRound(result_value, FPCR);
            endif
        endif
    endif
    return result;
```

Library pseudocode for aarch64/functions/memory/AArch64.CheckAlignment

```c
// AArch64.CheckAlignment()
// ========================

boolean AArch64.CheckAlignment(bits(64) address, integer alignment, AccType acctype, boolean iswrite)

        aligned = (address == Align(address, alignment));
        atomic = acctype IN {AccType_ATOMIC, AccType_ATOMICRW, AccType_ATOMICRWOATOMIC);
        ordered = acctype IN {AccType_ORDERED, AccType_ORDEREDRW, AccType_LIMITEDORDERED, AccType_ORDEREDATOMICRWOATOMIC};
        vector = acctype == AccType_VEC;
        if SCTLR[].A == '1' then check = TRUE;
        elsif HaveUA16Ext() then
            check = (UInt(address<0+:4>) + alignment > 16) && ((ordered && address<0+:4>) + alignment >= 16) && (ordered && SCTLR[].nAA == '0') || atomic;
        else check = atomic || ordered;
        if check && !aligned then
            secondstage = FALSE;
            AArch64.Abort(address, AArch64.AlignmentFault(acctype, iswrite, secondstage));
        endif
        return aligned;
```
// AArch64.MemSingle[] - non-assignment (read) form
// _________________________________________________
// Perform an atomic, little-endian read of 'size' bytes.

bits(size*8) AArch64.MemSingle(bits(64) address, integer size, AccType acctype, boolean wasaligned)
    assert size IN {1, 2, 4, 8, 16};
    assert address == Align(address, size);

    AddressDescriptor memaddrdesc;
    bits(size*8) value;
    iswrite = FALSE;

    // MMU or MPU
    memaddrdesc = AArch64.TranslateAddress(address, acctype, iswrite, wasaligned, size);
    // Check for aborts or debug exceptions
    if IsFault(memaddrdesc) then
        AArch64.Abort(address, memaddrdesc.fault);

    // Memory array access
    accdesc = CreateAccessDescriptor(acctype);
    if accdesc = HaveMTEExtCreateAccessDescriptor() then
        if (acctype);

        value = _Mem[memaddrdesc, size, accdesc];
        return value;

// AArch64.MemSingle[] - assignment (write) form
// _________________________________________________
// Perform an atomic, little-endian write of 'size' bytes.

AArch64.MemSingle[bits(64) address, integer size, AccType acctype, boolean wasaligned] = bits(size*8) value
    assert size IN {1, 2, 4, 8, 16};
    assert address == Align(address, size);

    AddressDescriptor memaddrdesc;
    iswrite = TRUE;

    // MMU or MPU
    memaddrdesc = AArch64.TranslateAddress(address, acctype, iswrite, wasaligned, size);
    // Check for aborts or debug exceptions
    if IsFault(memaddrdesc) then
        AArch64.Abort(address, memaddrdesc.fault);

    // Effect on exclusives
    if memaddrdesc.memattrs.shareable then
        ClearExclusiveByAddress(memaddrdesc.paddress, ProcessorID(), size);

    // Memory array access
    accdesc = CreateAccessDescriptor(acctype);
    if accdesc = HaveMTEExtCreateAccessDescriptor() then
        if AccessIsTagChecked(ZeroExtend(address, 64), acctype) then
            bits(4) ptag = TransformTag(ZeroExtend(address, 64));
            if !CheckTag(memaddrdesc, ptag, iswrite) then
                TagCheckFail(ZeroExtend(address, 64), iswrite);
            value = _Mem[memaddrdesc, size, accdesc];
            return value;
Library pseudocode for aarch64/functions/memory/AddressWithAllocationTag

```plaintext
// AddressWithAllocationTag()
// --------------------------------------------
// Generate a 64-bit value containing a Logical Address Tag from a 64-bit virtual address and an Allocation Tag. If the extension is disabled, treats the Allocation Tag as '0000'.

bits(64) AddressWithAllocationTag(bits(64) address, bits(4) allocation_tag)
    bits(64) result = address;
    bits(4) tag = allocation_tag - ('000':address<55>);
    result<59:56> = tag;
    return result;
```

Library pseudocode for aarch64/functions/memory/AllocationTagFromAddress

```plaintext
// AllocationTagFromAddress()
// --------------------------------------------
// Generate a Tag from a 64-bit value containing a Logical Address Tag. If access to Allocation Tags is disabled, this function returns '0000'.

bits(4) AllocationTagFromAddress(bits(64) tagged_address)
    bits(4) logical_tag = tagged_address<59:56>;
    bits(4) tag = logical_tag + ('000':tagged_address<55>);
    return tag;
```

Library pseudocode for aarch64/functions/memory/CheckSPAlignment

```plaintext
// CheckSPAlignment()
// -------------------------------
// Check correct stack pointer alignment for AArch64 state.

CheckSPAlignment()
    bits(64) sp = SP[];
    if PSTATE.EL == EL0 then
        stack_align_check = (SCTLR[].SA0 != '0');
    else
        stack_align_check = (SCTLR[].SA != '0');
    if stack_align_check && sp != Align(sp, 16) then
        AArch64.SPAlignmentFault();
    return;
```
// CheckTag()
// =========
// Performs a Tag Check operation for a memory access and returns
// whether the check passed
// MEM[] - non-assignment (read) form
// ================
// Perform a read of 'size' bytes. The access byte order is reversed for a big-endian access.
// Instruction fetches would call AArch64.MemSingle directly.

boolean bits(size*8) CheckTag(Mem[bits(64) address, integer size, AddressDescriptor acctype memaddrdesc, boolean write])
if memaddrdesc.memattrs.tagged then
    bits(64) paddr = acctype;
    assert size IN {1, 2, 4, 8, 16};
    bits(size*8) value;
    integer i;
    boolean iswrite = FALSE;
    aligned = ZeroExtend(AArch64.CheckAlignment(memaddrdesc.paddress.address));
    return ptag == (address, size, acctype, iswrite);
else
    // 128-bit SIMD&FP loads are treated as a pair of 64-bit single-copy atomic accesses
    // 64-bit aligned.
    atomic = address == Align(address, 8);
    if atomic then
        assert size > 1;
        value<7:0> = AArch64.MemSingle(address, 1, acctype, aligned);
    elseif size == 16 && acctype IN {AccType_VEC, AccType_VECSTREAM} then
        value<63:0> = AArch64.MemSingle(address, 8, acctype, aligned);
        value<127:64> = AArch64.MemSingle(address+8, 8, acctype, aligned);
    else
        value = AArch64.MemSingle(address, size, acctype, aligned);
    if (HaveNV2Ext() && acctype == AccType_NV2REGISTER && SCTLR_EL2.EE == '1') || BigEndian() then
        value = BigEndianReverse(value);
    return value;
else
    Shared Pseudocode Functions
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assert size > 1;
AArch64.MemSingle[address, 1, acctype, aligned] = value<7:0>;

// For subsequent bytes it is CONSTRAINED UNPREDICTABLE whether an unaligned Device memory
// access will generate an Alignment Fault, as to get this far means the first byte did
// not, so we must be changing to a new translation page.
if !aligned then
  c = ConstrainUnpredictable(Unpredictable_DEVPAGE);
assert c IN {Constraint_FAULT, Constraint_NONE};
if c == Constraint_NONE then aligned = TRUE;

for i = 1 to size-1
  AArch64.MemSingle[address+i, 1, acctype, aligned] = value<8*i+7:8*i>;
eselif size == 16 && acctype IN {AccType_VEC, AccType_VECSTREAM} then
  AArch64.MemSingle[address, 8, acctype, aligned] = value<63:0>;
  AArch64.MemSingle[address+8, 8, acctype, aligned] = value<127:64>;
else
  AArch64.MemSingleMemTagAccType_VEC[address];
else
  return TRUE;(address, size, acctype, aligned) = value;
return.
// If the implementation supports changing the block size without a break-before-make
// approach, then for implementations that have level 1 or 2 support, the nT bit in
// the block descriptor is valid.

// If the implementation supports changing the block size without a break-before-make
// approach, then for implementations that have level 1 or 2 support, the nT bit in
// the block descriptor is valid.

// IsBlockDescriptorNTBitValid(); AddPAC();

// Calculates the pointer authentication code for a 64-bit quantity and then
// inserts that into pointer authentication code field of that 64-bit quantity.

// If tagged pointers are in use for a regime with two TTBRs, use bit<55> of
// the pointer to select between upper and lower ranges, and preserve this.
// This handles the awkward case where there is apparently no correct choice between
// the upper and lower address range - ie an addr of 1xxxxxxx0... with TBI0=0 and TBI1=1
// and 0xxxxxxx1 with TBI1=0 and TBI0=1.

// If tagged pointers are in use for a regime with two TTBRs, use bit<55> of
// the pointer to select between upper and lower ranges, and preserve this.
// This handles the awkward case where there is apparently no correct choice between
// the upper and lower address range - ie an addr of 1xxxxxxx0... with TBI0=0 and TBI1=1
// and 0xxxxxxx1 with TBI1=0 and TBI0=1.

boolean tbi = CalculateTBI(ptr, data);
integer top_bit = if tbi then 55 else 63;

integer bottom_PAC_bit = CalculateBottomPACBit(ptr, selbit);

// The pointer authentication code field takes all the available bits in between
extfield = Replicate(selbit, 64);

// Compute the pointer authentication code for a ptr with good extension bits
if tbi then
  ext_ptr = ptr<63:56>:extfield<(56-bottom_PAC_bit)-1:0>:ptr<bottom_PAC_bit-1:0>;
else
  ext_ptr = extfield<(64-bottom_PAC_bit)-1:0>:ptr<bottom_PAC_bit-1:0>;

PAC = ComputePAC(ext_ptr, modifier, K<127:64>, K<63:0>);

// Check if the ptr has good extension bits and corrupt the pointer authentication code if not;
if !IsZero(ptr<top_bit:bottom_PAC_bit>) && !IsOnes(ptr<top_bit:bottom_PAC_bit>) then
  PAC<top_bit-1> = NOT(PAC<top_bit-1>);

// Preserve the determination between upper and lower address at bit<55> and insert PAC
if tbi then
  result = ptr<63:56>:selbit:PAC<54:bottom_PAC_bit>:ptr<bottom_PAC_bit-1:0>;
else
  result = PAC<63:56>:selbit:PAC<54:bottom_PAC_bit>:ptr<bottom_PAC_bit-1:0>;
return result;
// Mem[] - non-assignment (read) form
// ----------------------------------------------
// Perform a read of 'size' bytes. The access byte order is reversed for a big-endian access.
// Instruction fetches would call AArch64.MemSingle directly.

bits(size*8) Mem[bits(64) address, integer size, AccType acctype]
    assert size IN {1, 2, 4, 8, 16};
    bits(size*8) value;
    boolean iswrite = FALSE;
    
    aligned = AArch64.CheckAlignment(address, size, acctype, iswrite);
    if size != 16 || !(acctype IN {AccType_VEC, AccType_VECSTREAM}) then
        atomic = aligned;
    else
        // 128-bit SIMD&FP loads are treated as a pair of 64-bit single-copy atomic accesses
        // 64-bit aligned.
        atomic = address == Align(address, 8);
    
    if !atomic then
        assert size > 1;
        value<7:0> = AArch64.MemSingle[address, 1, acctype, aligned];
        // For subsequent bytes it is CONSTRAINED UNPREDICTABLE whether an unaligned Device memory
        // access will generate an Alignment Fault, as to get this far means the first byte did
        // not, so we must be changing to a new translation page.
        if !aligned then
            c = ConstrainUnpredictable(Unpredictable_DEVPAGE2);
            assert c IN {Constraint_FAULT, Constraint_NONE};
            if c == Constraint_NONE then aligned = TRUE;
            for i = 1 to size-1
                value<8*i+7:8*i> = AArch64.MemSingle[address+i, 1, acctype, aligned];
            elsif size == 16 && acctype IN {AccType_VEC, AccType_VECSTREAM} then
                value<63:0>   = AArch64.MemSingle[address, 8, acctype, aligned];
                value<127:64> = AArch64.MemSingle[address+8, 8, acctype, aligned];
            else
                value = AArch64.MemSingle[address, size, acctype, aligned];
        
        if (HaveNV2Ext() && acctype == AccType_NV2REGISTER && SCTLR_EL2.EE == '1') || BigEndian() then
            value = BigEndianReverse(value);
        
        return value;

    // Mem[] - assignment (write) form
    // -----------------------------------
    // Perform a write of 'size' bytes. The byte order is reversed for a big-endian access.

    Mem[bits(64) address, integer size, AccType acctype] = bits(size*8) value
    boolean iswrite = TRUE;
    
    if (HaveNV2Ext() && acctype == AccType_NV2REGISTER && SCTLR_EL2.EE == '1') || BigEndian() then
        value = BigEndianReverse(value);
    
    aligned = AArch64.CheckAlignment(address, size, acctype, iswrite);
    if size != 16 || !(acctype IN {AccType_VEC, AccType_VECSTREAM}) then
        atomic = aligned;
    else
        // 128-bit SIMD&FP stores are treated as a pair of 64-bit single-copy atomic accesses
        // 64-bit aligned.
        atomic = address == Align(address, 8);
    
    if !atomic then
        assert size > 1;
        AArch64.MemSingle[address, 1, acctype, aligned] = value<7:0>;
        // For subsequent bytes it is CONSTRAINED UNPREDICTABLE whether an unaligned Device memory
        // access will generate an Alignment Fault, as to get this far means the first byte did
        // not, so we must be changing to a new translation page.
        if !aligned then
            c = ConstrainUnpredictable(Unpredictable_DEVPAGE2);
            assert c IN {Constraint_FAULT, Constraint_NONE};

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if c == Constraint_NONE then aligned = TRUE;
for i = 1 to size-1
AArch64.MemSingle[address+i, 1, acctype, aligned] = value<8*i+7:8*i>;
elsif size == 16 && acctype IN {AccType_VEC, AccType_VECSTREAM} then
AArch64.MemSingle[address, 8, acctype, aligned] = value<63:0>;
AArch64.MemSingle[address+8, 8, acctype, aligned] = value<127:64>;
else
AArch64.MemSingle[address, size, acctype, aligned] = value;
return;

Library pseudocode for aarch64/functions/memory/MemTag

// MemTag[] - non-assignment (read) form
// ---------------------------------------------------------------
// Load an Allocation Tag from memory.

Bits(4) MemTag[Bits(64) address] = Bits(4) value;
iswrite = FALSE;

memaddrdesc = AArch64.TranslateAddress(address, AccType_NORMAL, iswrite, TRUE, TAG_GRANULE);
// Check for aborts or debug exceptions
if IsFault(memaddrdesc) then
AArch64.Abort(address, memaddrdesc.fault);
else
// ...otherwise read tag as zero.
return '0000';

// MemTag[] - assignment (write) form
// ---------------------------------------------------------------
// Store an Allocation Tag to memory.

MemTag[Bits(64) address] = Bits(4) value;
iswrite = TRUE;

// Stores of allocation tags must be aligned
if address != Align(address, TAG_GRANULE) then
boolean secondstage = FALSE;
AArch64.Abort(address, AArch64.AlignmentFault(AccType_NORMAL, iswrite, secondstage));
wasaligned = TRUE;
memaddrdesc = AArch64.TranslateAddress(address, AccType_NORMAL, iswrite, wasaligned, TAG_GRANULE);
// Check for aborts or debug exceptions
if IsFault(memaddrdesc) then
AArch64.Abort(address, memaddrdesc.fault);
else
// Memory array access
if AllocationTagAccessIsEnabled() then
MemTag[memaddrdesc] = value;

Library pseudocode for aarch64/functions/memory/TransformTag

// TransformTag()
// -------------
// Apply tag transformation rules.

Bits(4) TransformTag(Bits(64) vaddr) = Bits(4) vtag;
Bits(4) vtag = vaddr<59:56>;
Bits(4) tagdelta = ZeroExtend(vaddr<55>);
Bits(4) ptag = vtag + tagdelta;
return ptag;
// boolean AccessIsTagChecked()
// ============================
// TRUE if a given access is tag-checked, FALSE otherwise.

boolean AccessIsTagChecked(bits(64) vaddr, AccType accType)
    if PSTATE.M<4> == '1' then return FALSE;
    if EffectiveTBI(vaddr, FALSE, PSTATE.EL) == '0' then
        return FALSE;
    if EffectiveTCMA(vaddr, PSTATE.EL) == '1' && (vaddr<59:55> == '00000' || vaddr<59:55> == '11111') then
        return FALSE;
    if !AllocationTagAccessIsEnabled() then
        return FALSE;
    if accType IN {AccType_IFETCH, AccType_PTW} then
        return FALSE;
    if accType == AccType_NV2REGISTER then
        return FALSE;
    if PSTATE.TCO=='1' then
        return FALSE;
    if IsNonTagCheckedInstruction() then
        return FALSE;
    return TRUE;
// AddPAC()
// =========
// Calculates the pointer authentication code for a 64-bit quantity and then
// inserts that into pointer authentication code field of that 64-bit quantity.

bits(64) AddPAC(bits(64) ptr, bits(64) modifier, bits(128) K, boolean data)
bits(64) PAC;
bits(64) result;
bits(64) ext_ptr;
bits(64) extfield;
bit selbit;
boolean tbi = CalculateTBI(ptr, data);
integer top_bit = if tbi then 55 else 63;

// If tagged pointers are in use for a regime with two TTBRs, use bit<55> of
// the pointer to select between upper and lower ranges, and preserve this.
// This handles the awkward case where there is apparently no correct choice between
// the upper and lower address range - ie an addr of lxxxxxxxx0... with TBI0=0 and TBI1=1
// and Oxxxxxxxx1 with TBI1=0 and TBI0=1;
if PtrHasUpperAndLowerAddRanges() then
  assert S1TranslationRegime() IN {EL1, EL2};
  if S1TranslationRegime() == EL1 then
    // EL1 translation regime registers
    if data then
      selbit = if TCR_EL1.TBI1 == '1' || TCR_EL1.TBI0 == '1' then ptr<55> else ptr<63>;
    else
      selbit = ptr<63>;
  else
    // EL2 translation regime registers
    if data then
      selbit = if (HaveEL(EL2) && TCR_EL2.TBI1 == '1') ||
                 (HaveEL(EL2) && TCR_EL2.TBI0 == '1')) then ptr<55> else ptr<63>;
    else
      selbit = if tbi then ptr<55> else ptr<63>;
  integer bottom_PAC_bit = CalculateBottomPACBit(selbit);
  // The pointer authentication code field takes all the available bits in between
  extfield = Replicate(selbit, 64);

  // Compute the pointer authentication code for a ptr with good extension bits
  if tbi then
    ext_ptr = ptr<63:56>:extfield<(56-bottom_PAC_bit)-1:0>:ptr<bottom_PAC_bit-1:0>;
  else
    ext_ptr = extfield<(64-bottom_PAC_bit)-1:0>:ptr<bottom_PAC_bit-1:0>;

  PAC = ComputePAC(ext_ptr, modifier, K<127:64>, K<63:0>);

  // Check if the ptr has good extension bits and corrupt the pointer authentication code if not;
  if !IsZero(ptr<top_bit:bottom_PAC_bit>) && !Is Ones(ptr<top_bit:bottom_PAC_bit>) then
    PAC<top_bit-1> = NOT(PAC<top_bit-1>);

  // Preserve the determination between upper and lower address at bit<55> and insert PAC
  if tbi then
    result = ptr<63:56>:selbit:PAC<54:bottom_PAC_bit>:ptr<bottom_PAC_bit-1:0>;
  else
    result = PAC<63:56>:selbit:PAC<54:bottom_PAC_bit>:ptr<bottom_PAC_bit-1:0>;
return result;
Library pseudocode for aarch64/functions/pac/addpacda/AddPACDA

// AddPACDA()
// =========
// Returns a 64-bit value containing X, but replacing the pointer authentication code
// field bits with a pointer authentication code, where the pointer authentication
// code is derived using a cryptographic algorithm as a combination of X, Y and the
// APDAKey_EL1.

bits(64) AddPACDA(bits(64) X, bits(64) Y)
    boolean TrapEL2;
    boolean TrapEL3;
    bits(1) Enable;
    bits(128) APDAKey_EL1;

    APDAKey_EL1 = APDAKeyHi_EL1<63:0> : APDAKeyLo_EL1<63:0>;

    case PSTATE.EL of
        when EL0
            boolean IsEL1Regime = S1TranslationRegime() == EL1;
            Enable = if IsEL1Regime then SCTLR_EL1.EnDA else SCTLR_EL2.EnDA;
            TrapEL2 = (EL2Enabled() && HCR_EL2.API == '0' &&
               (HCR_EL2.TGE == '0' || HCR_EL2.E2H == '0'));
            TrapEL3 = HaveEL(EL3) && SCR_EL3.API == '0';
        when EL1
            Enable = SCTLR_EL1.EnDA;
            TrapEL2 = EL2Enabled() && HCR_EL2.API == '0';
            TrapEL3 = HaveEL(EL3) && SCR_EL3.API == '0';
        when EL2
            Enable = SCTLR_EL2.EnDA;
            TrapEL2 = FALSE;
            TrapEL3 = HaveEL(EL3) && SCR_EL3.API == '0';
        when EL3
            Enable = SCTLR_EL3.EnDA;
            TrapEL2 = FALSE;
            TrapEL3 = FALSE;

        if Enable == '0' then return X;
        elsif TrapEL2 then TrapPACUse(EL2);
        elsif TrapEL3 then TrapPACUse(EL3);
        else return AddPAC(X, Y, APDAKey_EL1, TRUE);
```c
// AddPACDB()
// =========
// Returns a 64-bit value containing X, but replacing the pointer authentication code
// field bits with a pointer authentication code, where the pointer authentication
// code is derived using a cryptographic algorithm as a combination of X, Y and the
// APDBKey_EL1.

bits(64) AddPACDB(bits(64) X, bits(64) Y)
    boolean TrapEL2;
    boolean TrapEL3;
    bits(1)  Enable;
    bits(128) APDBKey_EL1;

    APDBKey_EL1 = APDBKeyHi_EL1<63:0> : APDBKeyLo_EL1<63:0>;

case PSTATE.EL of
    when EL0
        boolean IsEL1Regime = S1TranslationRegime() == EL1;
        Enable = if IsEL1Regime then SCTLR_EL1.EnDB else SCTLR_EL2.EnDB;
        TrapEL2 = (EL2Enabled() && HCR_EL2.API == '0' &&
            (HCR_EL2.TGE == '0' || HCR_EL2.E2H == '0'));
        TrapEL3 = HaveEL(EL3) && SCR_EL3.API == '0';
    when EL1
        Enable = SCTLR_EL1.EnDB;
        TrapEL2 = EL2Enabled() && HCR_EL2.API == '0';
        TrapEL3 = HaveEL(EL3) && SCR_EL3.API == '0';
    when EL2
        Enable = SCTLR_EL2.EnDB;
        TrapEL2 = FALSE;
        TrapEL3 = HaveEL(EL3) && SCR_EL3.API == '0';
    when EL3
        Enable = SCTLR_EL3.EnDB;
        TrapEL2 = FALSE;
        TrapEL3 = FALSE;

    if Enable == '0' then return X;
    elsif TrapEL2 then TrapPACUse(EL2);
    elsif TrapEL3 then TrapPACUse(EL3);
    else return AddPAC(X, Y, APDBKey_EL1, TRUE);
```
Library pseudocode for aarch64/functions/pac/addpacga/AddPACGA

// AddPACGA()
// =========
// Returns a 64-bit value where the lower 32 bits are 0, and the upper 32 bits contain
// a 32-bit pointer authentication code which is derived using a cryptographic
// algorithm as a combination of X, Y and the APGAKey_EL1.

bits(64) AddPACGA(bits(64) X, bits(64) Y)
    boolean TrapEL2;
    boolean TrapEL3;
    bits(128) APGAKey_EL1;

    APGAKey_EL1 = APGAKeyHi_EL1<63:0> : APGAKeyLo_EL1<63:0>;

    case PSTATE.EL of
        when EL0
            TrapEL2 = (EL2Enabled() && HCR_EL2.API == '0' &&
                (HCR_EL2.TGE == '0' || HCR_EL2.E2H == '0'));
            TrapEL3 = HaveEL(EL3) && SCR_EL3.API == '0';
        when EL1
            TrapEL2 = EL2Enabled() && HCR_EL2.API == '0';
            TrapEL3 = HaveEL(EL3) && SCR_EL3.API == '0';
        when EL2
            TrapEL2 = FALSE;
            TrapEL3 = HaveEL(EL3) && SCR_EL3.API == '0';
        when EL3
            TrapEL2 = FALSE;
            TrapEL3 = FALSE;
        
        if TrapEL2 then TrapPACUse(EL2);
        elsif TrapEL3 then TrapPACUse(EL3);
        else return ComputePAC(X, Y, APGAKey_EL1<127:64>, APGAKey_EL1<63:0>)<63:32>:Zeros(32);
Library pseudocode for aarch64/functions/pac/addpacia/AddPACIA

// AddPACIA()
// ===========
// Returns a 64-bit value containing X, but replacing the pointer authentication code
// field bits with a pointer authentication code, where the pointer authentication
// code is derived using a cryptographic algorithm as a combination of X, Y, and the
// APIAKey_EL1.

bits(64) AddPACIA(bits(64) X, bits(64) Y)
boolean TrapEL2;
boolean TrapEL3;
bits(1) Enable;
bits(128) APIAKey_EL1;

APIAKey_EL1 = APIAKeyHi_EL1<63:0>:APIAKeyLo_EL1<63:0>;

case PSTATE.EL of
  when EL0
    boolean IsEL1Regime = S1TranslationRegime() == EL1;
    Enable = if IsEL1Regime then SCTLR_EL1.EnIA else SCTLR_EL2.EnIA;
    TrapEL2 = (EL2Enabled() && HCR_EL2.API == '0' &&
               (HCR_EL2.TGE == '0' || HCR_EL2.E2H == '0'));
    TrapEL3 = HaveEL(EL3) && SCR_EL3.API == '0';
  when EL1
    Enable = SCTLR_EL1.EnIA;
    TrapEL2 = EL2Enabled() && HCR_EL2.API == '0';
    TrapEL3 = HaveEL(EL3) && SCR_EL3.API == '0';
  when EL2
    Enable = SCTLR_EL2.EnIA;
    TrapEL2 = FALSE;
    TrapEL3 = HaveEL(EL3) && SCR_EL3.API == '0';
  when EL3
    Enable = SCTLR_EL3.EnIA;
    TrapEL2 = FALSE;
    TrapEL3 = FALSE;
if Enable == '0' then return X;
elseif TrapEL2 then TrapPACUse(EL2);
elseif TrapEL3 then TrapPACUse(EL3);
else return AddPAC(X, Y, APIAKey_EL1, FALSE);
// AddPACIB()
// ============
// Returns a 64-bit value containing X, but replacing the pointer authentication code
// field bits with a pointer authentication code, where the pointer authentication
// code is derived using a cryptographic algorithm as a combination of X, Y and the
// APIBKey_EL1.

bits(64) AddPACIB(bits(64) X, bits(64) Y)
  boolean TrapEL2;
  boolean TrapEL3;
  bits(1) Enable;
  bits(128) APIBKey_EL1;

  APIBKey_EL1 = APIBKeyHi_EL1<63:0> : APIBKeyLo_EL1<63:0>;

  case PSTATE.EL of
    when EL0
      boolean IsEL1Regime = S1TranslationRegime() == EL1;
      Enable = if IsEL1Regime then SCTLR_EL1.EnIB else SCTLR_EL2.EnIB;
      TrapEL2 = (EL2Enabled() && HCR_EL2.API == '0' && (HCR_EL2.TGE == '0' || HCR_EL2.E2H == '0'));
      TrapEL3 = HaveEL(EL3) && SCR_EL3.API == '0';
    when EL1
      Enable = SCTLR_EL1.EnIB;
      TrapEL2 = EL2Enabled() && HCR_EL2.API == '0';
      TrapEL3 = HaveEL(EL3) && SCR_EL3.API == '0';
    when EL2
      Enable = SCTLR_EL2.EnIB;
      TrapEL2 = FALSE;
      TrapEL3 = HaveEL(EL3) && SCR_EL3.API == '0';
    when EL3
      Enable = SCTLR_EL3.EnIB;
      TrapEL2 = FALSE;
      TrapEL3 = FALSE;
  if Enable == '0' then return X;
  elsif TrapEL2 then TrapPACUse(EL2);
  elsif TrapEL3 then TrapPACUse(EL3);
  else return AddPAC(X, Y, APIBKey_EL1, FALSE);
// Auth()
// ======
// Restores the upper bits of the address to be all zeros or all ones (based on the
// value of bit[55]) and computes and checks the pointer authentication code. If the
// check passes, then the restored address is returned. If the check fails, the
// second-top and third-top bits of the extension bits in the pointer authentication code
// field are corrupted to ensure that accessing the address will give a translation fault.

bits(64) Auth(bits(64) ptr, bits(64) modifier, bits(128) K, boolean data, bit keynumber)
bits(64) PAC;
bits(64) result;
bits(64) original_ptr;
bits(2) error_code;
bits(64) extfield;

// Reconstruct the extension field used of adding the PAC to the pointer
boolean tbi = CalculateTBI(ptr, data);
integer bottom_PAC_bit = CalculateBottomPACBit(ptr<55>);
{ptr, ptr<55>},
extfield = Replicate(ptr<55>, 64);
if tbi then
  original_ptr = ptr<63:56>:extfield<56-bottom_PAC_bit-1:0>:ptr<bottom_PAC_bit-1:0>;
else
  original_ptr = extfield<64-bottom_PAC_bit-1:0>:ptr<bottom_PAC_bit-1:0>;

PAC = ComputePAC(original_ptr, modifier, K<127:64>, K<63:0>);
// Check pointer authentication code
if tbi then
  if PAC<54:bottom_PAC_bit> == ptr<54:bottom_PAC_bit> then
    result = original_ptr;
  else
    error_code = keynumber:NOT(keynumber);
    result = original_ptr<63:55>:error_code:original_ptr<52:0>;
else
  if ((PAC<54:bottom_PAC_bit> == ptr<54:bottom_PAC_bit>) &&
  (PAC<63:56> == ptr<63:56>)) then
    result = original_ptr;
  else
    error_code = keynumber:NOT(keynumber);
    result = original_ptr<63>:error_code:original_ptr<60:0>;
return result;
Library pseudocode for aarch64/functions/pac/authda/AuthDA

// AuthDA()
// =========
// Returns a 64-bit value containing X, but replacing the pointer authentication code
// field bits with the extension of the address bits. The instruction checks a pointer
// authentication code in the pointer authentication code field bits of X, using the same
// algorithm and key as AddPACDA().

bits(64) AuthDA(bits(64) X, bits(64) Y)
  boolean TrapEL2;
  boolean TrapEL3;
  bits(1) Enable;
  bits(128) APDAKey_EL1;

  APDAKey_EL1 = APDAKeyHi_EL1<63:0> : APDAKeyLo_EL1<63:0>;

  case PSTATE.EL of
    when EL0
      boolean IsEL1Regime = S1TranslationRegime() == EL1;
      Enable = if IsEL1Regime then SCTLR_EL1.EnDA else SCTLR_EL2.EnDA;
      TrapEL2 = (El2Enabled() && HCR_EL2.API == '0' &&
                  (HCR_EL2.TGE == '0' || HCR_EL2.E2H == '0'));
      TrapEL3 = HaveEL(EL3) && SCR_EL3.API == '0';
    when EL1
      Enable = SCTLR_EL1.EnDA;
      TrapEL2 = EL2Enabled() && HCR_EL2.API == '0';
      TrapEL3 = HaveEL(EL3) && SCR_EL3.API == '0';
    when EL2
      Enable = SCTLR_EL2.EnDA;
      TrapEL2 = FALSE;
      TrapEL3 = HaveEL(EL3) && SCR_EL3.API == '0';
    when EL3
      Enable = SCTLR_EL3.EnDA;
      TrapEL2 = FALSE;
      TrapEL3 = FALSE;
  end case

  if Enable == '0' then return X;
  elsif TrapEL2 then TrapPACUse(EL2);
  elsif TrapEL3 then TrapPACUse(EL3);
  else return Auth(X, Y, APDAKey_EL1, TRUE, '0');
Library pseudocode for aarch64/functions/pac/authdb/AuthDB

```
// AuthDB()
// ========
// Returns a 64-bit value containing X, but replacing the pointer authentication code
// field bits with the extension of the address bits. The instruction checks a
// pointer authentication code in the pointer authentication code field bits of X, using
// the same algorithm and key as AddPACDB().

bits(64) AuthDB(bits(64) X, bits(64) Y)
  boolean TrapEL2;
  boolean TrapEL3;
  bits(1) Enable;
  bits(128) APDBKey_EL1;
  APDBKey_EL1 = APDBKeyHi_EL1<63:0> : APDBKeyLo_EL1<63:0>;

  case PSTATE.EL of
    when EL0
      boolean IsEL1Regime = S1TranslationRegime() == EL1;
      Enable = if IsEL1Regime then SCTLR_EL1.EnDB else SCTLR_EL2.EnDB;
      TrapEL2 = (EL2Enabled() && HCR_EL2.API == '0' &&
                   (HCR_EL2.TGE == '0' || HCR_EL2.E2H == '0'));
      TrapEL3 = HaveEL(EL3) && SCR_EL3.API == '0';
    when EL1
      Enable = SCTLR_EL1.EnDB;
      TrapEL2 = EL2Enabled() && HCR_EL2.API == '0';
      TrapEL3 = HaveEL(EL3) && SCR_EL3.API == '0';
    when EL2
      Enable = SCTLR_EL2.EnDB;
      TrapEL2 = FALSE;
      TrapEL3 = HaveEL(EL3) && SCR_EL3.API == '0';
    when EL3
      Enable = SCTLR_EL3.EnDB;
      TrapEL2 = FALSE;
      TrapEL3 = FALSE;

    if Enable == '0' then return X;
    elsif TrapEL2 then TrapPACUse(EL2);
    elsif TrapEL3 then TrapPACUse(EL3);
    else return Auth(X, Y, APDBKey_EL1, TRUE, '1');
```

Shared Pseudocode Functions
// AuthIA()
// =========
// Returns a 64-bit value containing X, but replacing the pointer authentication code
// field bits with the extension of the address bits. The instruction checks a pointer
// authentication code in the pointer authentication code field bits of X, using the same
// algorithm and key as AddPACIA().

bits(64) AuthIA(bits(64) X, bits(64) Y)
    boolean TrapEL2;
    boolean TrapEL3;
    bits(1) Enable;
    bits(128) APIAKey_EL1;
    
    APIAKey_EL1 = APIAKeyHi_EL1<63:0> : APIAKeyLo_EL1<63:0>;

    case PSTATE.EL of
        when EL0
            boolean IsEL1Regime = SiTranslationRegime() == EL1;
            Enable = if IsEL1Regime then SCTLR_EL1.EnIA else SCTLR_EL2.EnIA;
            TrapEL2 = (EL2Enabled() && HCR_EL2.API == '0' &&
                        (HCR_EL2.TGE == '0' || HCR_EL2.E2H == '0'));
            TrapEL3 = HaveEL(EL3) && SCR_EL3.API == '0';
        when EL1
            Enable = SCTLR_EL1.EnIA;
            TrapEL2 = EL2Enabled() && HCR_EL2.API == '0';
            TrapEL3 = HaveEL(EL3) && SCR_EL3.API == '0';
        when EL2
            Enable = SCTLR_EL2.EnIA;
            TrapEL2 = FALSE;
            TrapEL3 = HaveEL(EL3) && SCR_EL3.API == '0';
        when EL3
            Enable = SCTLR_EL3.EnIA;
            TrapEL2 = FALSE;
            TrapEL3 = FALSE;
    end case

    if Enable == '0' then return X;
    elsif TrapEL2 then TrapPACUse(EL2);
    elsif TrapEL3 then TrapPACUse(EL3);
    else return Auth(X, Y, APIAKey_EL1, FALSE, '0');

    Shared Pseudocode Functions
Library pseudocode for aarch64/functions/pac/authib/AuthIB

// AuthIB()
// =========
// Returns a 64-bit value containing X, but replacing the pointer authentication code
// field bits with the extension of the address bits. The instruction checks a pointer
// authentication code in the pointer authentication code field bits of X, using the same
// algorithm and key as AddPACIB().

bits(64) AuthIB(bits(64) X, bits(64) Y)
boolean TrapEL2;
boolean TrapEL3;
bits(1) Enable;
bits(128) APIBKey_EL1;

APIBKey_EL1 = APIBKeyHi_EL1<63:0> : APIBKeyLo_EL1<63:0>;

case PSTATE.EL of
  when EL0
    boolean IsEL1Regime = SITranslationRegime() == EL1;
    Enable = if IsEL1Regime then SCTLR_EL1.EnIB else SCTLR_EL2.EnIB;
    TrapEL2 = (EL2Enabled() && HCR_EL2.API == '0' &&
      (HCR_EL2.TGE == '0' || HCR_EL2.E2H == '0'));
    TrapEL3 = HaveEL(EL3) && SCR_EL3.API == '0';
  when EL1
    Enable = SCTLR_EL1.EnIB;
    TrapEL2 = EL2Enabled() && HCR_EL2.API == '0';
    TrapEL3 = HaveEL(EL3) && SCR_EL3.API == '0';
  when EL2
    Enable = SCTLR_EL2.EnIB;
    TrapEL2 = FALSE;
    TrapEL3 = HaveEL(EL3) && SCR_EL3.API == '0';
  when EL3
    Enable = SCTLR_EL3.EnIB;
    TrapEL2 = FALSE;
    TrapEL3 = FALSE;
if Enable == '0' then return X;
elseif TrapEL2 then TrapPACUse(EL2);
elseif TrapEL3 then TrapPACUse(EL3);
else return Auth(X, Y, APIBKey_EL1, FALSE, '1');
integer CalculateBottomPACBit() 
\[ \text{CalculateBottomPACBit(bit top_bit)} \]
integer tsz_field;

if \text{PtrHasUpperAndLowerAddRanges()} then 
  assert S1TranslationRegime() IN \{EL1, EL2\}; 
  if S1TranslationRegime() == EL1 then 
    // EL1 translation regime registers 
    tsz_field = if top_bit == '1' then UInt(TCR_EL1.T1SZ) else UInt(TCR_EL1.T0SZ); 
    using64k = if top_bit == '1' then TCR_EL1.TG1 == '11' else TCR_EL1.TG0 == '01'; 
  else 
    // EL2 translation regime registers 
    assert HaveEL(EL2); 
    tsz_field = if top_bit == '1' then UInt(TCR_EL2.T1SZ) else UInt(TCR_EL2.T0SZ); 
    using64k = if top_bit == '1' then TCR_EL2.TG1 == '11' else TCR_EL2.TG0 == '01'; 
  
else 
  tsz_field = if PSTATE.EL == EL2 then UInt(TCR_EL2.T0SZ) else UInt(TCR_EL3.T0SZ); 
  using64k = if PSTATE.EL == EL2 then TCR_EL2.TG0 == '01' else TCR_EL3.TG0 == '01'; 
max_limit_tsz_field = (if !HaveSmallPageTblExt() then 39 else if using64k then 47 else 48); 
if tsz_field > max_limit_tsz_field then 
  // TCR_ELx.TySZ is out of range 
  c = ConstrainUnpredictable(Unpredictable_RESTnSZ); 
  assert c IN \{Constraint_FORCE, Constraint_NONE\}; 
  if c == Constraint_FORCE then tsz_field = max_limit_tsz_field; 
  tszmin = if using64k && VAMax() == 52 then 12 else 16; 
  if tsz_field < tszmin then 
    c = ConstrainUnpredictable(Unpredictable_RESTnSZ); 
    assert c IN \{Constraint_FORCE, Constraint_NONE\}; 
    if c == Constraint_FORCE then tsz_field = tszmin; 
return (64-tsz_field);
// CalculateTBI()
// ==============

boolean CalculateTBI(bits(64) ptr, boolean data)
boolean tbi = FALSE;

if _PtrHasUpperAndLowerAddRanges_() then
    assert _S1TranslationRegime_() IN {EL1, EL2};
    if _S1TranslationRegime_() == EL1 then
        // EL1 translation regime registers
        if data then
            tbi = if ptr<55> == '1' then TCR_EL1.TBI1 == '1' else TCR_EL1.TBI0 == '1';
        else
            if ptr<55> == '1' then
                tbi = TCR_EL1.TBI1 == '1' && TCR_EL1.TBID1 == '0';
            else
                tbi = TCR_EL1.TBI0 == '1' && TCR_EL1.TBID0 == '0';
        end if
    else
        // EL2 translation regime registers
        if data then
            tbi = if ptr<55> == '1' then TCR_EL2.TBI1 == '1' else TCR_EL2.TBI0 == '1';
        else
            if ptr<55> == '1' then
                tbi = TCR_EL2.TBI1 == '1' && TCR_EL2.TBID1 == '0';
            else
                tbi = TCR_EL2.TBI0 == '1' && TCR_EL2.TBID0 == '0';
        end if
    end if
else
    // PSTATE.EL == EL2
    if data then
        tbi = if data then TCR_EL2.TBI=='1' else TCR_EL2.TBI=='1' && TCR_EL2.TBID=='0';
    else
        tbi = if data then TCR_EL2.TBI=='1' else TCR_EL2.TBI=='1' && TCR_EL2.TBID=='0';
    end if
    if data then
        tbi = if data then TCR_EL2.TBI=='1' else TCR_EL2.TBI=='1' && TCR_EL2.TBID=='0';
    else
        tbi = if data then TCR_EL2.TBI=='1' else TCR_EL2.TBI=='1' && TCR_EL2.TBID=='0';
    end if
end if
return tbi;
array bits(64) RC[0..4];

bits(64) ComputePAC(bits(64) data, bits(64) modifier, bits(64) key0, bits(64) key1)
    bits(64) workingval;
    bits(64) runningmod;
    bits(64) roundkey;
    bits(64) modk0;
    constant bits(64) Alpha = 0xCOAC29B7C97C50DD<63:0>;
    RC[0] = 0x0000000000000000<63:0>;
    RC[1] = 0x13198A2B03707344<63:0>;
    RC[2] = 0xA4093822299F31D0<63:0>;
    RC[3] = 0x082EFA98EC4E6C89<63:0>;
    RC[4] = 0x452821E638D01377<63:0>;
    modk0 = key0<0>:key0<63:2>:key0<63> EOR key0<1>);
    runningmod = modifier;
    workingval = data EOR key0;
    for i = 0 to 4
        roundkey = key1 EOR runningmod;
        workingval = workingval EOR roundkey;
        workingval = workingval EOR RC[i];
        if i > 0 then
            workingval = PACCellShuffle(workingval);
            workingval = PACMult(workingval);
            workingval = PACSub(workingval);
            runningmod = TweakShuffle(runningmod<63:0>);
        roundkey = modk0 EOR runningmod;
        workingval = workingval EOR roundkey;
        workingval = PACCellShuffle(workingval);
        workingval = PACMult(workingval);
        workingval = PACSub(workingval);
        workingval = key1 EOR workingval;
        workingval = PACCellInvShuffle(workingval);
        workingval = PACInvSub(workingval);
        workingval = PACMult(workingval);
        workingval = PACCellInvShuffle(workingval);
        workingval = workingval EOR key0;
        workingval = workingval EOR runningmod;
        for i = 0 to 4
            workingval = PACInvSub(workingval);
            if i < 4 then
                workingval = PACMult(workingval);
                workingval = PACCellInvShuffle(workingval);
                runningmod = TweakInvShuffle(runningmod<63:0>);
                roundkey = key1 EOR runningmod;
                workingval = workingval EOR RC[4-i];
                workingval = workingval EOR roundkey;
                workingval = workingval EOR Alpha;
            workingval = workingval EOR modk0;
    return workingval;
Library pseudocode for aarch64/functions/pac/computepac/PACCellInvShuffle

// PACCellInvShuffle()
// ===================

bits(64) PACCellInvShuffle(bits(64) indata)
  bits(64) outdata;
  outdata<3:0> = indata<15:12>;
  outdata<7:4> = indata<27:24>;
  outdata<11:8> = indata<51:48>;
  outdata<15:12> = indata<39:36>;
  outdata<19:16> = indata<59:56>;
  outdata<23:20> = indata<47:44>;
  outdata<27:24> = indata<7:4>;
  outdata<31:28> = indata<19:16>;
  outdata<35:32> = indata<35:32>;
  outdata<39:36> = indata<55:52>;
  outdata<43:40> = indata<31:28>;
  outdata<47:44> = indata<11:8>;
  outdata<51:48> = indata<23:20>;
  outdata<55:52> = indata<3:0>;
  outdata<59:56> = indata<43:40>;
  outdata<63:60> = indata<63:60>;
  return outdata;

Library pseudocode for aarch64/functions/pac/computepac/PACCellShuffle

// PACCellShuffle()
// ================

bits(64) PACCellShuffle(bits(64) indata)
  bits(64) outdata;
  outdata<3:0> = indata<55:52>;
  outdata<7:4> = indata<27:24>;
  outdata<11:8> = indata<47:44>;
  outdata<15:12> = indata<3:0>;
  outdata<19:16> = indata<31:28>;
  outdata<23:20> = indata<51:48>;
  outdata<27:24> = indata<7:4>;
  outdata<31:28> = indata<43:40>;
  outdata<35:32> = indata<35:32>;
  outdata<39:36> = indata<15:12>;
  outdata<43:40> = indata<59:56>;
  outdata<47:44> = indata<23:20>;
  outdata<51:48> = indata<11:8>;
  outdata<55:52> = indata<39:36>;
  outdata<59:56> = indata<19:16>;
  outdata<63:60> = indata<63:60>;
  return outdata;
Library pseudocode for aarch64/functions/pac/compute/pac/PACInvSub

```c
// PACInvSub()
// ===========
bits(64) PACInvSub(bits(64) Tinput)
// This is a 4-bit substitution from the PRINCE-family cipher

bits(64) Toutput;
for i = 0 to 15
  case Tinput<4*i+3:4*i> of
    when '0000' Toutput<4*i+3:4*i> = '0101';
    when '0001' Toutput<4*i+3:4*i> = '1110';
    when '0010' Toutput<4*i+3:4*i> = '1101';
    when '0011' Toutput<4*i+3:4*i> = '1000';
    when '0100' Toutput<4*i+3:4*i> = '1010';
    when '0101' Toutput<4*i+3:4*i> = '1011';
    when '0110' Toutput<4*i+3:4*i> = '0001';
    when '0111' Toutput<4*i+3:4*i> = '1001';
    when '1000' Toutput<4*i+3:4*i> = '0110';
    when '1001' Toutput<4*i+3:4*i> = '0111';
    when '1010' Toutput<4*i+3:4*i> = '1111';
    when '1011' Toutput<4*i+3:4*i> = '0000';
    when '1100' Toutput<4*i+3:4*i> = '0100';
    when '1101' Toutput<4*i+3:4*i> = '1100';
    when '1110' Toutput<4*i+3:4*i> = '0111';
    when '1111' Toutput<4*i+3:4*i> = '0011';
  return Toutput;
```

Library pseudocode for aarch64/functions/pac/compute/pac/PACMult

```c
// PACMult()
// =========
bits(64) PACMult(bits(64) Sinput)
for i = 0 to 3
  t0<3:0> = RotCell(Sinput<4*(i+8)+3:4*(i+8)>, 1) EOR RotCell(Sinput<4*(i+4)+3:4*(i+4)>, 2);
  t1<3:0> = t0<3:0> EOR RotCell(Sinput<4*(i+4)+3:4*(i+4)>, 1);
  t2<3:0> = RotCell(Sinput<4*(i+12)+3:4*(i+12)>, 2) EOR RotCell(Sinput<4*(i+8)+3:4*(i+8)>, 1);
  t3<3:0> = t2<3:0> EOR RotCell(Sinput<4*(i+8)+3:4*(i+8)>, 1);

Soutput<4*i+3:4*i> = t3<3:0>;
Soutput<4*(i+4)+3:4*(i+4)> = t2<3:0>;
Soutput<4*(i+8)+3:4*(i+8)> = t1<3:0>;
Soutput<4*(i+12)+3:4*(i+12)> = t0<3:0>;
return Soutput;
```
// PACSub()
// =========

bits(64) PACSub(bits(64) Tinput)
// This is a 4-bit substitution from the PRINCE-family cipher
bits(64) Toutput;
for i = 0 to 15
case Tinput<4*i+3:4*i> of
  when '0000'  Toutput<4*i+3:4*i> = '1011';
  when '0001'  Toutput<4*i+3:4*i> = '0110';
  when '0010'  Toutput<4*i+3:4*i> = '1000';
  when '0011'  Toutput<4*i+3:4*i> = '1111';
  when '0100'  Toutput<4*i+3:4*i> = '1100';
  when '0101'  Toutput<4*i+3:4*i> = '0000';
  when '0110'  Toutput<4*i+3:4*i> = '1001';
  when '0111'  Toutput<4*i+3:4*i> = '1110';
  when '1000'  Toutput<4*i+3:4*i> = '0011';
  when '1001'  Toutput<4*i+3:4*i> = '0111';
  when '1010'  Toutput<4*i+3:4*i> = '0100';
  when '1011'  Toutput<4*i+3:4*i> = '0101';
  when '1100'  Toutput<4*i+3:4*i> = '1101';
  when '1101'  Toutput<4*i+3:4*i> = '0010';
  when '1110'  Toutput<4*i+3:4*i> = '0001';
  when '1111'  Toutput<4*i+3:4*i> = '1010';
return Toutput;

// RotCell()
// ==========

bits(4) RotCell(bits(4) incell, integer amount)
bits(8) tmp;
bits(4) outcell;

// assert amount>3 || amount<1;
tmp<7:0> = incell<3:0>:incell<3:0>;
outcell = tmp<7-amount:4-amount>;
return outcell;

// TweakCellInvRot()
// ================

bits(4) TweakCellInvRot(bits(4) incell)
bits(4) outcell;
outcell<3> = incell<2>;
outcell<2> = incell<1>;
outcell<1> = incell<0>;
outcell<0> = incell<0> EOR incell<3>;
return outcell;

// TweakCellRot()
// ==============

bits(4) TweakCellRot(bits(4) incell)
bits(4) outcell;
outcell<3> = incell<0> EOR incell<1>;
outcell<2> = incell<3>;
outcell<1> = incell<2>;
outcell<0> = incell<1>;
return outcell;
// TweakInvShuffle()
// =================

bits(64) TweakInvShuffle(bits(64) indata)
    bits(64) outdata;
    outdata<3:0> = TweakCellInvRot(indata<51:48>);
    outdata<7:4> = indata<55:52>;
    outdata<11:8> = indata<23:20>;
    outdata<15:12> = indata<27:24>;
    outdata<19:16> = indata<3:0>;
    outdata<23:20> = indata<7:4>;
    outdata<27:24> = TweakCellInvRot(indata<11:8>);
    outdata<31:28> = indata<15:12>;
    outdata<35:32> = TweakCellInvRot(indata<31:28>);
    outdata<39:36> = TweakCellInvRot(indata<63:60>);
    outdata<43:40> = TweakCellInvRot(indata<59:56>);
    outdata<47:44> = TweakCellInvRot(indata<19:16>);
    outdata<51:48> = indata<35:32>;
    outdata<55:52> = indata<39:36>;
    outdata<59:56> = indata<43:40>;
    outdata<63:60> = TweakCellInvRot(indata<47:44>);
    return outdata;

// TweakShuffle()
// ==============

bits(64) TweakShuffle(bits(64) indata)
    bits(64) outdata;
    outdata<3:0> = indata<19:16>;
    outdata<7:4> = indata<23:20>;
    outdata<11:8> = TweakCellRot(indata<27:24>);
    outdata<15:12> = indata<31:28>;
    outdata<19:16> = TweakCellRot(indata<47:44>);
    outdata<23:20> = indata<11:8>;
    outdata<27:24> = indata<15:12>;
    outdata<31:28> = TweakCellRot(indata<35:32>);
    outdata<35:32> = TweakCellRot(indata<47:44>);
    outdata<39:36> = TweakCellRot(indata<35:32>);
    outdata<43:40> = TweakCellRot(indata<63:60>);
    outdata<47:44> = TweakCellRot(indata<59:56>);
    outdata<51:48> = TweakCellRot(indata<59:56>);
    outdata<55:52> = indata<43:40>;
    outdata<59:56> = TweakCellRot(indata<59:56>);
    outdata<63:60> = TweakCellRot(indata<39:36>);
    return outdata;

// HavePACExt()
// ============

boolean HavePACExt()
    return HasArchVersion(ARMv8p3);

// PtrHasUpperAndLowerAddRanges()
// =============================

// Returns TRUE if the pointer has upper and lower address ranges

boolean PtrHasUpperAndLowerAddRanges()
    return PSTATE.EL == EL1 | PSTATE.EL == EL0 | (PSTATE.EL == EL2 && HCR_EL2.E2H == '1');
// Strip()
// ========
// Strip() returns a 64-bit value containing A, but replacing the pointer authentication
// code field bits with the extension of the address bits. This can apply to either
// instructions or data, where, as the use of tagged pointers is distinct, it might be
// handled differently.

bits(64) Strip(bits(64) A, boolean data)
    boolean TrapEL2;
    boolean TrapEL3;
    bits(64) original_ptr;
    bits(64) extfield;
    boolean tbi = CalculateTBI(A, data);
    integer bottom_PAC_bit = CalculateBottomPACBit(A<55>);

    extfield = Replicate(A<55>, 64);
    if tbi then
        original_ptr = A<63:56>:extfield< 56-bottom_PAC_bit-1:0>:A<bottom_PAC_bit-1:0>;
    else
        original_ptr = extfield< 64-bottom_PAC_bit-1:0>:A<bottom_PAC_bit-1:0>;
    
    case PSTATE.EL of
        when EL0
            TrapEL2 = (EL2Enabled() && HCR_EL2.API == '0' &&
                        (HCR_EL2.TGE == '0' || HCR_EL2.E2H == '0'));
            TrapEL3 = HaveEL(EL3) && SCR_EL3.API == '0';
        when EL1
            TrapEL2 = EL2Enabled() && HCR_EL2.API == '0';
            TrapEL3 = HaveEL(EL3) && SCR_EL3.API == '0';
        when EL2
            TrapEL2 = FALSE;
            TrapEL3 = HaveEL(EL3) && SCR_EL3.API == '0';
        when EL3
            TrapEL2 = FALSE;
            TrapEL3 = FALSE;
    
    if TrapEL2 then TrapPACUse(EL2);
    elsif TrapEL3 then TrapPACUse(EL3);
    else return original_ptr;

Library pseudocode for aarch64/functions/pac/trappacuse/TrapPACUse

// TrapPACUse()
// =============
// Used for the trapping of the pointer authentication functions by higher exception
// levels.

TrapPACUse(bits(2) target_el)
    assert HaveEL(target_el) && target_el != EL0 && UInt(target_el) >= UInt(PSTATE.EL);
    bits(64) preferred_exception_return = ThisInstrAddr();
    ExceptionRecord exception;
    vect_offset = 0;
    exception = ExceptionSyndrome(Exception_PACTrap);
    AArch64.TakeException(target_el, exception, preferred_exception_return, vect_offset);
// AArch64.ESBOperation()
// ================
// Perform the AArch64 ESB operation, either for ESB executed in AArch64 state, or for
// ESB in AArch32 state when SError interrupts are routed to an Exception level using
// AArch64

AArch64.ESBOperation()

route_to_el3 = (HaveEL(EL3) && SCR_EL3.EA == '1');
route_to_el2 = (EL2Enabled() &&
(HCR_EL2.TGE == '1' || HCR_EL2.AMO == '1'));

target = (if route_to_el3 then EL3 elsif route_to_el2 then EL2 else EL1);

if target == EL1 then
  mask_active = (PSTATE.EL IN {EL0, EL1});
elsif HaveVirtHostExt() && target == EL2 && HCR_EL2.<E2H,TGE> == '11' then
  mask_active = (PSTATE.EL IN {EL0, EL2});
else
  mask_active = (PSTATE.EL == target);

mask_set = (PSTATE.A == '1' && (!
  mask_set = (PSTATE.A == '1');
intdis = (HaveDoubleFaultExt() || SCR_EL3.EA == '0' ||
  PSTATE.EL != EL3 || SCR_EL3.NMEA == '0'));

intdis = (Halted() || ExternalDebugInterruptsDisabled(target));
masked = (UInt(target) < UInt(PSTATE.EL)) || intdis || (mask_active && mask_set);

// Check for a masked Physical SError pending
if IsPhysicalSErrorPending() && masked then
  // This function might be called for an interworking case, and INTdis is masking
  // the SError interrupt.
  if ELUsingAArch32(S1TranslationRegime()) then
    syndrome32 = AArch32.PhysicalSErrorSyndrome();
    DISR = AArch32.ReportDeferredSError(syndrome32.AET, syndrome32.ExT);
  else
    implicit_esb = FALSE;
    syndrome64 = AArch64.PhysicalSErrorSyndrome(implicit_esb);
    DISR_EL1 = AArch64.ReportDeferredSError(syndrome64);
    ClearPendingPhysicalSError();               // Set ISR_EL1.A to 0
return;

Library pseudocode for aarch64/functions/ras/AArch64.PhysicalSErrorSyndrome

// Return the SError syndrome
bits(25) AArch64.PhysicalSErrorSyndrome(boolean implicit_esb);

Library pseudocode for aarch64/functions/ras/AArch64.ReportDeferredSError

// AArch64.ReportDeferredSError()
// =============================
// Generate deferred SError syndrome

bits(64) AArch64.ReportDeferredSError(bits(25) syndrome)
bits(64) target;
target<31> = '1';       // A
target<24> = syndrome<24>;   // IDS
target<23:0> = syndrome<23:0>;   // ISS
return target;
// AArch64.vESBOperation()
// =======================
// Perform the AArch64 ESB operation for virtual SError interrupts, either for ESB 
// executed in AArch64 state, or for ESB in AArch32 state with EL2 using AArch64 state

AArch64.vESBOperation()
assert EL2Enabled() && PSTATE.EL IN {EL0, EL1};

// If physical SError interrupts are routed to EL2, and TGE is not set, then a virtual 
// SError interrupt might be pending
vSEI_enabled = HCR_EL2.TGE == '0' && HCR_EL2.AMO == '1';
vSEI_pending = vSEI_enabled && HCR_EL2.VSE == '1';
vintdis = Halted() || ExternalDebugInterruptsDisabled(EL1);
vmasked = vintdis || PSTATE.A == '1';

// Check for a masked virtual SError pending
if vSEI_pending && vmasked then
  // This function might be called for the interworking case, and INTdis is masking 
  // the virtual SError interrupt.
  if ELUsingAArch32(EL1) then
    VDISR = AArch32.ReportDeferredSError(VDFSR<15:14>, VDFSR<12>);
  else
    VDISR_EL2 = AArch64.ReportDeferredSError(VSESR_EL2<24:0>);
    HCR_EL2.VSE = '0';  // Clear pending virtual SError
  return;

Library pseudocode for aarch64/functions/registers/AArch64.MaybeZeroRegisterUppers

// AArch64.MaybeZeroRegisterUppers()
// =================================
// On taking an exception to AArch64 from AArch32, it is CONSTRAINED UNPREDICTABLE whether the top 
// 32 bits of registers visible at any lower Exception level using AArch32 are set to zero.

AArch64.MaybeZeroRegisterUppers()
assert UsingAArch32(); // Always called from AArch32 state before entering AArch64 state

if PSTATE.EL == EL0 && !ELUsingAArch32(EL1) then
  first = 0; last = 14; include_R15 = FALSE;
elseif PSTATE.EL IN {EL0, EL1} && EL2Enabled() && !ELUsingAArch32(EL2) then
  first = 0; last = 30; include_R15 = FALSE;
else
  first = 0; last = 30; include_R15 = TRUE;

for n = first to last
  if (n != 15 || include_R15) && ConstrainUnpredictableBool(Unpredictable_ZEROUPPER) then
    _R[n]<63:32> = Zeros();
return;

Library pseudocode for aarch64/functions/registers/AArch64.ResetGeneralRegisters

// AArch64.ResetGeneralRegisters()
// ===============================

AArch64.ResetGeneralRegisters()
for i = 0 to 30
  X[i] = bits(64) UNKNOWN;
return;
// AArch64.ResetSIMDFPRegisters()
// ----------------------------------------

AArch64.ResetSIMDFPRegisters()

for i = 0 to 31
    V[i] = bits(128) UNKNOWN;

return;

// AArch64.ResetSpecialRegisters()
// ----------------------------------------

AArch64.ResetSpecialRegisters()

// AArch64 special registers
SP_EL0 = bits(64) UNKNOWN;
SP_EL1 = bits(64) UNKNOWN;
SPSR_EL1 = bits(32) UNKNOWN;
ELR_EL1  = bits(64) UNKNOWN;

if HaveEL(EL2) then
    SP_EL2 = bits(64) UNKNOWN;
    SPSR_EL2 = bits(32) UNKNOWN;
    ELR_EL2  = bits(64) UNKNOWN;

if HaveEL(EL3) then
    SP_EL3 = bits(64) UNKNOWN;
    SPSR_EL3 = bits(32) UNKNOWN;
    ELR_EL3  = bits(64) UNKNOWN;

// AArch32 special registers that are not architecturally mapped to AArch64 registers
if HaveAArch32EL(EL1) then
    SPSR_fiq = bits(32) UNKNOWN;
    SPSR_irq = bits(32) UNKNOWN;
    SPSR_abt = bits(32) UNKNOWN;
    SPSR_und = bits(32) UNKNOWN;

// External debug special registers
DLR_EL0 = bits(64) UNKNOWN;
DPSR_EL0 = bits(32) UNKNOWN;

return;

// AArch64.ResetSystemRegisters(boolean cold_reset);
Library pseudocode for aarch64/functions/registers/SP

// SP[] - assignment form
// ------------------------
// Write to stack pointer from either a 32-bit or a 64-bit value.

SP[] = bits(width) value
assert width IN {32,64};
if PSTATE.SP == '0' then
    SP_EL0 = ZeroExtend(value);
else
    case PSTATE_EL of
        when EL0 SP_EL0 = ZeroExtend(value);
        when EL1 SP_EL1 = ZeroExtend(value);
        when EL2 SP_EL2 = ZeroExtend(value);
        when EL3 SP_EL3 = ZeroExtend(value);
    return;

// SP[] - non-assignment form
// ---------------------------
// Read stack pointer with implicit slice of 8, 16, 32 or 64 bits.

bits(width) SP[]
assert width IN {8,16,32,64};
if PSTATE.SP == '0' then
    return SP_EL0<width-1:0>;
else
    case PSTATE_EL of
        when EL0 return SP_EL0<width-1:0>;
        when EL1 return SP_EL1<width-1:0>;
        when EL2 return SP_EL2<width-1:0>;
        when EL3 return SP_EL3<width-1:0>;

Library pseudocode for aarch64/functions/registers/V

// V[] - assignment form
// -----------------------
// V[integer n] = bits(width) value
assert n >= 0 && n <= 31;
assert width IN {8,16,32,64,128};
integer vlen = if IsSVEEnabled(PSTATE.EL) then VL else 128;
if ConstrainUnpredictableBool(Unpredictable_SVEZEROUPPER) then
    _Z[n] = ZeroExtend(value);
else
    _Z[n]<vlen-1:0> = ZeroExtend(value);

// V[] - non-assignment form
// ---------------------------

bits(width) V[integer n]
assert n >= 0 && n <= 31;
assert width IN {8,16,32,64,128};
return _Z[n]<width-1:0>;
Library pseudocode for aarch64/functions/registers/Vpart

// Vpart[] - non-assignment form
// -----------------------------------

bits(width) Vpart[integer n, integer part]
    assert n >= 0 && n <= 31;
    assert part IN {0, 1};
    if part == 0 then
        assert width IN {8,16,32,64};
        return V[n];
    else
        assert width == 64;
        return _V[n]<(width * 2)-1:width>;

// Vpart[] - assignment form
// -------------------------

Vpart[integer n, integer part] = bits(width) value
    assert n >= 0 && n <= 31;
    assert part IN {0, 1};
    if part == 0 then
        assert width IN {8,16,32,64};
        V[n] = value;
    else
        assert width == 64;
        bits(64) vreg = V[n];
        V[n] = value<63:0> : vreg;

Library pseudocode for aarch64/functions/registers/X

// X[] - assignment form
// ----------------------

// Write to general-purpose register from either a 32-bit or a 64-bit value.

X[integer n] = bits(width) value
    assert n >= 0 && n <= 31;
    assert width IN {32,64};
    if n != 31 then
        _R[n] = ZeroExtend(value);
    return;

// X[] - non-assignment form
// --------------------------

// Read from general-purpose register with implicit slice of 8, 16, 32 or 64 bits.

bits(width) X[integer n]
    assert n >= 0 && n <= 31;
    assert width IN {8,16,32,64};
    if n != 31 then
        return _R[n]<width-1:0>;
    else
        return Zeros(width);
// AArch32.IsFPEnabled()
// ---------------------

boolean AArch32.IsFPEnabled(bits(2) el)
if el == EL0 && !ELUsingAArch32(EL1) then
    return AArch64.IsFPEnabled(el);
if HaveEL(EL3) && ELUsingAArch32(EL3) && !IsSecure() then
    // Check if access disabled in NSACR
    if NSACR.cp10 == '0' then return FALSE;
if el IN {EL0, EL1} then
    // Check if access disabled in CPACR
    case CPACR.cp10 of
        when 'x0' disabled = TRUE;
        when '01' disabled = (el == EL0);
        when '11' disabled = FALSE;
    if disabled then return FALSE;
if el IN {EL0, EL1, EL2} then
    if EL2Enabled() then
        if !ELUsingAArch32(EL2) then
            if CPTR_EL2.FPEN == '1' then return FALSE;
        else
            if CPTR_EL2.TFP == '1' then return FALSE;
    if HaveEL(EL3) && ELUsingAArch32(EL3) then
        // Check if access disabled in CPTR_EL3
        if CPTR_EL3.TFP == '1' then return FALSE;
    return TRUE;

// AArch64.IsFPEnabled()
// ---------------------

boolean AArch64.IsFPEnabled(bits(2) el)
if el IN {EL0, EL1} then
    // Check if access disabled in CPACR_EL1
    if el IN {EL0, EL1} then
        // Check FP&SIMD at EL0/EL1
        case CPACR[].FPEN of
            when 'x0' disabled = TRUE;
            when '01' disabled = (el == EL0);
            when '11' disabled = FALSE;
        if disabled then return FALSE;
    if el IN {EL0, EL1, EL2} && EL2Enabled() then
        if !ELUsingAArch32(EL2) then
            if CPTR_EL2.FPEN == 'x0' then return FALSE;
        else
            if CPTR_EL2.TFP == '1' then return FALSE;
// Check if access disabled in CPTR_EL2
if el IN {EL0, EL1, EL2} && EL2Enabled() then
    if HaveVirtHostExt() && HCR_EL2.E2H == '1' then
        if CPTR_EL2.FPEN == 'x0' then return FALSE;
    else
        if CPTR_EL2.TFP == '1' then return FALSE;
// Check if access disabled in CPTR_EL3
if HaveEL(EL3) then
    if CPTR_EL3.TFP == '1' then return FALSE;
return TRUE;
Library pseudocode for aarch64/functions/sve/CeilPow2

```c
// CeilPow2()
// =========

// For a positive integer X, return the smallest power of 2 >= X

integer CeilPow2(integer x)
    if x == 0 then return 0;
    if x == 1 then return 2;
    return FloorPow2(x - 1) * 2;
```

Library pseudocode for aarch64/functions/sve/CheckSVEEnabled

```c
// CheckSVEEnabled()
// =============

CheckSVEEnabled()
// Check if access disabled in CPACR_EL1
if PSTATE.EL IN {EL0, EL1} then
    // Check SVE at EL0/EL1
    case CPACR[].ZEN of
        when 'x0' disabled = TRUE;
        when '01' disabled = PSTATE.EL == EL0;
        when '11' disabled = FALSE;
    if disabled then SVEAccessTrap(EL1);

    // Check FP&SIMD at EL0/EL1
    case CPACR[].FPEN of
        when 'x0' disabled = TRUE;
        when '01' disabled = PSTATE.EL == EL0;
        when '11' disabled = FALSE;
    if disabled then AArch64.AdvSIMDFPAccessTrap(EL1);

if PSTATE.EL IN {EL0, EL1, EL2} && EL2Enabled() then
    if HaveVirtHostExt() && HCR_EL2.E2H == '1' then
        if CPTR_EL2.ZEN == 'x0' then SVEAccessTrap(EL2);
        if CPTR_EL2.FPEN == 'x0' then AArch64.AdvSIMDFPAccessTrap(EL2);
    else
        if CPTR_EL2.TZ == '1' then SVEAccessTrap(EL2);
        if CPTR_EL2.TFP == '1' then AArch64.AdvSIMDFPAccessTrap(EL2);

    // Check if access disabled in CPTR_EL3
    if HaveEL(EL3) then
        if CPTR_EL3.EZ == '0' then SVEAccessTrap(EL3);
        if CPTR_EL3.TFP == '1' then AArch64.AdvSIMDFPAccessTrap(EL3);
```
// DecodePredCount()
// ===============

integer DecodePredCount(bits(5) pattern, integer esize)
    integer elements = VL DIV esize;
    integer numElem;
    case pattern of
        when '00000' numElem = FloorPow2(elements);
        when '00001' numElem = if elements >= 1 then 1 else 0;
        when '00010' numElem = if elements >= 2 then 2 else 0;
        when '00011' numElem = if elements >= 3 then 3 else 0;
        when '00100' numElem = if elements >= 4 then 4 else 0;
        when '00101' numElem = if elements >= 5 then 5 else 0;
        when '00110' numElem = if elements >= 6 then 6 else 0;
        when '00111' numElem = if elements >= 7 then 7 else 0;
        when '01000' numElem = if elements >= 8 then 8 else 0;
        when '01001' numElem = if elements >= 16 then 16 else 0;
        when '01010' numElem = if elements >= 32 then 32 else 0;
        when '01011' numElem = if elements >= 64 then 64 else 0;
        when '01100' numElem = if elements >= 128 then 128 else 0;
        when '01101' numElem = if elements >= 256 then 256 else 0;
        when '11101' numElem = elements - (elements MOD 4);
        when '11110' numElem = elements - (elements MOD 3);
        when '11111' numElem = elements;
        otherwise    numElem = 0;
    return numElem;

Library pseudocode for aarch64/functions/sve/ElemFFR

// ElemFFR[] - non-assignment form
// ===============================

bit ElemFFR[integer e, integer esize]
    return ElemP[FFR, e, esize];

// ElemFFR[integer e, integer esize] = bit value
// ==============================================

ElemFFR(integer e, integer esize] = bit value
    integer psize = esize DIV 8;
    integer n = e * psize;
    assert n >= 0 && (n + psize) <= PL;
    _FFR<n+psize-1:n> = ZeroExtend(value, psize);
    return;

Library pseudocode for aarch64/functions/sve/ElemP

// ElemP[] - non-assignment form
// =============================

bit ElemP[bits(N) pred, integer e, integer esize]
    integer n = e * (esize DIV 8);
    assert n >= 0 && n < N;
    return pred<n>;

// ElemP[] - assignment form
// =========================

ElemP(bits(N) &pred, integer e, integer esize] = bit value
    integer n = e * psize;
    assert n >= 0 && (n + psize) <= N;
    pred<n+psize-1:n> = ZeroExtend(value, psize);
    return;
Library pseudocode for aarch64/functions/sve/FFR

// FFR[] - non-assignment form
// ===========================

bits(width) FFR[]
assert width == PL;
return _FFR<width-1:0>;

// FFR[] - assignment form
// =======================

FFR[] = bits(width) value
assert width == PL;
if ConstrainUnpredictableBool(Unpredictable_SVEZEROUPPER) then
    _FFR = ZeroExtend(value);
else
    _FFR<width-1:0> = value;

Library pseudocode for aarch64/functions/sve/FPCompareNE

// FPCompareNE()
// =============

boolean FPCompareNE(bits(N) op1, bits(N) op2, FPCRType fpcr)
assert N IN {16,32,64};
(type1,sign1,value1) = FPUnpack(op1, fpcr);
(type2,sign2,value2) = FPUnpack(op2, fpcr);
if type1==FPType_SNaN || type1==FPType_QNaN || type2==FPType_SNaN || type2==FPType_QNaN then
    result = TRUE;
    if type1==FPType_SNaN || type2==FPType_SNaN then
        FPProcessException(FPExc_InvalidOp, fpcr);
    else // All non-NaN cases can be evaluated on the values produced by FPUnpack()
        result = (value1 != value2);
    return result;

Library pseudocode for aarch64/functions/sve/FPCompareUN

// FPCompareUN()
// =============

boolean FPCompareUN(bits(N) op1, bits(N) op2, FPCRType fpcr)
assert N IN {16,32,64};
(type1,sign1,value1) = FPUnpack(op1, fpcr);
(type2,sign2,value2) = FPUnpack(op2, fpcr);
if type1==FPType_SNaN || type2==FPType_SNaN then
    FPProcessException(FPExc_InvalidOp, fpcr);
return (type1==FPType_SNaN || type1==FPType_QNaN || type2==FPType_SNaN || type2==FPType_QNaN);

Library pseudocode for aarch64/functions/sve/FPConvertSVE

// FPConvertSVE()
// ==============

bits(M) FPConvertSVE(bits(N) op, FPCRType fpcr, FPRounding rounding)
fpcr.AHP = '0';
return FPConvert(op, fpcr, rounding);

// FPConvertSVE()
// ==============

bits(M) FPConvertSVE(bits(N) op, FPCRType fpcr)
fpcr.AHP = '0';
return FPConvert(op, fpcr, FPRoundingMode(fpcr));
/ FPExpA() /
// ---------------
bits(N) FPExpA(bits(N) op, FPCRType fpcr)
   assert N IN {16,32,64};
   bits(N) result;
   bits(N) coeff;
   integer idx = if N == 16 then UInt(op<4:0>) else UInt(op<5:0>);
   coeff = FPExpCoefficient[idx];
   if N == 16 then
      result<15:0> = '0':op<9:5>:coeff<9:0>;
   elsif N == 32 then
      result<31:0> = '0':op<13:6>:coeff<22:0>;
   else // N == 64
      result<63:0> = '0':op<16:6>:coeff<51:0>;
   return result;
// FPExpCoefficient()
// ==================

bits(N) FPExpCoefficient[integer index]
assert N IN {16,32,64};
integer result;
if N == 16 then
    case index of
        when 0 result = 0x0000;
        when 1 result = 0x0016;
        when 2 result = 0x002d;
        when 3 result = 0x0045;
        when 4 result = 0x005d;
        when 5 result = 0x0075;
        when 6 result = 0x008e;
        when 7 result = 0x00a8;
        when 8 result = 0x00c2;
        when 9 result = 0x00dc;
        when 10 result = 0x0114;
        when 11 result = 0x0130;
        when 12 result = 0x014d;
        when 13 result = 0x016b;
        when 14 result = 0x0189;
        when 15 result = 0x01a8;
        when 16 result = 0x01c8;
        when 17 result = 0x01e8;
        when 18 result = 0x0209;
        when 19 result = 0x022b;
        when 20 result = 0x024e;
        when 21 result = 0x0271;
        when 22 result = 0x0295;
        when 23 result = 0x02ba;
        when 24 result = 0x02e0;
        when 25 result = 0x0306;
        when 26 result = 0x032e;
        when 27 result = 0x0356;
        when 28 result = 0x037f;
        when 29 result = 0x03a9;
        when 30 result = 0x03d4;
    elsif N == 32 then
        case index of
            when 0 result = 0x000000;
            when 1 result = 0x0164d2;
            when 2 result = 0x02cd87;
            when 3 result = 0x043a29;
            when 4 result = 0x05aac3;
            when 5 result = 0x071f62;
            when 6 result = 0x08980f;
            when 7 result = 0x0a14d5;
            when 8 result = 0x0b95c2;
            when 9 result = 0x0d1adf;
            when 10 result = 0x0ea43a;
            when 11 result = 0x1031dc;
            when 12 result = 0x11c3d3;
            when 13 result = 0x135a2b;
            when 14 result = 0x14f4f0;
            when 15 result = 0x16942d;
            when 16 result = 0x1837f0;
            when 17 result = 0x19e046;
            when 18 result = 0x1be8d3;
            when 19 result = 0x1d3eda;
            when 20 result = 0x1ef532;
            when 21 result = 0x20b051;
            when 22 result = 0x227043;
            when 23 result = 0x243516;
            when 24 result = 0x25fed7;
            when 25 result = 0x27cd94;
when 26 result = 0x29a15b;
when 27 result = 0x2b7a3a;
when 28 result = 0x2d583f;
when 29 result = 0x3123f4;
when 30 result = 0x3311c4;
when 31 result = 0x3504f3;
when 32 result = 0x36fd92;
when 33 result = 0x38fbaf;
when 34 result = 0x3aff5b;
when 35 result = 0x3d08a4;
when 36 result = 0x3f179a;
when 37 result = 0x412c4d;
when 38 result = 0x4346cd;
when 39 result = 0x45672a;
when 40 result = 0x478d75;
when 41 result = 0x49b9be;
when 42 result = 0x4bec15;
when 43 result = 0x506334;
when 44 result = 0x52a81e;
when 45 result = 0x54f35b;
when 46 result = 0x56fd92;
when 47 result = 0x58fbaf;
when 48 result = 0x5aff5b;
when 49 result = 0x5eb8a4;
when 50 result = 0x54f35b;
when 51 result = 0x56fd92;
when 52 result = 0x58fbaf;
when 53 result = 0x5aff5b;
when 54 result = 0x5eb8a4;
when 55 result = 0x54f35b;
when 56 result = 0x56fd92;
when 57 result = 0x58fbaf;
when 58 result = 0x5aff5b;
when 59 result = 0x5eb8a4;
when 60 result = 0x54f35b;
when 61 result = 0x56fd92;
when 62 result = 0x58fbaf;
when 63 result = 0x5aff5b;

else // N == 64
    case index of
     when  0 result = 0x0000000000000000;
     when  1 result = 0x0293A3E778061;
     when  2 result = 0x059B0D3158574;
     when  3 result = 0x0874518759BC8;
     when  4 result = 0x0B5586CF9890F;
     when  5 result = 0x0E3EC32D3D1A2;
     when  6 result = 0x11301D0125B51;
     when  7 result = 0x1429AAEA92DE0;
     when  8 result = 0x172B83C7D517B;
     when  9 result = 0x1A35BE66FCB75;
     when 10 result = 0x1D4873168B9AA;
     when 11 result = 0x2063B88628CD6;
     when 12 result = 0x2387A6E756238;
     when 13 result = 0x26B456E27CDD;
     when 14 result = 0x29E9DF51FDEE1;
     when 15 result = 0x2D285A6E4030B;
     when 16 result = 0x306FE0A31B715;
     when 17 result = 0x33C0B26416FF;
     when 18 result = 0x371A7373AA9CB;
     when 19 result = 0x3A7DB34E59FF7;
     when 20 result = 0x3DE4A61C13422;
     when 21 result = 0x4160A21F72E2A;
     when 22 result = 0x44E086061892D;
     when 23 result = 0x486A2B5C13CDD;
     when 24 result = 0x4BFAD5362A27;
     when 25 result = 0x4F9B7692E2A;
     when 26 result = 0x5342B569D4F82;
     when 27 result = 0x56F4736B527DA;
     when 28 result = 0x59AB07DD485429;
when 29 result = 0x5E76F15AD2148;
when 30 result = 0x6247EB03A5585;
when 31 result = 0x6623882552225;
when 32 result = 0x6A09E667F3BCD;
when 33 result = 0x6DFB23C651A2F;
when 34 result = 0x71F75E8EC5F74;
when 35 result = 0x75FEB564267C9;
when 36 result = 0x7A11473EB0187;
when 37 result = 0x7E2F336CF4E62;
when 38 result = 0x82589994CCE13;
when 39 result = 0x868D99B4492ED;
when 40 result = 0x8ACE5422AA0DB;
when 41 result = 0x8F1AE99157736;
when 42 result = 0x93737B0CDC5E5;
when 43 result = 0x97D829FDE4E50;
when 44 result = 0x9C49182A3F090;
when 45 result = 0xA0C667B5DE565;
when 46 result = 0xA5503B23E255D;
when 47 result = 0xA9E65579FDBF;
when 48 result = 0xAE89F995AD3AD;
when 49 result = 0xB33A2B84F15FB;
when 50 result = 0xB7F76F2FB5E47;
when 51 result = 0xBC1CE904BC1D2;
when 52 result = 0xC199BDD85529C;
when 53 result = 0xC67F12E5714B;
when 54 result = 0xCB720DCEFB9069;
when 55 result = 0xD072D4A07897C;
when 56 result = 0xD5818DCFBA487;
when 57 result = 0xDA9E603DB3285;
when 58 result = 0xDFC97337B9B5F;
when 59 result = 0xE502EE78B3FF6;
when 60 result = 0xEA4AFA2A490DA;
when 61 result = 0xEF41BEE615A27;
when 62 result = 0xF50765B6E4540;
when 63 result = 0xFA7C1819E90D8;

return result<N-1:0>;

Library pseudocode for aarch64/functions/sve/FPMinNormal

```
// FPMinNormal()
// =============

bits(N) FPMinNormal(bit sign)
assert N IN {16,32,64};
constant integer E = (if N == 16 then 5 elsif N == 32 then 8 else 11);
constant integer F = N - (E + 1);
exp = Zeros(E-1):'1';
frac = Zeros(F);
return sign : exp : frac;
```

Library pseudocode for aarch64/functions/sve/FPOne

```
// FPOne()
// ========

bits(N) FPOne(bit sign)
assert N IN {16,32,64};
constant integer E = (if N == 16 then 5 elsif N == 32 then 8 else 11);
constant integer F = N - (E + 1);
exp = '0':Ones(E-1);
frac = Zeros(F);
return sign : exp : frac;
```
Library pseudocode for aarch64/functions/sve/FPPointFive

```c
// FPPointFive()
// =============
bits(N) FPPointFive(bit sign)
    assert N IN {16,32,64};
    constant integer E = (if N == 16 then 5 elsif N == 32 then 8 else 11);
    constant integer F = N - (E + 1);
    exp = '0':Ones(E-2):'0';
    frac = Zeros(F);
    return sign : exp : frac;
```

Library pseudocode for aarch64/functions/sve/FPProcess

```c
// FPProcess()
// ===========
bits(N) FPProcess(bits(N) input)
    bits(N) result;
    assert N IN {16,32,64};
    (type,sign,value) = FPUnpack(input, FPCR);
    if type == FPTYPE_SNaN || type == FPTYPE_QNaN then
        result = FPProcessNaN(type, input, FPCR);
    elsif type == FPTYPE_Infinity then
        result = FPInfinity(sign);
    elsif type == FPTYPE_Zero then
        result = FPZero(sign);
    else
        result = FPRound(value, FPCR);
    return result;
```

Library pseudocode for aarch64/functions/sve/FPScale

```c
// FPScale()
// =========
bits(N) FPScale(bits(N) op, integer scale, FPCRType fpcr)
    assert N IN {16,32,64};
    (type,sign,value) = FPUnpack(op, fpcr);
    if type == FPTYPE_SNaN || type == FPTYPE_QNaN then
        result = FPProcessNaN(type, op, fpcr);
    elsif type == FPTYPE_Zero then
        result = FPZero(sign);
    elsif type == FPTYPE_Infinity then
        result = FPInfinity(sign);
    else
        result = FPRound(value * (2.0^scale), fpcr);
    return result;
```
// FPTrigMAdd()
// ===========

bits(N) FPTrigMAdd(integer x, bits(N) op1, bits(N) op2, FPCRType fpcr)
   assert N IN {16,32,64};
   assert x >= 0;
   assert x < 8;
   bits(N) coeff;

   if op2<N-1> == '1' then
      x = x + 8;
      op2<N-1> = '0';

   coeff = FPTrigMAddCoefficient[x];
   result = FPMulAdd(coeff, op1, op2, fpcr);

return result;
Library pseudocode for aarch64/functions/sve/FPTriAMAddCoefficient

// FPTriAMAddCoefficient()
// =======================

bits(N) FPTriAMAddCoefficient[integer index]
assert N IN {16,32,64};
integer result;

if N == 16 then
    case index of
    when 0 result = 0x3c00;
    when 1 result = 0xb155;
    when 2 result = 0x2030;
    when 3 result = 0x0000;
    when 4 result = 0x0000;
    when 5 result = 0x0000;
    when 6 result = 0x0000;
    when 7 result = 0x0000;
    when 8 result = 0x3c00;
    when 9 result = 0xb800;
    when 10 result = 0x293a;
    when 11 result = 0x0000;
    when 12 result = 0x0000;
    when 13 result = 0x0000;
    when 14 result = 0x0000;
    when 15 result = 0x0000;
elsif N == 32 then
    case index of
    when 0 result = 0x3f800000;
    when 1 result = 0xbe2aaaab;
    when 2 result = 0x3c088886;
    when 3 result = 0xb95008b9;
    when 4 result = 0x36369d6d;
    when 5 result = 0x00000000;
    when 6 result = 0x00000000;
    when 7 result = 0x00000000;
    when 8 result = 0x3f800000;
    when 9 result = 0xbf000000;
    when 10 result = 0x3d2aaaa6;
    when 11 result = 0xbab60705;
    when 12 result = 0x37cd37cc;
    when 13 result = 0x00000000;
    when 14 result = 0x00000000;
    when 15 result = 0x00000000;
else // N == 64
    case index of
    when 0 result = 0x3ff0000000000000;
    when 1 result = 0xbfc555555555543;
    when 2 result = 0x3f81111111110f30c;
    when 3 result = 0xbf2a01a019b92fc6;
    when 4 result = 0x3ec71de351f3d22b;
    when 5 result = 0xbe5ae5e2b60f7b91;
    when 6 result = 0x3de5d8408868552f;
    when 7 result = 0x0000000000000000;
    when 8 result = 0x3ff0000000000000;
    when 9 result = 0xbbf6000000000000;
    when 10 result = 0x3fa555555555536;
    when 11 result = 0xbfa56c16c16c13a0b;
    when 12 result = 0x3efa01a019b1e8d8;
    when 13 result = 0xbfa927e4f7282f468;
    when 14 result = 0x3e21ee96d2641b13;
    when 15 result = 0xbbda8f76380fbb401;

return result<N-1:0>;}
Library pseudocode for aarch64/functions/sve/FPTrigSMul

// FPTrigSMul()
// ============

bits(N) FPTrigSMul(bits(N) op1, bits(N) op2, FPCRType fpcr)
assert N IN {16, 32, 64};
result = FPMul(op1, op1, fpcr);
(type, sign, value) = FPUnpack(result, fpcr);
if (type != FPTYPE_QNaN) && (type != FPTYPE_SNaN) then
  result<N-1> = op2<0>;
return result;

Library pseudocode for aarch64/functions/sve/FPTrigSSel

// FPTrigSSel()
// ============

bits(N) FPTrigSSel(bits(N) op1, bits(N) op2)
assert N IN {16, 32, 64};
bits(N) result;
if op2<0> == '1' then
  result = FPOne(op2<1>);
else
  result = op1;
  result<N-1> = result<N-1> EOR op2<1>;
return result;

Library pseudocode for aarch64/functions/sve/FirstActive

// FirstActive()
// =============

bit FirstActive(bits(N) mask, bits(N) x, integer esize)
integer elements = N DIV (esize DIV 8);
for e = 0 to elements-1
  if ElemP[mask, e, esize] == '1' then return ElemP[x, e, esize];
return '0';

Library pseudocode for aarch64/functions/sve/FloorPow2

// FloorPow2()
// ===========

// For a positive integer X, return the largest power of 2 <= X

integer FloorPow2(integer x)
assert x >= 0;
integer n = 1;
if x == 0 then return 0;
while x >= 2^n do
  n = n + 1;
return 2^(n - 1);

Library pseudocode for aarch64/functions/sve/HaveSVE

// HaveSVE()
// =========

boolean HaveSVE()
return HasArchVersion(ARMv8p2) && boolean IMPLEMENTATION_DEFINED "Have SVE ISA";
// ImplementedSVEVectorLength()
// ============================
// Reduce SVE vector length to a supported value (e.g. power of two)

integer ImplementedSVEVectorLength(integer nbits)
return integer IMPLEMENTATION_DEFINED;

// IsEven()
// ========

boolean IsEven(integer val)
return val MOD 2 == 0;

// IsFPEnabled()
// =============

boolean IsFPEnabled(bits(2) el)
if ELUsingAArch32(el) then
  return AArch32.IsFPEnabled(el);
else
  return AArch64.IsFPEnabled(el);

// IsSVEEnabled()
// ==============

boolean IsSVEEnabled(bits(2) el)
if ELUsingAAarch32(el) then
  return FALSE;

// Check if access disabled in CPACR_EL1
if el IN {EL0, EL1} then
  // Check SVE at EL0/EL1
  case CPACR[].ZEN of
    when 'x0' disabled = TRUE;
    when '01' disabled = (el == EL0);
    when '11' disabled = FALSE;
  if disabled then return FALSE;

// Check if access disabled in CPTR_EL2
if el IN {EL0, EL1, EL2} & EL2Enabled() then
  if HaveVirtHostExt() & HCR_EL2.E2H == '1' then
    if CPTR_EL2.ZEN == 'x0' then return FALSE;
  else
    if CPTR_EL2.TZ == '1' then return FALSE;

// Check if access disabled in CPTR_EL3
if HaveEL(EL3) then
  if CPTR_EL3.EZ == '0' then return FALSE;

return TRUE;
// LastActive()
// ============
bit LastActive(bits(N) mask, bits(N) x, integer esize)
integer elements = N DIV (esize DIV 8);
for e = elements-1 downto 0
  if ElemP[mask, e, esize] == '1' then return ElemP[x, e, esize];
return '0';

// LastActiveElement()
// ===============
integer LastActiveElement(bits(N) mask, integer esize)
assert esize IN {8, 16, 32, 64};
integer elements = VL DIV esize;
for e = elements-1 downto 0
  if ElemP[mask, e, esize] == '1' then return e;
return -1;

// MaybeZeroSVEUppers()
// ================
MaybeZeroSVEUppers(bits(2) target_el)
boolean lower_enabled;
if UInt(target_el) <= UInt(PSTATE.EL) || !IsSVEEnabled(target_el) then
  return;
if target_el == EL3 then
  if EL2Enabled() then
    lower_enabled = IsFPEnabled(EL2);
  else
    lower_enabled = IsFPEnabled(EL1);
else
  lower_enabled = IsFPEnabled(target_el - 1);
if lower_enabled then
  integer vl = if IsSVEEnabled(PSTATE.EL) then VL else 128;
  integer pl = vl DIV 8;
  for n = 0 to 31
    if ConstrainUnpredictableBool(Unpredictable_SVEZEROUPPER) then
      _Z[n] = ZeroExtend(Z[n]<vl-1:0>);
  for n = 0 to 15
    if ConstrainUnpredictableBool(Unpredictable_SVEZEROUPPER) then
      _P[n] = ZeroExtend(P[n]<pl-1:0>);
  if ConstrainUnpredictableBool(Unpredictable_SVEZEROUPPER) then
    _FFR = ZeroExtend(_FFR<pl-1:0>);
// MemNF[] - non-assignment form
// -------------------------------------

(bits(8*size), boolean) MemNF[bits(64) address, integer size, AccType acctype]
assert size IN {1, 2, 4, 8, 16};
bits(8*size) value;

aligned = (address == Align(address, size));
A = SCTLR[].A;

if !aligned && (A == '1') then
  return (bits(8*size) UNKNOWN, TRUE);
atomic = aligned || size == 1;

if !atomic then
  (value<7:0>, bad) = MemSingleNF[address, 1, acctype, aligned];
  if bad then
    return (bits(8*size) UNKNOWN, TRUE);
  // For subsequent bytes it is CONSTRAINED UNPREDICTABLE whether an unaligned Device memory
  // access will generate an Alignment Fault, as to get this far means the first byte did
  // not, so we must be changing to a new translation page.
  if !aligned then
    c = ConstrainUnpredictable(Unpredictable_DEVPAGE2);
    assert c IN {Constraint_FAULT, Constraint_NONE};
    if c == Constraint_NONE then aligned = TRUE;
  for i = 1 to size-1
    (value<8*i+7:8*i>, bad) = MemSingleNF[address+i, 1, acctype, aligned];
    if bad then
      return (bits(8*size) UNKNOWN, TRUE);
  else
    (value, bad) = MemSingleNF[address, size, acctype, aligned];
    if bad then
      return (bits(8*size) UNKNOWN, TRUE);
  if BigEndian() then
    value = BigEndianReverse(value);
  return (value, FALSE);
// MemSingleNF[] - non-assignment form
// -----------------------------------------------

(bits(8*size), boolean) MemSingleNF(bits(64) address, integer size, AccType acctype, boolean wasaligned)

bits(8*size) value;
boolean iswrite = FALSE;
AddressDescriptor memaddrdesc;

// Implementation may suppress NF load for any reason
if ConstrainUnpredictableBool(Unpredictable NONFAULT) then
   return (bits(8*size) UNKNOWN, TRUE);

// MMU or MPU
memaddrdesc = AArch64.TranslateAddress(address, acctype, iswrite, wasaligned, size);

// Non-fault load from Device memory must not be performed externally
if memaddrdesc.memattrs.type == MemType_Device then
   return (bits(8*size) UNKNOWN, TRUE);

// Check for aborts or debug exceptions
if IsFault(memaddrdesc) then
   return (bits(8*size) UNKNOWN, TRUE);

// Memory array access
accdesc = CreateAccessDescriptor(acctype);

if ! HaveMTEExtCreateAccessDescriptor() then
   if AccessIsTagChecked(address, acctype) then
      bits(4) ptag = TransformTag(address);
      if ! CheckTag(memaddrdesc, ptag, iswrite) then
         return (bits(8*size) UNKNOWN, TRUE);

value = _Mem[memaddrdesc, size, accdesc];
return (value, FALSE);

Library pseudocode for aarch64/functions/sve/NoneActive

// NoneActive()
// ------------

bit NoneActive(bits(N) mask, bits(N) x, integer esize)

integer elements = N DIV (esize DIV 8);
for e = 0 to elements-1
   if ElemP[mask, e, esize] == '1' & ElemP[x, e, esize] == '1' then return '0';
return '1';
Library pseudocode for aarch64/functions/sve/P

// P[] - non-assignment form
// ------------------------

bits(width) P[integer n]
assert n >= 0 && n <= 31;
assert width == PL;
return _P[n]<width-1:0>;

// P[] - assignment form
// ---------------------

P[integer n] = bits(width) value
assert n >= 0 && n <= 31;
assert width == PL;
if ConstrainUnpredictableBool(Unpredictable_SVEZEROUPPER) then
  _P[n] = ZeroExtend(value);
else
  _P[n]<width-1:0> = value;

Library pseudocode for aarch64/functions/sve/PL

// PL - non-assignment form
// ------------------------

integer PL
return VL DIV 8;

Library pseudocode for aarch64/functions/sve/PredTest

// PredTest()
// -------

bits(4) PredTest(bits(N) mask, bits(N) result, integer esize)
  bit n = FirstActive(mask, result, esize);
  bit z = NoneActive(mask, result, esize);
  bit c = NOT LastActive(mask, result, esize);
  bit v = '0';
  return n:z:c:v;

Library pseudocode for aarch64/functions/sve/ReducePredicated

// ReducePredicated()
// -----------------

bits(esize) ReducePredicated(ReduceOp op, bits(N) input, bits(M) mask, bits(esize) identity)
assert(N == M * 8);
integer p2bits = CeilPow2(N);
bits(p2bits) operand;
integer elements = p2bits DIV esize;
for e = 0 to elements-1
  if e * esize < N && ElemP[mask, e, esize] == '1' then
    Elem[operand, e, esize] = Elem[input, e, esize];
  else
    Elem[operand, e, esize] = identity;
return Reduce(op, operand, esize);
Library pseudocode for aarch64/functions/sve/Reverse

```c
// Reverse()
// =========
// Reverse subwords of M bits in an N-bit word

bits(N) Reverse(bits(N) word, integer M)
    bits(N) result;
    integer sw = N DIV M;
    assert N == sw * M;
    for s = 0 to sw-1
        Elem[result, sw - 1 - s, M] = Elem[word, s, M];
    return result;
```

Library pseudocode for aarch64/functions/sve/SVEAccessTrap

```c
// SVEAccessTrap()
// ===============
// Trapped access to SVE registers due to CPACR_EL1, CPTR_EL2, or CPTR_EL3.

SVEAccessTrap(bits(2) target_el)
    assert UInt(target_el) >= UInt(PSTATE.EL) && target_el != EL0 && HaveEL(target_el);
    route_to_el2 = target_el == EL1 && EL2Enabled() && HCR_EL2.TGE == '1';
    exception = ExceptionSyndrome(Exception_SVEAccessTrap);
    bits(64) preferred_exception_return = ThisInstrAddr();
    vect_offset = 0x0;
    if route_to_el2 then
        AArch64.TakeException(EL2, exception, preferred_exception_return, vect_offset);
    else
        AArch64.TakeException(target_el, exception, preferred_exception_return, vect_offset);
```

Library pseudocode for aarch64/functions/sve/SVECmp

```c
enumeration SVECmp { Cmp_EQ, Cmp_NE, Cmp_GE, Cmp_GT, Cmp_LT, Cmp_LE, Cmp_UN };
```
boolean SVEMoveMaskPreferred(bits(13) imm13) {
    bits(64) imm;
    (imm, -) = DecodeBitMasks(imm13<12>, imm13<5:0>, imm13<11:6>, TRUE);

    // Check for 8 bit immediates
    if !IsZero(imm<7:0>) then
        // Check for 'ffffffffffffffxy' or '00000000000000xy'
        if IsZero(imm<63:7>) || IsOnes(imm<63:7>) then return FALSE;

        // Check for 'ffffffxyffffffxy' or '000000xy000000xy'
        if imm<63:32> == imm<31:0> && (IsZero(imm<31:7>) || IsOnes(imm<31:7>)) then return FALSE;

        // Check for 'ffxyffxyffxyffxy' or '00xy00xy00xy00xy'

        // Check for 'xyxyxyxyxyxyxyxy'
        if imm<63:32> == imm<31:0> && imm<31:16> == imm<15:0> && (imm<15:8> == imm<7:0>) then return FALSE;

    // Check for 16 bit immediates
    else
        // Check for 'ffffffffffffffxy00' or '000000000000xy00'
        if IsZero(imm<63:15>) || IsOnes(imm<63:15>) then return FALSE;

        // Check for 'ffffxy00ffxy00' or '0000xy000000xy00'
        if imm<63:32> == imm<31:0> && (IsZero(imm<31:7>) || IsOnes(imm<31:7>)) then return FALSE;

        // Check for 'xy00xy00xy00xy00'
        if imm<63:32> == imm<31:0> && imm<31:16> == imm<15:0> then return FALSE;
    
    return TRUE;
}
// VL - non-assignment form
// ========================

integer VL
    integer vl;
    if PSTATE.EL == EL1 || (PSTATE.EL == EL0 && !IsInHost()) then
        vl = UInt(ZCR_EL1.LEN);
    end if;
    if PSTATE.EL == EL2 || (PSTATE.EL == EL0 && IsInHost()) then
        vl = UInt(ZCR_EL2.LEN);
    end if;
    elsif EL2Enabled() && PSTATE.EL IN {EL0, EL1} then
        vl = Min(vl, UInt(ZCR_EL2.LEN));
    end if;
    if PSTATE.EL == EL3 then
        vl = UInt(ZCR_EL3.LEN);
    end if;
    elsif HaveEL(EL3) then
        vl = Min(vl, UInt(ZCR_EL3.LEN));
    end if;
    vl = (vl + 1) * 128;
    vl = ImplementedSVEVectorLength(vl);
    return vl;

// Z[] - non-assignment form
// =========================

bits(width) Z[integer n]
    assert n >= 0 && n <= 31;
    assert width == VL;
    return _Z[n]<width-1:0>;

// Z[] - assignment form
// =====================

Z[integer n] = bits(width) value
    assert n >= 0 && n <= 31;
    assert width == VL;
    if ConstrainUnpredictableBool(Unpredictable_SVEZEROUPPER) then
        _Z[n] = ZeroExtend(value);
    else
        _Z[n]<width-1:0> = value;
    end if;

// CNTKCTL[] - non-assignment form
// ===============================

CNTKCTLType CNTKCTL[]
    bits(32) r;
    if IsInHost() then
        r = CNTKCTL_EL2;
        return r;
    end if;
    r = CNTKCTL_EL1;
    return r;

type CNTKCTLType;
Library pseudocode for aarch64/functions/sysregisters/CPACR

// CPACR[] - non-assignment form
// --------------------------------

CPACRTypet CPACR[]

    bits(32) r;
    if isInHost() then
        r = CPTR_EL2;
        return r;
    r = CPACR_EL1;
    return r;

Library pseudocode for aarch64/functions/sysregisters/CPACRTypet

type CPACRTypet;

Library pseudocode for aarch64/functions/sysregisters/ELR

// ELR[] - non-assignment form
// ---------------------------

bits(64) ELR[bits(2) el]

    bits(64) r;
    case el of
        when EL1 r = ELR_EL1;
        when EL2 r = ELR_EL2;
        when EL3 r = ELR_EL3;
        otherwise Unreachable();
    return r;

// ELR[] - non-assignment form
// ---------------------------

bits(64) ELR[]

    assert PSTATE.EL != EL0;
    return ELR[PSTATE.EL];

// ELR[] - assignment form
// -----------------------

ELR[bits(2) el] = bits(64) value

    bits(64) r = value;
    case el of
        when EL1 ELR_EL1 = r;
        when EL2 ELR_EL2 = r;
        when EL3 ELR_EL3 = r;
        otherwise Unreachable();
    return;

// ELR[] - assignment form
// -----------------------

ELR[] = bits(64) value

    assert PSTATE.EL != EL0;
    ELR[PSTATE.EL] = value;
    return;
// ESR[] - non-assignment form
// --------------------------------

ESRType ESR[bits(2) regime]
  bits(32) r;
  case regime of
    when EL1  r = ESR_EL1;
    when EL2  r = ESR_EL2;
    when EL3  r = ESR_EL3;
    otherwise Unreachable();
  return r;

// ESR[] - non-assignment form
// --------------------------------

ESRType ESR[]
  return ESR[S1TranslationRegime()];

// ESR[] - assignment form
// --------------------------------

ESR[bits(2) regime] = ESRType value
  bits(32) r = value;
  case regime of
    when EL1  ESR_EL1 = r;
    when EL2  ESR_EL2 = r;
    when EL3  ESR_EL3 = r;
    otherwise Unreachable();
  return;

// ESR[] - assignment form
// --------------------------------

ESR[] = ESRType value
  ESR[S1TranslationRegime()] = value;

Library pseudocode for aarch64/functions/sysregisters/ESRType

type ESRType;
Library pseudocode for aarch64/functions/sysregisters/FAR

// FAR[] - non-assignment form
// ----------------------------------

bits(64) FAR[bits(2) regime]
  bits(64) r;
  case regime of
    when EL1 r = FAR_EL1;
    when EL2 r = FAR_EL2;
    when EL3 r = FAR_EL3;
    otherwise unreachable();
  return r;

// FAR[] - non-assignment form
// ----------------------------------

bits(64) FAR[]
  return FAR[S1TranslationRegime()];

// FAR[] - assignment form
// ------------------------

FAR[bits(2) regime] = bits(64) value
  bits(64) r = value;
  case regime of
    when EL1 FAR_EL1 = r;
    when EL2 FAR_EL2 = r;
    when EL3 FAR_EL3 = r;
    otherwise unreachable();
  return;

// FAR[] - assignment form
// ------------------------

FAR[] = bits(64) value
  FAR[S1TranslationRegime()] = value;
  return;

Library pseudocode for aarch64/functions/sysregisters/MAIR

// MAIR[] - non-assignment form
// -----------------------------

MAIRTType MAIR[bits(2) regime]
  bits(64) r;
  case regime of
    when EL1 MAIR_EL1 = r;
    when EL2 MAIR_EL2 = r;
    when EL3 MAIR_EL3 = r;
    otherwise unreachable();
  return r;

// MAIR[] - non-assignment form
// -----------------------------

MAIRTType MAIR[]
  return MAIR[S1TranslationRegime()];

Library pseudocode for aarch64/functions/sysregisters/MAIRTType

type MAIRTType;
// SCTLR[] - non-assignment form
// ------------------------------------------

SCTLRType SCTLR[bits(2) regime]

  bits(64) r;
  bits(32) m;
  case regime of
    when EL1  r = SCTLR_EL1;
    when EL2  r = SCTLR_EL2;
    when EL3  r = SCTLR_EL3;
    otherwise unreachable();
  return r;

// SCTLR[] - non-assignment form
// ------------------------------------------

SCTLRType SCTLR[]

  return SCTLR[1TranslationRegime()];

Library pseudocode for aarch64/functions/sysregisters/SCTLRType

type SCTLRType;

Library pseudocode for aarch64/functions/sysregisters/VBAR

// VBAR[] - non-assignment form
// -----------------------------

bits(64) VBAR[bits(2) regime]

  bits(64) r;
  case regime of
    when EL1  r = VBAR_EL1;
    when EL2  r = VBAR_EL2;
    when EL3  r = VBAR_EL3;
    otherwise unreachable();
  return r;

// VBAR[] - non-assignment form
// -----------------------------

bits(64) VBAR[]

  return VBAR[1TranslationRegime()];

Library pseudocode for aarch64/functions/system/AArch64.CheckAdvSIMDFPSystemRegisterTraps

// Checks if an AArch64 MSR, MRS or SYS instruction on a SIMD or floating-point register is trapped under the current configuration. Returns a boolean which is TRUE if trapping occurs, plus a binary value that specifies the Exception level trapped to.

(boolean, bits(2)) AArch64.CheckAdvSIMDFPSystemRegisterTraps(bits(2) op0, bits(3) op1, bits(4) crn, bits(4) crm, bits(3) op2, bit read);

Library pseudocode for aarch64/functions/system/AArch64.CheckSVESystemRegisterTraps

// Checks if an AArch64 MSR/MRS/SYS instruction on a Scalable Vector register is trapped under the current configuration

(boolean, bits(2)) AArch64.CheckSVESystemRegisterTraps(bits(2) op0, bits(3) op1, bits(4) crn, bits(4) crm, bits(3) op2, bit read)
Library pseudocode for aarch64/functions/system/AArch64.CheckSystemAccess

```c
// AArch64.CheckSystemAccess()
// ===========================

AArch64.CheckSystemAccess(bits(2) op0, bits(3) op1, bits(4) crn, bits(4) crm, bits(3) op2, bits(5) rt, bit read)

// Checks if an AArch64 MSR, MRS or SYS instruction is UNALLOCATED or trapped at the current exception level, security state and configuration, based on the opcode's encoding.
boolean unallocated = FALSE;
boolean need_secure = FALSE;
bits(2) min_EL;

// Check for traps by HCR_EL2.TIDCP
if PSTATE.EL IN {EL0, EL1} && HCR_EL2.TIDCP == 1 && op0 == 'x1' && crn == '1x1' then
    // At EL0, it is IMPLEMENTATION DEFINED whether attempts to execute system register access instructions with reserved encodings are trapped to EL2 or UNDEFINED
    rcs_el0_trap = boolean IMPLEMENTATION_DEFINED "Reserved Control Space EL0 Trapped";
    if PSTATE.EL == EL1 || rcs_el0_trap then
        AArch64.SystemRegisterTrap(EL2, op0, op2, op1, crn, rt, crm, read);

// Check for unallocated encodings
    case op1 of
        when '00x', '010'
            min_EL = EL1;
        when '011'
            min_EL = EL0;
        when '100'
            min_EL = EL2;
        when '101'
            if !HaveVirtHostExt() then UNDEFINED;
                min_EL = EL2;
            else
                min_EL = EL1;
                need_secure = TRUE;
        when '110'
            min_EL = EL3;
        when '111'
            min_EL = EL1;
    end

    if UInt(PSTATE.EL) < UInt(min_EL) then
        // Check for traps on read/write access to registers named _EL2, _EL02, _EL12 from non-secure EL1 when HCR_EL2.NV bit is set
        nv_access = HaveNVExt() && min_EL == EL2 && PSTATE.EL == EL1 && EL2Enabled() && HCR_EL2.NV == '1';
        if !nv_access then
            UNDEFINED;
            elsif need_secure && !IsSecure() then
                UnallocatedEncoding();
                elsif AArch64.CheckUnallocatedSystemAccess(PSTATE.EL, op0, op1, crn, crm, op2, read) then
                    UNDEFINED;
                elsif AArch64.CheckUnallocatedSystemAccess(PSTATE.EL, op0, op1, crn, crm, op2, read) then
                    UNDEFINED;
                end

                // Check for traps on accesses to SIMD or floating-point registers
                (take_trap, target_el) = AArch64.CheckAdvSIMDFPSystemRegisterTraps(op0, op1, crn, crm, op2, read);
                if take_trap then
                    AArch64.AdvSIMDFPAccessTrap(target_el);

                // Check for traps on accesses to Scalable Vector registers
                (take_trap, target_el) = AArch64.CheckSVESystemRegisterTraps(op0, op1, crn, crm, op2);
                if take_trap then
                    SVEAccessTrap(target_el);

                // Check for traps on access to all other system registers
                (take_trap, target_el) = AArch64.CheckSystemRegisterTraps(op0, op1, crn, crm, op2, read);
                if take_trap then
                    AArch64.SystemRegisterTrap(target_el, op0, op2, op1, crn, rt, crm, read);
```
Library pseudocode for aarch64/functions/system/AArch64.CheckSystemRegisterTraps

// Checks if an AArch64 MSR, MRS or SYS instruction on a system register is trapped under the current configuration. Returns a boolean which is TRUE if trapping occurs, plus a binary value that specifies the Exception level trapped to.

(booleans) AArch64.CheckSystemRegisterTraps(booleans) op0, booleans op1, booleans crn, booleans crm, booleans op2);

Library pseudocode for aarch64/functions/system/AArch64.CheckUnallocatedSystemAccess

// Checks if an AArch64 MSR, MRS or SYS instruction is unallocated under the current configuration.

boolean AArch64.CheckUnallocatedSystemAccess(booleans) op0, booleans op1, booleans crn, booleans crm, booleans op2);

Library pseudocode for aarch64/functions/system/AArch64.ExecutingATS1xPInstr

// AArch64.ExecutingATS1xPInstr()
// ==============================
// Return TRUE if current instruction is AT S1E1R/WP

boolean AArch64.ExecutingATS1xPInstr()

if !HavePrivATExt() then return FALSE;

instr = ThisInstr();
if instr<22+:10> == '1101010100' then
    op1 = instr<16+:3>;
    CRn = instr<12+:4>;
    CRm = instr<8+:4>;
    op2 = instr<5+:3>;
    return op1 == '000' && CRn == '0111' && CRm == '1001' && op2 IN {'000','001'};
else
    return FALSE;

Library pseudocode for aarch64/functions/system/AArch64.ExecutingBROrBLROrRetInstr

// AArch64.ExecutingBROrBLROrRetInstr()
// ====================================
// Returns TRUE if current instruction is a BR, BLR, RET, B[L]RA[B][Z], or RETA[B].

boolean AArch64.ExecutingBROrBLROrRetInstr()

if !HaveBTIExt() then return FALSE;

instr = ThisInstr();
if instr<31:25> == '1101011' && instr<20:16> == '11111' then
    opc = instr<24:21>;
    return opc != '0101';
else
    return FALSE;

Library pseudocode for aarch64/functions/system/AArch64.ExecutingBTIInstr

// AArch64.ExecutingBTIInstr()
// ===========================
// Returns TRUE if current instruction is a BTI.

boolean AArch64.ExecutingBTIInstr()

if !HaveBTIExt() then return FALSE;

instr = ThisInstr();
if instr<31:22> == '1101010100' && instr<21:12> == '0000110010' && instr<4:0> == '11111' then
    CRm = instr<11:8>;
    op2 = instr<7:5>;
    return (CRm == '0100' && op2<0> == '0');
else
    return FALSE;
// Execute a system instruction with write (source operand).
AArch64.SysInstr(integer op0, integer op1, integer crn, integer crm, integer op2, bits(64) val);

// Execute a system instruction with read (result operand).
// Returns the result of the instruction.
bits(64) AArch64.SysInstrWithResult(integer op0, integer op1, integer crn, integer crm, integer op2);

// Read from a system register and return the contents of the register.
bits(64) AArch64.SysRegRead(integer op0, integer op1, integer crn, integer crm, integer op2);

// Write to a system register.
AArch64.SysRegWrite(integer op0, integer op1, integer crn, integer crm, integer op2, bits(64) val);

boolean BTypeCompatible;  // AArch64.ExceptionReturn()
// SynchronizeContext();
AArch64.ExceptionReturn(bits(64) new_pc, bits(32) spsr);

if HaveRASExt() && SCTLR[].IESB == '1' then
  SynchronizeErrors();
  TakeUnmaskedPhysicalErrorInterrupt(iesb_req);
  // Attempts to change to an illegal state will invoke the Illegal Execution state mechanism
  SetPSTATEComESP(spsr);
  ClearExclusiveLocal(ProcessorID());
  SendEventLocal();

if PSTATE.T == '1' && spsr<4> == '1' && spsr<20> == '0' then
  // If the exception return is illegal, PC[63:32,1:0] are UNKNOWN
  new_pc<63:32> = bits(32) UNKNOWN;
  new_pc<1:0> = bits(2) UNKNOWN;
elsif UsingAArch32() then  // Return to AArch32
  // ELR_ELx[1:0] or ELR_ELx[0] are treated as being 0, depending on the target instruction set
  if PSTATE.T == '1' then
    new_pc<0> = '0';  // T32
  else
    new_pc<1:0> = '00';  // A32
  else
    // Return to AArch64
    // ELR_ELx[63:56] might include a tag
    new_pc = AArch64.BranchAddr(new_pc);
else
  // 32 most significant bits are ignored.
  BranchTo(new_pc<31:0>, BranchType_UNKNOWN);
else
  BranchToAddr(new_pc, BranchType_ERET);
// BTypeCompatible_BTI
// ===================
// This function determines whether a given hint encoding is compatible with the current value of
// PSTATE.BTYPE. A value of TRUE here indicates a valid Branch Target Identification instruction.

boolean BTypeCompatible_BTI(bits(2) hintcode)
{
  case hintcode of
    when '00'
      return FALSE;
    when '01'
      return PSTATE.BTYPE != '11';
    when '10'
      return PSTATE.BTYPE != '10';
    when '11'
      return TRUE;
  end;
}

// BTypeCompatible_PACIXSP()
// =========================
// Returns TRUE if PACIASP, PACIBSP instruction is implicit compatible with PSTATE.BTYPE,
// FALSE otherwise.

boolean BTypeCompatible_PACIXSP()
{
  if PSTATE.BTYPE IN {'01', '10'} then
    return TRUE;
  elsif PSTATE.BTYPE == '11' then
    index = if PSTATE.EL == EL0 then 35 else 36;
    return SCTLR[index] == '0';
  else
    return FALSE;
  end;
}

bits(2) BTypeNext;
// AArch64.ExceptionReturn()
// ------------------------
AArch64.ExceptionReturn(bits(64) new_pc, bits(32) spsr)

SynchronizeContext();

sync_errors = HaveIESB() && SCTLR().IESB == '1';
if HaveDoubleFaultExt() then
    sync_errors = sync_errors || (SCR_EL3.EA == '1' && SCR_EL3.NMEA == '1' && PSTATE.EL == EL3);
if sync_errors then
    SynchronizeErrors();
    iesb_req = TRUE;
    TakeUnmaskedPhysicalSErrorInterrupts(iesb_req);
// Attempts to change to an illegal state will invoke the Illegal Execution state mechanism
SetPSTATEFromPSR(spsr);
ClearExclusiveLocal(ProcessorID());
SendEventLocal();

if PSTATE.IL == '1' && spsr<4> == '1' && spsr<20> == '0' then
    // If the exception return is illegal, PC[63:32,1:0] are UNKNOWN
    new_pc<63:32> = bits(32) UNKNOWN;
    new_pc<1:0> = bits(2) UNKNOWN;
elsif UsingAArch32() then // Return to AArch32
    // ELR_ELx[1:0] or ELR_ELx[0] are treated as being 0, depending on the target instruction set architecture
    if PSTATE.T == '1' then
        new_pc<0> = '0'; // T32
    else
        new_pc<1:0> = '00'; // A32
    else
        // Return to AArch64
        // ELR_ELx[63:56] might include a tag
        new_pc = AArch64.BranchAddr(new_pc);

if UsingAArch32() then // 32 most significant bits are ignored.
    BranchTo(new_pc<31:0>, BranchType_ERET);
else
    BranchToAddr(new_pc, BranchType_ERET);

Library pseudocode for aarch64/instrs/countop/CountOp


Library pseudocode for aarch64/instrs/extendreg/DecodeRegExtend

// DecodeRegExtend()
// ------------------
// Decode a register extension option

ExtendType DecodeRegExtend(bits(3) op)

case op of
    when '000' return ExtendType_UXTB;
    when '001' return ExtendType_UXTH;
    when '010' return ExtendType_UXTW;
    when '011' return ExtendType_UXTX;
    when '100' return ExtendType_SXTB;
    when '101' return ExtendType_SXTH;
    when '110' return ExtendType_SXTW;
    when '111' return ExtendType_SXTX;
// ExtendReg()
// ===========
// Perform a register extension and shift

bits(N) ExtendReg(integer reg, ExtendType type, integer shift)
assert shift >= 0 && shift <= 4;
bits(N) val = X[reg];
boolean unsigned;
integer len;

case type of
  when ExtendType_SXTB unsigned = FALSE; len = 8;
  when ExtendType_SXTH unsigned = FALSE; len = 16;
  when ExtendType_SXTW unsigned = FALSE; len = 32;
  when ExtendType_SXTX unsigned = FALSE; len = 64;
  when ExtendType_UXTB unsigned = TRUE; len = 8;
  when ExtendType_UXTH unsigned = TRUE; len = 16;
  when ExtendType_UXTW unsigned = TRUE; len = 32;
  when ExtendType_UXTX unsigned = TRUE; len = 64;

  // Note the extended width of the intermediate value and
  // that sign extension occurs from bit <len+shift-1>, not
  // from bit <len-1>. This is equivalent to the instruction
  // [SU]BFIZ Rtmp, Rreg, #shift, #len
  // It may also be seen as a sign/zero extend followed by a shift:
  // LSL(Extend(val<len-1:0>, N, unsigned), shift);

  len = Min(len, N - shift);
  return Extend(val<len-1:0> : Zeros(shift), N, unsigned);

Library pseudocode for aarch64/instrs/extendreg/ExtendType

enumeration ExtendType {ExtendType_SXTB, ExtendType_SXTH, ExtendType_SXTW, ExtendType_SXTX,
  ExtendType_UXTB, ExtendType_UXTH, ExtendType_UXTW, ExtendType_UXTX};

Library pseudocode for aarch64/instrs/float/arithmetic/max-min/fpmaxminop/FPMaxMinOp

enumeration FPMaxMinOp {FPMaxMinOp_MAX, FPMaxMinOp_MIN,
  FPMaxMinOp_MAXNUM, FPMaxMinOp_MINNUM};

Library pseudocode for aarch64/instrs/float/arithmetic/unary/fpunaryop/FPUnaryOp

enumeration FPUnaryOp {FPUnaryOp_ABS, FPUnaryOp_MOV,
  FPUnaryOp_NEG, FPUnaryOp_SQRT};

Library pseudocode for aarch64/instrs/float/convert/fpconvop/FPConvOp

enumeration FPConvOp {FPConvOp_CVT_FtoI, FPConvOp_CVT_ItoF,
  FPConvOp_MOV_FtoI, FPConvOp_MOV_ItoF,
  FPConvOp_CVT_FtoI_US};
Boolean BFXPreferred(bit sf, bit uns, bits(6) imms, bits(6) immr)

integer S = UInt(imms);
integer R = UInt(immr);

// must not match UBFIZ/SBFIX alias
if UInt(imms) < UInt(immr) then
    return FALSE;

// must not match LSR/ASR/LSL alias (imms == 31 or 63)
if imms == sf:'11111' then
    return FALSE;

// must not match UXTx/SXTx alias
if immr == '000000' then
    // must not match 32-bit UXT[BH] or SXT[BH]
    if sf == '0' && imms IN {'000111', '001111'} then
        return FALSE;
    // must not match 64-bit SXT[BHW]
    if sf:uns == '10' && imms IN {'000111', '001111', '011111'} then
        return FALSE;

// must be UBFX/SBFX alias
return TRUE;
// DecodeBitMasks()
// ================
// Decode AArch64 bitfield and logical immediate masks which use a similar encoding structure
// (bits(M), bits(M)) DecodeBitMasks(bit immN, bits(6) imms, bits(6) immr, boolean immediate)
// bits(64) tmask, wmask;
// bits(6) tmask_and, wmask_and;
// bits(6) tmask_or, wmask_or;
// bits(6) levels;

// Compute log2 of element size
// 2^len must be in range [2, M]
// len = HighestSetBit(immN:NOT(imms));
// if len < 1 then UNDEFINED;
// assert M >= (1 << len);

// Determine S, R and S - R parameters
// levels = if len < 1 then ReservedValue();
// assert M >= (1 << len);

// Determine S, R and S - R parameters
// levels = ZeroExtend(Ones(len), 6);

// For logical immediates an all-ones value of S is reserved
// since it would generate a useless all-ones result (many times)
// if immediate && (imms AND levels) == levels then
// ReservedValue(len), 6);

// For logical immediates an all-ones value of S is reserved
// since it would generate a useless all-ones result (many times)
// if immediate && (imms AND levels) == levels then
// UNDEFINED;

S = UInt(imms AND levels);
R = UInt(immr AND levels);
diff = S - R;  // 6-bit subtract with borrow

// From a software perspective, the remaining code is equivalent to:
//   esize = 1 << len;
//   d = UInt(diff<len-1:0>);
//   welem = ZeroExtend(Ones(S + 1), esize);
//   telem = ZeroExtend(Ones(d + 1), esize);
//   wmask = Replicate(ROR(welem, R));
//   tmask = Replicate(telem);
//   return (wmask, tmask);

// Compute "top mask"
// tmask_and = diff<5:0> OR NOT(levels);
// tmask_or = diff<5:0> AND levels;

tmask = Ones(64);
tmask = (tmask
   AND Replicate(Replicate(tmask_and<0>, 1) : Ones(1), 32))
   OR Replicate(Zeroes(1) : Replicate(tmask_or<0>, 1), 32));

// optimization of first step:
// tmask = Replicate(tmask_and<0> : '1', 32);

tmask = (tmask
   AND Replicate(Replicate(tmask_and<1>, 2) : Ones(2), 16))
   OR Replicate(Zeroes(2) : Replicate(tmask_or<1>, 2), 16));

tmask = (tmask
   AND Replicate(Replicate(tmask_and<2>, 4) : Ones(4), 8))
   OR Replicate(Zeroes(4) : Replicate(tmask_or<2>, 4), 8));

tmask = (tmask
   AND Replicate(Replicate(tmask_and<3>, 8) : Ones(8), 4))
   OR Replicate(Zeroes(8) : Replicate(tmask_or<3>, 8), 4));

tmask = (tmask
   AND Replicate(Replicate(tmask_and<4>, 16) : Ones(16), 2))
   OR Replicate(Zeroes(16) : Replicate(tmask_or<4>, 16), 2));
tmask = ((tmask
  AND Replicate(Replicate(tmask_and<5>, 32) : Ones(32), 1))
OR Replicate(Zeros(32) : Replicate(tmask_or<5>, 32), 1));

// Compute "wraparound mask"
wmask_and = immr OR NOT(levels);
wmask_or = immr AND levels;

wmask = Zeros(64);
wmask = (wmask
  AND Replicate(Ones(1) : Replicate(wmask_and<0>, 1), 32))
OR Replicate(Replicate(wmask_or<0>, 1) : Zeros(1), 32));

// optimization of first step:
// wmask = Replicate(wmask_or<0> : '0', 32);
wmask = (wmask
  AND Replicate(Ones(2) : Replicate(wmask_and<1>, 2), 16))
OR Replicate(Replicate(wmask_or<1>, 2) : Zeros(2), 16));
wmask = (wmask
  AND Replicate(Ones(4) : Replicate(wmask_and<2>, 4), 8))
OR Replicate(Replicate(wmask_or<2>, 4) : Zeros(4), 8));
wmask = (wmask
  AND Replicate(Ones(8) : Replicate(wmask_and<3>, 8), 4))
OR Replicate(Replicate(wmask_or<3>, 8) : Zeros(8), 4));
wmask = (wmask
  AND Replicate(Ones(16) : Replicate(wmask_and<4>, 16), 2))
OR Replicate(Replicate(wmask_or<4>, 16) : Zeros(16), 2));
wmask = (wmask
  AND Replicate(Ones(32) : Replicate(wmask_and<5>, 32), 1))
OR Replicate(Replicate(wmask_or<5>, 32) : Zeros(32), 1));

if diff<6> != '0' then // borrow from S - R
  wmask = wmask AND tmask;
else
  wmask = wmask OR tmask;
return (wmask<M-1:0>, tmask<M-1:0>);

---

Library pseudocode for aarch64/intrs/integer/ins-ext/insert/movewide/movewideop/MoveWideOp

```
```
Library pseudocode for aarch64/instrs/integer/logical/movwpreferred/MoveWidePreferred

// MoveWidePreferred()
// ===============
// Return TRUE if a bitmask immediate encoding would generate an immediate
// value that could also be represented by a single MOVZ or MOVN instruction.
// Used as a condition for the preferred MOV<-ORR alias.

boolean MoveWidePreferred(bit sf, bit immN, bits(6) imms, bits(6) immr)

integer S = UInt(imms);
integer R = UInt(immr);
integer width = if sf == '1' then 64 else 32;

// element size must equal total immediate size
if sf == '1' && immN:imms != '1xxxxxx' then
    return FALSE;
if sf == '0' && immN:imms != '00xxxxx' then
    return FALSE;

// for MOVZ must contain no more than 16 ones
if S < 16 then
    // ones must not span halfword boundary when rotated
    return (~R MOD 16) <= (15 - S);

// for MOVN must contain no more than 16 zeros
if S >= width - 15 then
    // zeros must not span halfword boundary when rotated
    return (R MOD 16) <= (S - (width - 15));

return FALSE;

Library pseudocode for aarch64/instrs/integer/shiftrreg/DecodeShift

// DecodeShift()
// =============
// Decode shift encodings

ShiftType DecodeShift(bits(2) op)
    case op of
        when '00'  return ShiftType_LSL;
        when '01'  return ShiftType_LSR;
        when '10'  return ShiftType_ASR;
        when '11'  return ShiftType_ROR;

Library pseudocode for aarch64/instrs/integer/shiftrreg/ShiftReg

// ShiftReg()
// ===========
// Perform shift of a register operand

bits(N) ShiftReg(integer reg, ShiftType type, integer amount)
    bits(N) result = X[reg];
    case type of
        when ShiftType_LSL result = LSL(result, amount);
        when ShiftType_LSR result = LSR(result, amount);
        when ShiftType_ASR result = ASR(result, amount);
        when ShiftType_ROR result = ROR(result, amount);
    return result;

Library pseudocode for aarch64/instrs/integer/shiftrreg/ShiftType

enumeration ShiftType   {ShiftType_LSL, ShiftType_LSR, ShiftType_ASR, ShiftType_ROR};

Library pseudocode for aarch64/instrs/logicalop/LogicalOp

enumeration LogicalOp   {LogicalOp_AND, LogicalOp_EOR, LogicalOp_ORR};
Library pseudocode for aarch64/instrs/memory/memop/MemAtomicOp

```c

Library pseudocode for aarch64/instrs/memory/memop/MemOp

```c
enum MemOp { MemOp_LOAD, MemOp_STORE, MemOp_PREFETCH };```

Library pseudocode for aarch64/instrs/memory/prefetch/Prefetch

```c
// Prefetch()
// =========
// Decode and execute the prefetch hint on ADDRESS specified by PRFOP

Prefetch(bits(64) address, bits(5) prfop)
```

```c
    PrefetchHint hint;
    integer target;
    boolean stream;
    case prfop<4:3> of
    when '00' hint = Prefetch_READ; // PLD: prefetch for load
    when '01' hint = Prefetch_EXEC; // PLI: preload instructions
    when '10' hint = Prefetch_WRITE; // PST: prepare for store
    when '11' return;                    // unallocated hint
    target = UInt(prfop<2:1>);         // target cache level
    stream = (prfop<0> != '0');        // streaming (non-temporal)
    Hint_Prefetch(address, hint, target, stream);
    return;
```

Library pseudocode for aarch64/instrs/system/barriers/barrierop/MemBarrierOp

```c
enum MemBarrierOp {
    MemBarrierOp_DSB, // Data Synchronization Barrier
    MemBarrierOp_DMB, // Data Memory Barrier
    MemBarrierOp_ISB, // Instruction Synchronization Barrier
    MemBarrierOp_SSBB, // Speculative Synchronization Barrier to VA
    MemBarrierOp_PSSBB // Speculative Synchronization Barrier to PA
};
```

Library pseudocode for aarch64/instrs/system/hints/syshintop/SystemHintOp

```c
enum SystemHintOp {
    SystemHintOp_NOP,
    SystemHintOp_YIELD,
    SystemHintOp_WFE,
    SystemHintOp_WFI,
    SystemHintOp_SEV,
    SystemHintOp_SEVL,
    SystemHintOp_ESB,
    SystemHintOp_PSB,
    SystemHintOp_TSB,
    SystemHintOp_BTI, // Speculation Barrier
    SystemHintOp_CSDB
};
```
library pseudocode for aarch64/instrs/system/register/cpsr/pstatefield/PSTATEField

```c
enum PSTATEField {PSTATEField_DAIFSet, PSTATEField_DAIFClr,
                PSTATEField_PAN, // ARMv8.1
                PSTATEField_UAO, // ARMv8.2
                PSTATEField_DIT, // ARMv8.4
                PSTATEField_SP, // PSTATEField_CCS
                PSTATEField_SSBS
             };
```

SystemOp SysOp(bits(3) op1, bits(4) CRn, bits(4) CRm, bits(3) op2)
  case op1:CRn:CRm:op2 of
    when '000 0111 1000 000' return Sys_AT; // S1E1R
    when '100 0111 1000 000' return Sys_AT; // S1E2R
    when '110 0111 1000 000' return Sys_AT; // S1E3R
    when '000 0111 1000 001' return Sys_AT; // S1E1W
    when '100 0111 1000 001' return Sys_AT; // S1E2W
    when '110 0111 1000 001' return Sys_AT; // S1E3W
    when '000 0111 1000 010' return Sys_AT; // S1E0R
    when '000 0111 1000 011' return Sys_AT; // S1E0W
    when '100 0111 1000 100' return Sys_AT; // S12E1R
    when '100 0111 1000 101' return Sys_AT; // S12E1W
    when '100 0111 1000 110' return Sys_AT; // S12E0R
    when '100 0111 1000 111' return Sys_AT; // S12E0W
    when '011 0111 0100 001' return Sys_DC; // ZVA
    when '000 0111 0110 001' return Sys_DC; // IVAC
    when '000 0111 0110 010' return Sys_DC; // ISW
    when '011 0111 0101 001' return Sys_DC; // CVAC
    when '000 0111 1010 001' return Sys_DC; // CSW
    when '000 0111 1011 001' return Sys_DC; // CVAU
    when '000 0111 1110 001' return Sys_DC; // CIVAC
    when '000 0111 1110 010' return Sys_DC; // CISW
    return Sys_SYS;

Library pseudocode for aarch64/instrs/system/sysops/sysop/SystemOp

equation SystemOp {Sys_AT, Sys_DC, Sys_IC, Sys_TLBI, Sys_SYS};
Library pseudocode for aarch64/instrs/vector/arithmetic/binary/uniform/logical/bsl-eor/vbitop/VBitOp

    enumeration VBitOp {VBitOp_VBIF, VBitOp_VBIT, VBitOp_VBSL, VBitOp_VEOR};

Library pseudocode for aarch64/instrs/vector/arithmetic/unary/cmp/compareop/CompareOp


Library pseudocode for aarch64/instrs/vector/logical/immediateop/ImmediateOp


Library pseudocode for aarch64/instrs/vector/reduce/reduceop/Reduce

    // Reduce()
    // =========
    bits(esize) Reduce(ReduceOp op, bits(N) input, integer esize)
        integer half;
        bits(esize) hi;
        bits(esize) lo;
        bits(esize) result;
        if N == esize then
            return input<esize-1:0>;
        half = N DIV 2;
        hi = Reduce(op, input<N-1:half>, esize);
        lo = Reduce(op, input<half-1:0>, esize);
        case op of
            when ReduceOp_FMINNUM
                result = FPMinNum(lo, hi, FPCR);
            when ReduceOp_FMAXNUM
                result = FPMaxNum(lo, hi, FPCR);
            when ReduceOp_FMIN
                result = FPMin(lo, hi, FPCR);
            when ReduceOp_FMAX
                result = FPMax(lo, hi, FPCR);
            when ReduceOp_FADD
                result = FPAdd(lo, hi, FPCR);
            when ReduceOp_ADD
                result = lo + hi;
        return result;

Library pseudocode for aarch64/instrs/vector/reduce/reduceop/ReduceOp

// AArch64.InstructionDevice()
// ---------------------------
// Instruction fetches from memory marked as Device but not execute-never might generate a
// Permission Fault but are otherwise treated as if from Normal Non-cacheable memory.

AddressDescriptor AArch64.InstructionDevice(AddressDescriptor addrdesc, bits(64) vaddress,
                                           bits(52) ipaddress, integer level,
                                           AccType acctype, boolean iswrite, boolean secondstage,
                                           boolean s2fs1walk)

c = ConstrainUnpredictable(Unpredictable_INSTRDEVICE);
assert c IN {Constraint_NONE, ConstraintFAULT};

if c == Constraint_FAULT then
    addrdesc.fault = AArch64.PermissionFault(ipaddress, bit UNKNOWN, level, acctype, iswrite,
                                              secondstage, s2fs1walk);
else
    addrdesc.memattrs.type = MemType_Normal;
    addrdesc.memattrs.inner.attrs = MemAttr_NC;
    addrdesc.memattrs.inner.hints = MemHint_No;
    addrdesc.memattrs.outer = addrdesc.memattrs.inner;
    addrdesc.memattrs.tagged = FALSE;
    addrdesc.memattrs = MemAttrDefaults(addrdesc.memattrs);

return addrdesc;
// AArch64.S1AttrDecode()
// ======================
// Converts the Stage 1 attribute fields, using the MAIR, to orthogonal
// attributes and hints.

MemoryAttributes AArch64.S1AttrDecode(bits(2) SH, bits(3) attr, AccType acctype)

    MemoryAttributes memattrs;
    mair = MAIR[];
    index = 8 * Uint(attr);
    attrfield = mair<index+7:index>;
    memattrs.tagged = FALSE;
    if ((attrfield<7:4> != '0000' && attrfield<7:4> != '1111' && attrfield<3:0> == '0000') ||
        if ((attrfield<7:4> == '0000' && attrfield<3:0> != 'xx00')) then
        // Reserved, maps to an allocated value
        (~, attrfield) = ConstrainUnpredictableBits(Unpredictable_RESMAIR);
        if attrfield<7:4> == '0000' then            // Device
            memattrs.type = MemType_Device;
            case attrfield<3:0> of
                when '0000'  memattrs.device = DeviceType_nGnRnE;
                when '0100'  memattrs.device = DeviceType_nGnRE;
                when '1000'  memattrs.device = DeviceType_nGRE;
                when '1100'  memattrs.device = DeviceType_GRE;
                otherwise Unreachable();         // Reserved, handled above
            elsif attrfield<3:0> != '0000'  then        // Normal
                memattrs.type = MemType_Normal;
                memattrs.outer = LongConvertAttrsHints(attrfield<7:4>, acctype);
                memattrs.inner = LongConvertAttrsHints(attrfield<3:0>, acctype);
                memattrs.shareable = SH<1> == '1';
                memattrs.outershareable = SH == '10';
            elsif HaveMTEExt() && attrfield == '11110000' then // Tagged, Normal
                memattrs.tagged = TRUE;
                memattrs.type = MemType_Normal;
                memattrs.outer.attrs = MemAttr_WB;
                memattrs.inner.attrs = MemAttr_WB;
                memattrs.outer.hints = MemHint_RWA;
                memattrs.inner.hints = MemHint_RWA;
            else Unreachable();                          // Reserved, handled above
        else
            return MemAttrDefaults(memattrs);
    end

Shared Pseudocode Functions
// AArch64.TranslateAddressS1Off()
// ===============================
// Called for stage 1 translations when translation is disabled to supply a default translation.
// Note that there are additional constraints on instruction prefetching that are not described in
// this pseudocode.

TLBRecord AArch64.TranslateAddressS1Off(bits(64) vaddress, AccType acctype, boolean iswrite)
assert !EUUsingAArch32(S1TranslationRegime());

TLBRecord result;

Top = AddrTop(vaddress, (acctype == AccType_IFETCH), PSTATE.EL);
if !IsZero(vaddress<Top:PAMax>()) then
  level = 0;
  ipaddress = bits(52) UNKNOWN;
  secondstage = FALSE;
  s2fs1walk = FALSE;
  result.addrdesc.fault = AArch64.AddressSizeFault(ipaddress,bit UNKNOWN, level, acctype, iswrite, secondstage, s2fs1walk);
  return result;

default_cacheable = (HasS2Translation() && HCR_EL2.DC == '1');
if default_cacheable then
  // Use default cacheable settings
  result.addrdesc.memattrs.type = MemType_Normal;
  result.addrdesc.memattrs.inner.attrs = MemAttr_WB;  // Write-back
  result.addrdesc.memattrs.inner.hints = MemHint_RWA;
  result.addrdesc.memattrs.shareable = FALSE;
  result.addrdesc.memattrs.outershareable = FALSE;
  result.addrdesc.memattrs.tagged = HCR_EL2.DCT == '1';
elsif acctype != AccType_IFETCH then
  // Treat data as Device
  result.addrdesc.memattrs.type = MemType_Device;
  result.addrdesc.memattrs.device = DeviceType_nGnRnE;
  result.addrdesc.memattrs.inner = MemAttrHints UNKNOWN;
  result.addrdesc.memattrs.tagged = FALSE;
else
  // Instruction cacheability controlled by SCTLR_ELx.I
  cacheable = SCTLR[].I == '1';
  result.addrdesc.memattrs.type = MemType_Normal;
  if cacheable then
    result.addrdesc.memattrs.inner.attrs = MemAttr_WT;
    result.addrdesc.memattrs.inner.hints = MemHint_RA;
  else
    result.addrdesc.memattrs.inner.attrs = MemAttr_NC;
    result.addrdesc.memattrs.inner.hints = MemHint_No;
  result.addrdesc.memattrs.shareable = TRUE;
  result.addrdesc.memattrs.outershareable = TRUE;
  result.addrdesc.memattrs.tagged = FALSE;
result.addrdesc.memattrs.outer = result.addrdesc.memattrs.inner;
result.addrdesc.memattrs = MemAttrDefaults(result.addrdesc.memattrs);

result.perms.ap = bits(3) UNKNOWN;
result.perms.xn = '0';
result.perms.pxn = '0';
result.nG = bit UNKNOWN;
result.contiguous = boolean UNKNOWN;
result.domain = bits(4) UNKNOWN;
result.level = integer UNKNOWN;
result.blocksize = integer UNKNOWN;
result.addrdesc.paddress.address = vaddress<51:0>;
result.addrdesc.paddress.NS = if IsSecure() then '0' else '1';
result.addrdesc.fault = AArch64.NoFault();
return result;
boolean AArch64.AccessIsPrivileged(AccType acctype)
{
    el = if () && acctype == AccType_NV2REGISTER then EL1
             AArch64.AccessUsesEL(HaveNV2Ext(acctype))
    else PSTATE_EL1:
        if el == EL0 then
            ispriv = FALSE;
        elsif el == EL3 then
            ispriv = TRUE;
        elsif el == EL2 && !IsInHost() || HCR_EL2.TGE == '0') then
            ispriv = TRUE;
        elsif HaveUAOExt() && PSTATE.UAO == '1' then
            ispriv = TRUE;
        else
            ispriv = (acctype != AccType_UNPRIV);
    return ispriv;
}
// AArch64.AccessUsesEL()
// ---------------------
// Returns the Exception Level of the regime that will manage the translation for a given access type.

// AArch64.CheckPermission()
// ------------------------
// Function used for permission checking from AArch64 stage 1 translations

bits(2) FaultRecord AArch64.AccessUsesEL(AArch64.CheckPermission(Permissions perms, bits(64) vaddress, int bit NS, AccType acctype))

    if acctype == acctype, boolean iswrite
        assert ! AccType UNPRIVUsingAArch32 then
            return S1TranslationRegime();

        wxn = SCTLR[].WXN == '1';

    if PSTATE.EL == EL0
        elsif acctype == AccType DC then
            return || ! ELIsInHost(EL2) then

        priv = TRUE;
        user_r = perms.ap<2> == '0';
        user_w = perms.ap<1> == '1';
        ispriv = AArch64.AccessIsPrivileged(acctype);

        pan = if HavePANExt() then PSTATE.PAN else '0';
        if (EL2Enabled() && ((PSTATE.EL == EL1 && HaveNVExt() && HCR_EL2.<NV, NV1> == '1') || (HaveNVExt() && acctype == AccType NV2REGISTER && HCR_EL2.<NV, NV2> == '1'))) then
            pan = '0';

        if (pan == '1' && user_r && ispriv &&
            (acctype IN {AccType_DC, AccType_AT, AccType_IFETCH})
            || (acctype == AccType_AT && AArch64.ExecutingATS1xPInstr())) then
            priv_r = FALSE;
            priv_w = FALSE;

        user_xn = perms.xn == '1' || (user_w && wxn);
        priv_xn = perms.pxn == '1' || (priv_w && wxn) || user_w;

        if ispriv then
            (r, w, xn) = (priv_r, priv_w, priv_xn);
        else
            (r, w, xn) = (user_r, user_w, user_xn);

    else
        // Access from EL2 or EL3
        r = TRUE;
        w = perms.ap<2> == '0';
        xn = perms.xn == '1' || (w && wxn);

    // Restriction on Secure instruction fetch
    if HaveEL(EL) && IsSecure() && NS == '1' && SCR_EL3.SIF == '1' then
        xn = TRUE;

    if acctype == AccType_IFETCH then
        fail = xn;
        failedread = TRUE;
        elsif acctype IN {AccType_ATOMICRW, AccType_ORDEREDRW} then
            fail = ! r || ! w;
        failedread = ! r;

    else
        fail = ! w;
        failedread = FALSE;

    elsif acctype == AccType_DC then
        if ! iswrite then
            fail = FALSE;
        else
            fail = ! r;

Shared Pseudocode Functions
failedread = TRUE;

if fail then
    secondstage = FALSE;
    s2fswalk = FALSE;
    ipaddress = bits(52) UNKNOWN;
    return AArch64.PermissionFault(ipaddress, bit UNKNOWN, level, acctype, !failedread, secondstage, s2fswalk);
else
    return AArch64.NoFault;
else
    return PSTATE.EL;
Library pseudocode for aarch64/translation/checks/AArch64.CheckPermission AArch64.CheckS2Permission
AArch64.CheckPermission()
// Function used for permission checking from AArch64 stage 1 translations
AArch64.CheckS2Permission()
// Function used for permission checking from AArch64 stage 2 translations

FaultRecord AArch64.CheckPermission(AArch64.CheckS2Permission(Permissions perms, bits(64) vaddress, integer level, AccType acctype, boolean iswrite),
                                        bit NS,perms, bits(64) vaddress, bits(52) ipaddress,
                                        integer level, AccType acctype, boolean iswrite)

assert !acctype, boolean iswrite, bit NS,
boolean s2fs1walk, boolean hwupdatewalk,

assert ELUsingAArch32,IsSecureEL2Enabled(), (S1TranslationRegimeHaveExt());

wxn = SCTLR[].WXN == '1';
if (PSTATE.EL == EL0) ||
    (!IsInHost && ELUsingAArch32) ||
    (PSTATE.EL == 4) ||
    !HaveNV2Ext();

priv_r = TRUE;
priv_w = perms.ap<2> == '0';
user_r = perms.ap<1> == '1';
user_w = perms.ap<2:1> == '01';

ispriv = AArch64.AccessIsPrivilegedHaveS2Translation(acctype);

pan = if priv_r == TRUE;
   priv_w == perms.ap<2> == '0';
   user_r == perms.ap<1> == '1';
   user_w == perms.ap<2:1> == '01';

is_priv = AArch64.AccessIsPrivilegedHaveS2Translation(acctype);

if is_priv then
   (r, w, xn) = (priv_r, priv_w, priv_xn);
else
   (r, w, xn) = (user_r, user_w, user_xn);
else
   // Access from EL2 or EL3
   r = TRUE;
   w = perms.ap<2> == '0';
   xn = perms.xn == '1';

// Restriction on Secure instruction fetch
if HaveEL(3) && IsSecure() && NS == '1' && SCR_EL3.SIF == '1' then
   xn = TRUE;

// Stage 1 walk is checked as a read, regardless of the original type
if acctype == haveNV2Ext() && acctype == AccType_NV2REGISTER && HCR_EL2.NV2 == '1')) then
   pan = '0';
   is_ldst = !(acctype IN {AccType_DC, AccType_DC_UNPRIV, AccType_AT, AccType_IFETCH});
   is_atlsx = (acctype == & AArch64.ExecutingATS1xPInstr());
   if pan == '1' && user_r && ispriv && (is_ldst || is_atlsx) then
      priv_r = FALSE;
      priv_w = FALSE;

   user_xn = perms.xn == '1' || (user_w && wxn);
   priv_xn = perms.pxn == '1' || (priv_w && wxn) || user_w;

   if ispriv then
      (r, w, xn) = (priv_r, priv_w, priv_xn);
   else
      (r, w, xn) = (user_r, user_w, user_xn);
   else
      // Access from EL2 or EL3
      r = TRUE;
      w = perms.ap<2> == '0';
      xn = perms.xn == '1';

// Stage 1 walk is checked as a read, regardless of the original type
if acctype == haveNV2Ext() && acctype == AccType_NV2REGISTER && HCR_EL2.NV2 == '1')) then
   pan = '0';
   is_ldst = !(acctype IN {AccType_DC, AccType_DC_UNPRIV, AccType_AT, AccType_IFETCH});
   is_atlsx = (acctype == & AArch64.ExecutingATS1xPInstr());
   if pan == '1' && user_r && ispriv && (is_ldst || is_atlsx) then
      priv_r = FALSE;
      priv_w = FALSE;

   user_xn = perms.xn == '1' || (user_w && wxn);
   priv_xn = perms.pxn == '1' || (priv_w && wxn) || user_w;

   if ispriv then
      (r, w, xn) = (priv_r, priv_w, priv_xn);
   else
      (r, w, xn) = (user_r, user_w, user_xn);
   else
      // Access from EL2 or EL3
      r = TRUE;
      w = perms.ap<2> == '0';
      xn = perms.xn == '1';

// Restriction on Secure instruction fetch
if HaveEL(3) && IsSecure() && NS == '1' && SCR_EL3.SIF == '1' then
   xn = TRUE;
if acctype == AccType_IFETCH then
  fail = xn;
  failedread = TRUE;
elsif acctype IN {AccType_ATOMICRW, AccType_ORDEREDRW, AccType_ORDEREDATOMICRW} then
  fail = !r || !w;
  failedread = !r;
elsif iswrite then
  fail = !w;
  failedread = FALSE;
elsif acctype == AccType_DC && PSTATE.EL != EL0 then
  fail = FALSE;
  if !s2fs1walk then
    fail = !r || !w;
    failedread = !r;
    elsif iswrite && !s2fs1walk then
      fail = !w;
    failedread = !iswrite;
  else
    failedread = TRUE;
  end;
  if fail then
    secondstage = FALSE;
    s2fs1walk = FALSE;
    ipaddress = bits(52) UNKNOWN;
    domain = bits(4) UNKNOWN;
    secondstage = TRUE;
    return AArch64.PermissionFault(ipaddress, bit UNKNOWN, level, acctype, !failedread, secondstage, s2fs1walk);
else
  return AArch64.NoFault();
library pseudocode for aarch64/translation/checks/AArch64.CheckS2Permission

// AArch64.CheckS2Permission()
// ==================================
// Function used for permission checking from AArch64 stage 2 translations

FaultRecord AArch64.CheckS2Permission(Permissions perms, bits(64) vaddress, bits(52) ipaddress, integer level, AccType acctype, boolean iswrite, bit NS, boolean s2fs1walk, boolean hwupdatewalk)

assert IsSecureEL2Enabled() || (HaveEL(EL2) && !IsSecure() && !ELUsingAArch32(EL2)) && HasS2Translation();

r = perms.ap<1> == '1';
w = perms.ap<2> == '1';
Venta

if HaveExtendedExecuteNeverExt() then
    case perms.xn:perms.xxn of
        when '00' xn = FALSE;
        when '01' xn = PSTATE.EL == EL1;
        when '10' xn = TRUE;
        when '11' xn = PSTATE.EL == EL0;
    else
        xn = perms.xn == '1';
    end
else
    xn = perms.xn == '1';
end

if stage 1 walk is checked as a read, regardless of the original type
if acctype == AccType_IFETCH && !s2fs1walk then
    fail = xn;
    failedread = TRUE;
elsif (acctype IN {AccType_ATOMICRW, AccType_ORDEREDRW, AccType_ORDERED_ATOMICRW }) && !s2fs1walk then
    fail = !r || !w;
    failedread = !r;
elsif iswrite && !s2fs1walk then
    fail = !w;
    failedread = FALSE;
elsif acctype == AccType_DC && PSTATE.EL != EL0 && !s2fs1walk then
    // DC maintenance instructions operating by VA, with the exception of DC IVAC, do
    // not generate Permission faults from stage 2 translation, other than when
    // performing a stage 1 translation table walk.
    fail = FALSE;
elsif hwupdatewalk then
    fail = !w;
    failedread = !iswrite;
else
    fail = !r;
    failedread = !iswrite;
endif

if fail then
    domain = bits(4) UNKNOWN;
    secondstage = TRUE;
    return AArch64.PermissionFault(ipaddress,NS, level, acctype,
        !failedread, secondstage, s2fs1walk);
else
    return AArch64.NoFault();
end
Library pseudocode for aarch64/translation/debug/AArch64.CheckBreakpoint

```c
// AArch64.CheckBreakpoint()
// ------------------------
// Called before executing the instruction of length "size" bytes at "vaddress" in an AArch64
// translation regime.
// The breakpoint can in fact be evaluated well ahead of execution, for example, at instruction
// fetch. This is the simple sequential execution of the program.

FaultRecord AArch64.CheckBreakpoint(bits(64) vaddress, AccType acctype, integer size)
        assert !ELUsingAArch32(SITranslationRegime());
        assert (UsingAArch32() && size IN {2,4}) || size == 4;
        match = FALSE;
        for i = 0 to UInt(ID_AA64DFR0_EL1.BRPs)
            match_i = AArch64.BreakpointMatch(i, vaddress, acctype, size);
            match = match || match_i;
        if match && HaltOnBreakpointOrWatchpoint() then
            reason = DebugHalt_Breakpoint;
            Halt(reason);
        elsif match && MDSCR_EL1.MDE == '1' && AArch64.GenerateDebugExceptions() then
            acctype = AccType_IFETCH;
            iswrite = FALSE;
            return AArch64.DebugFault(acctype, iswrite);
        else
            return AArch64.NoFault();
```

Library pseudocode for aarch64/translation/debug/AArch64.CheckDebug

```c
// AArch64.CheckDebug()
// ---------------------
// Called on each access to check for a debug exception or entry to Debug state.

FaultRecord AArch64.CheckDebug(bits(64) vaddress, AccType acctype, boolean iswrite, integer size)
        FaultRecord fault = AArch64.NoFault();
        d_side = (acctype != AccType_IFETCH);
        generate_exception = AArch64.GenerateDebugExceptions() && MDSCR_EL1.MDE == '1';
        halt = HaltOnBreakpointOrWatchpoint();
        if generate_exception || halt then
            if d_side then
                fault = AArch64.CheckWatchpoint(vaddress, acctype, iswrite, size);
            else
                fault = AArch64.CheckBreakpoint(vaddress, acctype, size);
            return fault;
```
// AArch64.CheckWatchpoint()
// =========================
// Called before accessing the memory location of "size" bytes at "address".

FaultRecord AArch64.CheckWatchpoint(bits(64) vaddress, AccType acctype, boolean iswrite, integer size)
assert !ELUsingAArch32(S1TranslationRegime());

match = FALSE;
ispriv = AArch64.AccessIsPrivileged(acctype);

for i = 0 to UInt(ID_AA64DFR0_EL1.WRPs)
match = match || AArch64.WatchpointMatch(i, vaddress, size, ispriv, acctype, iswrite);

if match && HaltOnBreakpointOrWatchpoint() then
    if acctype != AccType_NONFAULT && acctype != AccType_CNOTFIRST then
        reason = DebugHalt_Watchpoint;
        Halt(reason);
    else
        // Fault will be reported and cancelled
        return AArch64.DebugFault(acctype, iswrite);
    endif
else
    if MDSCR_EL1.MDE == '1' && AArch64.GenerateDebugExceptions() then
        return AArch64.DebugFault(acctype, iswrite);
    else
        return AArch64.NoFault();
    endif
endif

Library pseudocode for aarch64/translation/faults/AArch64.AccessFlagFault

// AArch64.AccessFlagFault()
// =========================

FaultRecord AArch64.AccessFlagFault(bits(52) ipaddress,bit NS, integer level, AccType acctype, boolean iswrite, boolean secondstage, boolean s2fs1walk)

extflag = bit UNKNOWN;
errortype = bits(2) UNKNOWN;
return AArch64.CreateFaultRecord(Fault_AccessFlag, ipaddress, NS, level, acctype, iswrite, extflag, errortype, secondstage, s2fs1walk);

Library pseudocode for aarch64/translation/faults/AArch64.AddressSizeFault

// AArch64.AddressSizeFault()
// =========================

FaultRecord AArch64.AddressSizeFault(bits(52) ipaddress,bit NS, integer level, AccType acctype, boolean iswrite, boolean secondstage, boolean s2fs1walk)

extflag = bit UNKNOWN;
errortype = bits(2) UNKNOWN;
return AArch64.CreateFaultRecord(Fault_AddressSize, ipaddress, NS, level, acctype, iswrite, extflag, errortype, secondstage, s2fs1walk);
Library pseudocode for aarch64/translation/faults/AArch64.AlignmentFault

// AArch64.AlignmentFault()
// -------------------------

FaultRecord AArch64.AlignmentFault(AccType acctype, boolean iswrite, boolean secondstage) {
    ipaddress = bits(52) UNKNOWN;
    level = integer UNKNOWN;
    extflag = bit UNKNOWN;
    errortype = bits(2) UNKNOWN;
    s2fs1walk = boolean UNKNOWN;

    return AArch64.CreateFaultRecord(Fault_Alignment, ipaddress, bit UNKNOWN, level, acctype, iswrite, extflag, errortype, secondstage, s2fs1walk);
}

Library pseudocode for aarch64/translation/faults/AArch64.AsynchExternalAbort

// AArch64.AsynchExternalAbort()
// -----------------------------

// Wrapper function for asynchronous external aborts

FaultRecord AArch64.AsynchExternalAbort(boolean parity, bits(2) errortype, bit extflag) {
    type = if parity then Fault_AsyncParity else Fault_AsyncExternal;
    ipaddress = bits(52) UNKNOWN;
    level = integer UNKNOWN;
    acctype = AccType_NORMAL;
    iswrite = boolean UNKNOWN;
    secondstage = FALSE;
    s2fs1walk = FALSE;

    return AArch64.CreateFaultRecord(type, ipaddress, bit UNKNOWN, level, acctype, iswrite, extflag, errortype, secondstage, s2fs1walk);
}

Library pseudocode for aarch64/translation/faults/AArch64.DebugFault

// AArch64.DebugFault()
// ---------------------

FaultRecord AArch64.DebugFault(AccType acctype, boolean iswrite) {
    ipaddress = bits(52) UNKNOWN;
    errortype = bits(2) UNKNOWN;
    level = integer UNKNOWN;
    extflag = bit UNKNOWN;
    secondstage = FALSE;
    s2fs1walk = FALSE;

    return AArch64.CreateFaultRecord(Fault_Debug, ipaddress, bit UNKNOWN, level, acctype, iswrite, extflag, errortype, secondstage, s2fs1walk);
}
Library pseudocode for aarch64/translation/faults/AArch64.NoFault

```plaintext
// AArch64.NoFault()
// ------------------
FaultRecord AArch64.NoFault()
    ipaddress = bits(52) UNKNOWN;
    level = integer UNKNOWN;
    acctype = AccType.NORMAL;
    iswrite = boolean UNKNOWN;
    extflag = bit UNKNOWN;
    errortype = bits(2) UNKNOWN;
    secondstage = FALSE;
    s2fs1walk = FALSE;
    return AArch64.CreateFaultRecord(Fault_None, ipaddress, bit UNKNOWN, level, acctype, iswrite,
                                      extflag, errortype, secondstage, s2fs1walk);
```

Library pseudocode for aarch64/translation/faults/AArch64.PermissionFault

```plaintext
// AArch64.PermissionFault()
// -------------------------
FaultRecord AArch64.PermissionFault(bits(52) ipaddress, bit NS, integer level,    AccType acctype, boolean iswrite, boolean secondstage, boolean s2fs1walk)
    extflag = bit UNKNOWN;
    errortype = bits(2) UNKNOWN;
    return AArch64.CreateFaultRecord(Fault_Permission, ipaddress, NS, level, acctype, iswrite,
                                      extflag, errortype, secondstage, s2fs1walk);
```

Library pseudocode for aarch64/translation/faults/AArch64.TranslationFault

```plaintext
// AArch64.TranslationFault()
// ---------------------------
FaultRecord AArch64.TranslationFault(bits(52) ipaddress, bit NS, integer level,    AccType acctype, boolean iswrite, boolean secondstage, boolean s2fs1walk)
    extflag = bit UNKNOWN;
    errortype = bits(2) UNKNOWN;
    return AArch64.CreateFaultRecord(Fault_Translation, ipaddress, NS, level, acctype, iswrite,
                                      extflag, errortype, secondstage, s2fs1walk);
```
Library pseudocode for aarch64/translation/translation/AArch64.CheckAndUpdateDescriptor
AArch64.CheckAndUpdateDescriptor()  
// Check and update translation table descriptor if hardware update is configured

FaultRecord AArch64.CheckAndUpdateDescriptor(DescriptorUpdate result, FaultRecord fault,  
boolean secondstage, bits(64) vaddress, AccType accctype,  
boolean iswrite, boolean s2fs1walk, boolean hwupdatewalk)

// Check if access flag can be updated  
// Address translation instructions are permitted to update AF but not required
if result.AF then
  if fault.type == Fault_None then
    hw_update_AF = TRUE;
  elsif ConstrainUnpredictable(Unpredictable_AFUPDATE) == Constraint_TRUE then
    hw_update_AF = TRUE;
  else
    hw_update_AF = FALSE;
if result.AP && fault.type == Fault_None then
  write_perm_req = (iswrite || accctype IN {AccType_ATOMICRW,AccType_ORDEREDRW}) && !s2fs1walk;
  hw_update_AP = (write_perm_req && !(accctype IN {AccType_ATOMICRW,AccType_ORDEREDATOMICRW})) && !s2fs1walk;
else
  hw_update_AP = FALSE;

if hw_update_AF || hw_update_AP then
  if secondstage || !AccType_DC_UNPRIV) || hwupdatewalk;
else
  hw_update_AP = FALSE;

if hw_update_AF || hw_update_AP then
  if secondstage || HasS2Translation() then
    descaddr2 = result.descaddr;
  else
    hwupdatewalk = TRUE;
    descaddr2 = AArch64.SecondStageWalk(result.descaddr, vaddress, accctype, iswrite, 8, hwupdatewalk);
  if IsFault(descaddr2) then
    return descaddr2.fault;

accdesc = CreateAccessDescriptor();  
accdesc = CreateAccessDescriptor(AccType_ATOMICRW);
desc = _Mem[descaddr2, 8, accdesc];
el = AArch64.AccessUsesEL(accctype);
case el of
  when EL3  
    reversedescriptors = SCTLR_EL3.EE == '1';
  when EL2  
    reversedescriptors = SCTLR_EL2.EE == '1';
  otherwise
    reversedescriptors = SCTLR_EL1.EE == '1';
if reversedescriptors then
  desc = BigEndianReverse(desc);

if hw_update_AF then
  desc<10> = '1';
if hw_update_AP then
  desc<7> = (if secondstage then '1' else '0');
_Mem[descaddr2,8,accdesc] = if reversedescriptors then BigEndianReverse(desc) else desc;

return fault;
// AArch64.FirstStageTranslate()
// =-----------------------------
// Perform a stage 1 translation walk. The function used by Address Translation operations is
// similar except it uses the translation regime specified for the instruction.

AddressDescriptor AArch64.FirstStageTranslate(bits(64) vaddress, AccType acctype, boolean iswrite, boolean wasaligned, integer size)

if HaveNV2Ext() && acctype == AccType_NV2REGISTER then
    s1_enabled = SCTLR_EL2.M == '1';
elsif HasS2Translation() then
    s1_enabled = HCR_EL2.TGE == '0' && HCR_EL2.DC == '0' && SCTLR_EL1.M == '1';
else
    s1_enabled = SCTLR[].M == '1';

ipaddress = bits(52) UNKNOWN;
secondstage = FALSE;
s2fs1walk = FALSE;
if s1_enabled then                         // First stage enabled
    S1 = AArch64.TranslationTableWalk(ipaddress, '1', vaddress, acctype, iswrite, secondstage, s2fs1walk, size);
    permissioncheck = TRUE;
    if acctype == AccType_IFETCH then
        InGuardedPage = S1.GP == '1';      // Global state updated on instruction fetch that denotes
    // if the fetched instruction is from a guarded page.
    else
        S1 = AArch64.TranslateAddressS1Off(vaddress, acctype, iswrite);
    permissioncheck = FALSE;
    if UsingAArch32() && HaveTrapLoadStoreMultipleDeviceExt() && AArch32.ExecutingLSMInstr() then
        if S1.addrdesc.memattrs.type == MemType_Device && S1.addrdesc.memattrs.device != DeviceType_GRE then
            nTLSMD = if S1TranslationRegime() == EL2 then SCTLR_EL2.nTLSMD else SCTLR_EL1.nTLSMD;
            if nTLSMD == '0' then
                S1.addrdesc.fault = AArch64.AlignmentFault(acctype, iswrite, secondstage);
            if !IsFault(S1.addrdesc) && permissioncheck then
                S1.addrdesc.fault = AArch64.CheckPermission(S1.perms, vaddress, S1.level, S1.addrdesc.paddress.NS, acctype, iswrite);
            if !IsFault(S1.addrdesc) && S1.addrdesc.memattrs.type == MemType_Device && acctype == AccType_IFETCH then
                S1.addrdesc = AArch64.InstructionDevice(S1.addrdesc, vaddress, ipaddress, S1.level, acctype, iswrite, secondstage, s2fs1walk);
            if !IsFault(S1.addrdesc) && S1.addrdesc.memattrs.type == MemType_Device && acctype == AccType_IFETCH then
                S1.addrdesc = AArch64.InstructionDevice(S1.addrdesc, vaddress, ipaddress, S1.level, acctype, iswrite, secondstage, s2fs1walk, hwupdatewalk);
            // Check for unaligned data accesses to Device memory
            if (!wasaligned && acctype != AccType_IFETCH) || (acctype == AccType_DCZVA) && S1.addrdesc.memattrs.type == MemType_Device && !IsFault(S1.addrdesc) then
                S1.addrdesc.fault = AArch64.AlignmentFault(acctype, iswrite, secondstage);
        // Check for instruction fetches from Device memory not marked as execute-never. If there has not been a Permission Fault then the memory is not marked execute-never.
        if (!IsFault(S1.addrdesc) && S1.addrdesc.memattrs.type == MemType_Device && acctype == AccType_IFETCH) then
            S1.addrdesc = AArch64.InstructionDevice(S1.addrdesc, vaddress, ipaddress, S1.level, acctype, iswrite, secondstage, s2fs1walk);
            // Check and update translation table descriptor if required
            hwupdatewalk = FALSE;
            s2fs1walk = FALSE;
            S1.addrdesc.fault = AArch64.CheckAndUpdateDescriptor(S1.descupdate, S1.addrdesc.fault, secondstage, vaddress, acctype, iswrite, s2fs1walk, hwupdatewalk);
        return S1.addrdesc;
Library pseudocode for aarch64/translation/translation/AArch64.FullTranslate

// AArch64.FullTranslate()
// =======================
// Perform both stage 1 and stage 2 translation walks for the current translation regime. The
// function used by Address Translation operations is similar except it uses the translation
// regime specified for the instruction.

AddressDescriptor AArch64.FullTranslate(bits(64) vaddress, AccType acctype, boolean iswrite,
    boolean wasaligned, integer size)

    // First Stage Translation
    S1 = AArch64.FirstStageTranslate(vaddress, acctype, iswrite, wasaligned, size);
    if !IsFault(S1) && !HaveNV2Ext() && acctype == AccType_NV2REGISTER) && HasS2Translation() then
        s2fs1walk = FALSE;
        hwupdatewalk = FALSE;
        result = AArch64.SecondStageTranslate(S1, vaddress, acctype, iswrite, wasaligned, s2fs1walk,
            size, hwupdatewalk);
    else
        result = S1;
    return result;
// AArch64.SecondStageTranslate()
// ==============================
// Perform a stage 2 translation walk. The function used by Address Translation operations is
// similar except it uses the translation regime specified for the instruction.

AddressDescriptor AArch64.SecondStageTranslate(AddressDescriptor S1, bits(64) vaddress,
    AccType acctype, boolean iswrite, boolean wasaligned,
    boolean s2fs1walk, integer size, boolean hwupdatewalk)

assert HasS2Translation();

s2_enabled = HCR_EL2.VM == '1' || HCR_EL2.DC == '1';
secondstage = TRUE;

if s2_enabled then // Second stage enabled
  ipaddress = S1.paddress.address<51:0>;
  NS = S1.paddress.NS;
  S2 = AArch64.TranslationTableWalk(ipaddress, NS, vaddress, acctype, iswrite, secondstage,
                                   s2fs1walk, size);

  // Check for unaligned data accesses to Device memory
  if ((!wasaligned && acctype != AccType_IFETCH) || (acctype == AccType_DCZVA)
      && S2.addrdesc.memattrs.type == MemType_Device && !IsFault(S2.addrdesc) then
    S2.addrdesc.fault = AArch64.AlignmentFault(acctype, iswrite, secondstage);

  // Check for permissions on Stage2 translations
  if !IsFault(S2.addrdesc) then
    S2.addrdesc.fault = AArch64.CheckS2Permission(S2.perms, vaddress, ipaddress, S2.level,
                                                 acctype, iswrite, NS,s2fs1walk, hwupdatewalk);

  // Check for instruction fetches from Device memory not marked as execute-never. As there
  // has not been a Permission Fault then the memory is not marked execute-never.
  if (!s2fs1walk && !IsFault(S2.addrdesc) && S2.addrdesc.memattrs.type == MemType_Device
      && acctype == AccType_IFETCH) then
    S2.addrdesc = AArch64.InstructionDevice(S2.addrdesc, vaddress, ipaddress, S2.level,
                                             acctype, iswrite,
                                             secondstage, s2fs1walk);

  // Check for protected table walk
  if (s2fs1walk && !IsFault(S2.addrdesc) && HCR_EL2.PTW == '1' &&
    S2.addrdesc.memattrs.type == MemType_Device) then
    S2.addrdesc.fault = AArch64.PermissionFault(ipaddress, S1.paddress.NS, S2.level, acctype,
                                               iswrite, secondstage, s2fs1walk);

  // Check and update translation table descriptor if required
  S2.addrdesc.fault = AArch64.CheckAndUpdateDescriptor(S2.descupdate, S2.addrdesc.fault,
                                           secondstage, vaddress, acctype,
                                           iswrite, s2fs1walk, hwupdatewalk);

result = CombineS1S2Desc(S1, S2.addrdesc);
else
  result = S1;

return result;
// AArch64.SecondStageWalk()
// ---------------------------------------
// Perform a stage 2 translation on a stage 1 translation page table walk access.

AddressDescriptor AArch64.SecondStageWalk(AddressDescriptor S1, bits(64) vaddress, AccType acctype, boolean iswrite, integer size, boolean hwupdatewalk)

    assert HasS2Translation();
    s2fs1walk = TRUE;
    wasaligned = TRUE;
    return AArch64.SecondStageTranslate(S1, vaddress, acctype, iswrite, wasaligned, s2fs1walk, size, hwupdatewalk);

// AArch64.TranslateAddress()
// ---------------------------
// Main entry point for translating an address

AddressDescriptor AArch64.TranslateAddress(bits(64) vaddress, AccType acctype, boolean iswrite, boolean wasaligned, integer size)

    result = AArch64.FullTranslate(vaddress, acctype, iswrite, wasaligned, size);
    if !(acctype IN {AccType_PTW, AccType_IC, AccType_AT}) && !IsFault(result) then
        result.fault = AArch64.CheckDebug(vaddress, acctype, iswrite, size);
    // Update virtual address for abort functions
    result.vaddress = ZeroExtend(vaddress);
    return result;
AArch64.TranslationTableWalk()
// ==============================================================
// Returns a result of a translation table walk
//
// Implementations might cache information from memory in any number of non-coherent TLB
// caching structures, and so avoid memory accesses that have been expressed in this
// pseudocode. The use of such TLBs is not expressed in this pseudocode.

TLBRecord AArch64.TranslationTableWalk(bits(52) ipaddress, bit s1_nonsecure, bits(64) vaddress, AccType acctype, boolean iswrite, boolean secondstage, boolean s2fs1walk, integer size)

if !secondstage then
  assert !ELUsingAArch32(S1TranslationRegime());
else
  assert IsSecureEL2Enabled() || (HaveEL(EL2) && !IsSecure() && !ELUsingAArch32(EL2) && HasSTT());

TLBRecord result;
AddressDescriptor descaddr;
bits(64) baseregister;
bits(64) inputaddr; // Input Address is 'vaddress' for stage 1, 'ipaddress' for stage 2

descaddr.memattrs.type = MemType_Normal;

// Derived parameters for the page table walk:
// grainsize = Log2(Size of Table)         - Size of Table is 4KB, 16KB or 64KB in AArch64
// stride = Log2(Address per Level)        - Bits of address consumed at each level
// firstblocklevel = First level where a block entry is allowed
// ps = Physical Address size as encoded in TCR_EL1.IPS or TCR_ELx/VTCR_EL2.PS
// inputsize = Log2(Size of Input Address) - Input Address size in bits
// level = Level to start walk from
// This means that the number of levels after start level = 3-level

if !secondstage then
  // First stage translation
  inputaddr = ZeroExtend(vaddress);
  el = if AArch64.AccessUsesELHaveNU2Ext(acctype);
  top = if acctype == AccType_NV2REGISTER then EL2 else PSTATE.EL;
  top = AddrTop(inputaddr, (acctype == AccType_IFETCH), el);
  if el == EL3 then
    largegrain = TCR_EL3.TG0 == '01';
    midgrain = TCR_EL3.TG0 == '10';
    inputsize = 64 - Uint(TCR_EL3.T0SZ);
  else
    inputsize_max = if Have52BitVAExt() && largegrain then 52 else 48;
    inputsize_min = 64 - (if !HaveSmallPageTblExt() then 39 else if largegrain then 47 else 48);
  if inputsize > inputsize_max then
    c = ConstrainsUnpredictable(Unexpected_RESTnSZ);
    assert c IN {Constraint_FORCE, Constraint_FAULT};
    if c == Constraint_FORCE then inputsize = inputsize_max;
  if inputsize < inputsize_min then
    c = ConstrainsUnpredictable(Unexpected_RESTnSZ);
    assert c IN {Constraint_FORCE, Constraint_FAULT};
    if c == Constraint_FORCE then inputsize = inputsize_min;
  ps = TCR_EL3.PS;
  basefound = inputsize >= inputsize_min && inputsize <= inputsize_max && IsZero(inputaddr<top:inputsize>);
  disabled = FALSE;
  baseregister = TTBR0_EL3;
  descaddr.memattrs = WalkAttrDecode(TCR_EL3.SH0, TCR_EL3.ORGN0, TCR_EL3.IRGN0, secondstage);
  reversedescriptors = SCTLR_EL3.EE == '1';
  lookupsecure = TRUE;
  singlepriv = TRUE;
  update_AF = HaveAccessFlagUpdateExt() && TCR_EL3.HA == '1';
  update_AP = HaveDirtyBitModifierExt() && update_AF && TCR_EL3.HD == '1';
  hierattrdisenabled = AArch64(HaveHPDExt()) && TCR_EL3.HPD == '1';
elsif ELIsInHost(el) then
  if inputaddr<top> == '0' then
    largegrain = TCR_EL2.TG0 == '01';
    midgrain = TCR_EL2.TG0 == '10';
    inputsize = 64 - Uint(TCR_EL2.TOSZ);
  inputsize_max = if Have52BitVAExt() && largegrain then 52 else 48;
  inputsize_min = 64 - (if !HaveSmallPageTblExt() then 39 else if largegrain then 47 else 48);
inputsize_min = 64 - (if ! HaveSmallPageTblExt() then 39 else if largegrain then 47 else 48);
if inputsize > inputsize_max then
    c = ConstrainsUnpredictable(Unpredictable_RESTnSZ);
    assert c IN {Constraint_FORCE, Constraint_FAULT};
    if c == Constraint_FORCE then inputsize = inputsize_max;
    inputsize > inputsize_max then
    c = ConstrainsUnpredictable(Unpredictable_RESTnSZ);
    assert c IN {Constraint_FORCE, Constraint_FAULT};
    if c == Constraint_FORCE then inputsize = inputsize_max;
    basefound = inputsize >= inputsize_min && inputsize <= inputsize_max && IsZero(inputaddr<top:inputsize>);
    disabled = TCR_EL2.EPD0 == '1' || (PSTATE.EL == disabled = TCR_EL2.EPD0 == '1';
    baseregister = TTBR0_EL2;
    descaddr.memattrs = EL0 && HaveE0PDExt() && TCR_EL2.E0PD0 == '1';
    baseregister = TTBR0_EL2;
    descaddr.memattrs = WalkAttrDecode(TCR_EL2.SH0, TCR_EL2.ORGN0, TCR_EL2.IRGN0, secondstage);
    hierattrdisabled = AArch64.HaveHPDExt() && TCR_EL2.HPD0 == '1';
else
    inputsize = 64 - UInt(TCR_EL2.T1SZ);
    largegrain = TCR_EL2.TG1 == '1'; // TGl and TG0 encodings differ
    midgrain = TCR_EL2.TG1 == '01';
inputsize_max = if inputsize_max = (if ! Have52BitVAExt() && largegrain then 52 else 48);
if inputsize > inputsize_max then
    c = ConstrainsUnpredictable(Unpredictable_RESTnSZ);
    assert c IN {Constraint_FORCE, Constraint_FAULT};
    if c == Constraint_FORCE then inputsize = inputsize_max;
    inputsize_min = 64 - (if ! HaveSmallPageTblExt() then 39 else if largegrain then 47 else 48);
if inputsize < inputsize_min then
    c = ConstrainsUnpredictable(Unpredictable_RESTnSZ);
    assert c IN {Constraint_FORCE, Constraint_FAULT};
    if c == Constraint_FORCE then inputsize = inputsize_min;
    basefound = inputsize >= inputsize_min && inputsize <= inputsize_max && IsOnes(inputaddr<top:inputsize>);
    disabled = TCR_EL2.EPD1 == '1' || (PSTATE.EL == disabled = TCR_EL2.EPD1 == '1';
    baseregister = TTBR1_EL2;
    descaddr.memattrs = EL0 && HaveE0PDExt() && TCR_EL2.E0PD1 == '1';
    baseregister = TTBR1_EL2;
    descaddr.memattrs = WalkAttrDecode(TCR_EL2.SH1, TCR_EL2.ORGN1, TCR_EL2.IRGN1, secondstage);
    hierattrdisabled = AArch64.HaveHPDExt() && TCR_EL2.HPD1 == '1';
else if el == EL2 then
    inputsize = 64 - UInt(TCR_EL2.T0SZ);
    largegrain = TCR_EL2.TG0 == '01';
    midgrain = TCR_EL2.TG0 == '10';
inputsize_max = if inputsize_max = (if ! Have52BitVAExt() && largegrain then 52 else 48);
if inputsize > inputsize_max then
    c = ConstrainsUnpredictable(Unpredictable_RESTnSZ);
    assert c IN {Constraint_FORCE, Constraint_FAULT};
    if c == Constraint_FORCE then inputsize = inputsize_max;
    inputsize_min = 64 - (if ! HaveSmallPageTblExt() then 39 else if largegrain then 47 else 48);
if inputsize < inputsize_min then
    c = ConstrainsUnpredictable(Unpredictable_RESTnSZ);
    assert c IN {Constraint_FORCE, Constraint_FAULT};
    if c == Constraint_FORCE then inputsize = inputsize_min;
    ps = TCR_EL2.PS;
    reversedescriptors = SCTLR_EL2.EE == '1';
    lookupsecure = if IsSecureEL2Enabled() then IsSecure() else FALSE;
    singlepriv = FALSE;
    update_AF = HaveAccessFlagUpdateExt() && TCR_EL2.HA == '1';
    update_AP = HaveDirtyBitModifierExt() && update_AF && TCR_EL2.HD == '1';
elsif el == EL2 then
    inputsize = 64 - UInt(TCR_EL2.TOSZ);
    largegrain = TCR_EL2.TG0 == '01';
    midgrain = TCR_EL2.TG0 == '10';
inputsize_max = if inputsize_max = (if ! Have52BitVAExt() && largegrain then 52 else 48);
if inputsize > inputsize_max then
    c = ConstrainsUnpredictable(Unpredictable_RESTnSZ);
    assert c IN {Constraint_FORCE, Constraint_FAULT};
    if c == Constraint_FORCE then inputsize = inputsize_max;
    inputsize_min = 64 - (if ! HaveSmallPageTblExt() then 39 else if largegrain then 47 else 48);
if inputsize < inputsize_min then
    c = ConstrainsUnpredictable(Unpredictable_RESTnSZ);
    assert c IN {Constraint_FORCE, Constraint_FAULT};
    if c == Constraint_FORCE then inputsize = inputsize_min;
    ps = TCR_EL2.PS;
    reversedescriptors = SCTLR_EL2.EE == '1';
    lookupsecure = if IsSecureEL2Enabled() then IsSecure() else FALSE;
    singlepriv = TRUE;
    update_AF = HaveAccessFlagUpdateExt() && TCR_EL2.HA == '1';
    update_AP = HaveDirtyBitModifierExt() && update_AF && TCR_EL2.HD == '1';
hierattrsdisabled = AArch64.HaveHPDExt() && TCR_EL2.HPD == '1';
else
    if inputaddr<top:2 == '0' then
        inputsize = 64 - UInt(TCR_EL1.T0SZ);
        largegrain = TCR_EL1.TG0 == '01';
        midgrain = TCR_EL1.TG0 == '10';
    else
        if inputsize < top:inputsize == '0' then
            inputsize = 64 - (if Have52BitVAExt() && largegrain then 52 else 48);
            largegrain = TCR_EL1.TG1 == '11'; // TG1 and TG0 encodings differ
            midgrain = TCR_EL1.TG1 == '01';
            inputsize_max = if inputsize_max = (if Have52BitVAExt() && largegrain then 52 else 48;
            inputsize_min = 64 - (if ! HaveSmallPageTblExt() then 39 else if largegrain then 47 else 48);
            if inputsize > inputsize_max then
                c = ConstrainUnpredictable(Unpredictable_RESTnSZ);
                assert c IN {Constraint_FORCE, Constraint_FAULT};
                if c == Constraint_FORCE then inputsize = inputsize_max;
            inputsize_min = 64 - (if ! HaveSmallPageTblExt() then 39 else if largegrain then 47 else 48);
            if inputsize < inputsize_min then
                c = ConstrainUnpredictable(Unpredictable_RESTnSZ);
                assert c IN {Constraint_FORCE, Constraint_FAULT};
                if c == Constraint_FORCE then inputsize = inputsize_min;
            basefound = inputsize >= inputsize_min && inputsize <= inputsize_max &&
            IsZero(inputaddr<top:inputsize>);
            disabled = TCR_EL1.EPD0 == '1' || (PSTATE.EL ==
            disabled = TCR_EL1.EPD0 == '1';
            disabled = disabled || (el == EL0 && acctype ==
            disabled = disabled || (el == EL0 && acctype ==
            disabled = disabled || (el == EL0 && acctype ==
            disabled = disabled || (el == EL0 && acctype ==
            baseregister = TTBR1_EL1;
            descaddr.memattrs = WalkAttrDecode(TCR_EL1.SH1, TCR_EL1.ORGN1, TCR_EL1.IRGN1, secondstage);
            hierattrsdisabled = AArch64.HaveHPDExt() && TCR_EL1.HPD0 == '1';
else
    inputsize = 64 - UInt(TCR_EL1.T1SZ);
    largegrain = TCR_EL1.TG1 == '11'; // TG1 and TG0 encodings differ
    midgrain = TCR_EL1.TG1 == '01';
    inputsize_max = if inputsize_max = (if Have52BitVAExt() && largegrain then 52 else 48;
    inputsize_min = 64 - (if ! HaveSmallPageTblExt() then 39 else if largegrain then 47 else 48);
    if inputsize > inputsize_max then
        c = ConstrainUnpredictable(Unpredictable_RESTnSZ);
        assert c IN {Constraint_FORCE, Constraint_FAULT};
        if c == Constraint_FORCE then inputsize = inputsize_max;
    inputsize_min = 64 - (if ! HaveSmallPageTblExt() then 39 else if largegrain then 47 else 48);
    if inputsize < inputsize_min then
        c = ConstrainUnpredictable(Unpredictable_RESTnSZ);
        assert c IN {Constraint_FORCE, Constraint_FAULT};
        if c == Constraint_FORCE then inputsize = inputsize_min;
    basefound = inputsize >= inputsize_min && inputsize <= inputsize_max &&
    IsOne(inputaddr<top:inputsize>);
    disabled = TCR_EL1.EPD1 == '1' || (PSTATE.EL ==
    disabled = TCR_EL1.EPD1 == '1';
    disabled = disabled || (el == EL0 && acctype ==
    disabled = disabled || (el == EL0 && acctype ==
    disabled = disabled || (el == EL0 && acctype ==
    disabled = disabled || (el == EL0 && acctype ==
    baseregister = TTBR0_EL1;
    descaddr.memattrs = WalkAttrDecode(TCR_EL1.SH0, TCR_EL1.ORGN0, TCR_EL1.IRGN0, secondstage);
    hierattrsdisabled = AArch64.HaveHPDExt() && TCR_EL1.HPD0 == '1';
else
    inputsize = 64 - UInt(TCR_EL1.TLSZ);
    largegrain = TCR_EL1.TG1 == '11'; // TG1 and TG0 encodings differ
    midgrain = TCR_EL1.TG1 == '01';
    inputsize_max = if inputsize_max = (if Have52BitVAExt() && largegrain then 52 else 48;
    inputsize_min = 64 - (if ! HaveSmallPageTblExt() then 39 else if largegrain then 47 else 48);
    if inputsize > inputsize_max then
        c = ConstrainUnpredictable(Unpredictable_RESTnSZ);
        assert c IN {Constraint_FORCE, Constraint_FAULT};
        if c == Constraint_FORCE then inputsize = inputsize_max;
    inputsize_min = 64 - (if ! HaveSmallPageTblExt() then 39 else if largegrain then 47 else 48);
    if inputsize < inputsize_min then
        c = ConstrainUnpredictable(Unpredictable_RESTnSZ);
        assert c IN {Constraint_FORCE, Constraint_FAULT};
        if c == Constraint_FORCE then inputsize = inputsize_min;
    basefound = inputsize >= inputsize_min && inputsize <= inputsize_max &&
    IsOne(inputaddr<top:inputsize>);
    disabled = TCR_EL1.EPD1 == '1' || (PSTATE.EL ==
    disabled = TCR_EL1.EPD1 == '1';
    disabled = disabled || (el == EL0 && acctype ==
    disabled = disabled || (el == EL0 && acctype ==
    disabled = disabled || (el == EL0 && acctype ==
    disabled = disabled || (el == EL0 && acctype ==
    baseregister = TTBR1_EL1;
    descaddr.memattrs = WalkAttrDecode(TCR_EL1.SH1, TCR_EL1.ORGN1, TCR_EL1.IRGN1, secondstage);
    hierattrsdisabled = AArch64.HaveHPDExt() && TCR_EL1.HPD1 == '1';
ps = TCR_EL1.IPS;
reversedescriptors = SCTLR_EL1.EE == '1';
lookupsecure = IsSecure();
singlepriv = FALSE;
update_AF = HaveAccessFlagUpdateExt() && TCR_EL1.HA == '1';
update_AP = HaveDirtyBitModifierExt() && update_AF && TCR_EL1.HD == '1';
if largegrain then
    grainsize = 16; // Log2(64KB page size)
    firstblocklevel = (if Have52BitPAExt() then 1 else 2); // Largest block is 4TB (2^42 bytes)
    if and 512MB (2^29 bytes) other
else // Small grain
    grainsize = 14;
else // Small grain
    grainsize = 12;
else // Small grain
    grainsize = 11;
else // Small grain
    grainsize = 10;
else // Small grain
    stride = grainsize - 3;
else // Small grain
    stride = (if RoundUp(Real(inputsize - grainsize) / Real(stride)));
else // Second stage translation
    inputaddr = ZeroExtend(ipaddress);
else // Second stage translation
    Stage 2 translation table walk for the Secure EL2 translation regime
if IsSecureEL2Enabled() && IsSecure() then

    // Stage 2 translation walk is in the Non-secure IPA space or the Secure IPA space
    t0size = if s1_nonsecure == '1' then VTCR_EL2.T0SZ else VSTCR_EL2.T0SZ;
tg0 = if s1_nonsecure == '1' then VTCR_EL2.TG0 else VSTCR_EL2.TG0;

    // Stage 2 translation table walk is to the Non-secure PA space or to the Secure PA space
    nswalk = if s1_nonsecure == '1' then VTCR_EL2.NSW else VSTCR_EL2.SW;

    // Stage 2 translation accesses the Non-secure PA space or the Secure PA space
    if nswalk == '1' then
        nsaccess = '1'; // When walk is non-secure, access must be to the Non-secure PA space
    else
        if s1_nonsecure == '0' then
            nsaccess = VSTCR_EL2.SA; // When walk is secure and in the Secure IPA space, access is specified by VSTCR_EL2.SA
        else
            if VSTCR_EL2.SW == '1' || VSTCR_EL2.SA == '1' then nsaccess = '1'; // When walk is secure and in the Non-secure IPA space, access is non-secure when VSTCR_EL2.SA specifies the Non-secure PA space
            else nsaccess = VTCR_EL2.NSA; // When walk is secure and in the Non-secure IPA space, if VSTCR_EL2.SA specifies the Secure PA space, access is specified by VSTCR_EL2.NSA
        else
            t0size = VTCR_EL2.T0SZ;
tg0 = VTCR_EL2.TG0;

    inputsize = 64 - UInt(t0size);
largegrain = tg0 == '01';
midgrain = tg0 == '10';

    if inputsize > inputsize_max then
        inputsize_max = (if Have52BitVAExt() && largegrain then 52 else 48);
    if inputsize < inputsize_min then
        inputsize_min = 64 - (if !HaveSmallPageTblExt() then 39 else if largegrain then 47 else 48);

    ps = VTCR_EL2.PS;
basefound = inputsize >= inputsize_min && inputsize <= inputsize_max && IsZero(inputaddr<63:inputsize>);
disabled = FALSE;
descaddr.memattrs = WalkAttrDecode(VTCR_EL2.IRGN0, VTCR_EL2.ORGN0, VTCR_EL2.SH0, secondstage);
reversedescriptors = SCTLR_EL2.EE == '1';
singlepriv = TRUE;
update_AF = HaveAccessFlagUpdateExt() && VTCR_EL2.HA == '1';
update_AP = HaveDirtyBitModifierExt() && update_AF && VTCR_EL2.HD == '1';
lookupsecure = if IsSecureEL2Enabled() then s1_nonsecure == '0' else FALSE;
// Stage2 translation table walk is to secure PA space or to Non-secure PA space
baseregister = if lookupsecure then VSTTBR_EL2 else VTTBR_EL2;
startlevel = if lookupsecure then UInt(VSTCR_EL2.SL0) else UInt(VTCR_EL2.SL0);
if largegrain then
    grainsize = 16; // Log2(64KB page size)
    level = 3 - startlevel;
    firstblocklevel = (if Have52BitPAExt() then 1 else 2); // Largest block is 4TB (2^42 bytes) and 512MB (2^29 bytes) otherwise
elsif midgrain then
    grainsize = 14; // Log2(16KB page size)
    level = 3 - startlevel;
    firstblocklevel = 2;
else // Small grain
    grainsize = 12; // Log2(4KB page size)
    if HaveSmallPageTblExt() && startlevel == 3 then
        level = startlevel;
    else
        level = 2 - startlevel;
    firstblocklevel = 1;
    stride = grainsize - 3;
// Limits on IPA controls based on implemented PA size. Level 0 is only
// supported by small grain translations
if largegrain then  // 64KB pages
    if level == 0 || (level == 1 && PAMax() <= 42) then basefound = FALSE;
elsif midgrain then  // 16KB pages
    if level == 0 || (level == 1 && PAMax() <= 40) then basefound = FALSE;
else                // Small grain, 4KB pages
    if level < 0 || (level == 0 && PAMax() <= 42) then basefound = FALSE;

// If the inputsize exceeds the PAMax value, the behavior is CONSTRAINED UNPREDICTABLE
if inputsize > PAMax() && (!ELUsingAArch32(EL1) || inputsize > 40) then
    case ConstrainUnpredictable(Unpredictable_LARGEIPA) of
        when Constraint_FORCE
            inputsize = PAMax();
            inputsizecheck = PAMax();
        when Constraint_FORCENOSLCHECK
            // As FORCE, except use the configured inputsize in the size checks below
            inputsize = PAMax();
        when Constraint_FAULT
            // Generate a translation fault
            basefound = FALSE;
        otherwise
            Unreachable();
    end

// Number of entries in the starting level table =
//     (Size of Input Address)/((Address per level)^(Num levels remaining)*(Size of Table))
startsizecheck = inputsizecheck - ((3 - level)*stride + grainsize); // Log2(Num of entries)

// Check for starting level table with fewer than 2 entries or longer than 16 pages.
// Lower bound check is: startsizecheck < Log2(2 entries)
// Upper bound check is: startsizecheck > Log2(pagesize/8*16)
if startsizecheck < 1 || startsizecheck > stride + 4 then basefound = FALSE;

if !basefound || disabled then
    level = 0;           // AArch32 reports this as a level 1 fault
    result.addrdesc.fault = AArch64.TranslationFault(ipaddress, s1_nonsecure, level, acctype, iswrite,
                                                      secondstage, s2fs1walk);
    return result;

case ps of
    when '000'  outputsize = 32;
    when '001'  outputsize = 36;
    when '010'  outputsize = 40;
    when '011'  outputsize = 42;
    when '100'  outputsize = 44;
    when '101'  outputsize = 48;
    when '110'  outputsize = (if Have52BitPAExt() && largegrain then 52 else 48);
    otherwise outputsize = integer IMPLEMENTATION_DEFINED "Reserved Intermediate Physical Address size value";

if outputsize > PAMax() then outputsize = PAMax();
if outputsize < 48 && !IsZero(baseregister<47:outputsize>) then
    level = 0;
    result.addrdesc.fault = AArch64.AddressSizeFault(ipaddress, s1_nonsecure, level, acctype, iswrite,
                                                      secondstage, s2fs1walk);
    return result;

// Bottom bound of the Base address is:
//     Log2(8 bytes per entry)+Log2(Number of entries in starting level table)
// Number of entries in starting level table =
//     (Size of Input Address)/((Address per level)^(Num levels remaining)*(Size of Table))
baselowerbound = 3 + inputsize - ((3-level)*stride + grainsize); // Log2(Num of entries*8)
if outputsize == 52 then
    z = (if baselowerbound < 6 then 6 else baselowerbound);
    baseaddress = baseregister<5:2>:baseregister<47:z>:Zeros(z);
else

Shared Pseudocode Functions
baseaddress = ZeroExtend(baseregister<47:baselowerbound>:Zeros(baselowerbound));

ns_table = if lookupsecure then '0' else '1';
ap_table = '00';
xn_table = '0';
pxn_table = '0';

addrselecttop = inputsize - 1;

apply_nvnl_effect = HaveNVExt() \&\& EL2Enabled() \&\& HCR_EL2.<NV,NV1> == '11' \&\& S1Translation;

repeat
  addrselectbottom = (3-level)*stride + grainsize;
  bits(52) index = EL1 \&\& !secondstage;
  repeat
    addrselectbottom = (3-level)*stride + grainsize;
  end repeat

bits(52) index = ZeroExtend(inputaddr<addrselecttop:addrselectbottom>:'000');
descaddr.paddress.address = baseaddress OR index;
descaddr.paddress.NS = ns_table;

// If there are two stages of translation, then the first stage table walk addresses
// are themselves subject to translation
if secondstage || !HasS2Translation() || (HaveNVExt() \&\& acctype == AccType_NV2REGISTER) then
  descaddr2 = descaddr;
else
  hwupdatewalk = FALSE;
  descaddr2 = AArch64.SecondStageWalk(descaddr, vaddress, acctype, iswrite, 8, hwupdatewalk);
  // Check for a fault on the stage 2 walk
  if IsFault(descaddr2) then
      result.addrdesc.fault = descaddr2.fault;
      return result;
  // Update virtual address for abort functions
  descaddr2.vaddress = ZeroExtend(vaddress);
end if

accdesc = CreateAccessDescriptorPTW(acctype, secondstage, s2fs1walk, level);
desc = _Mem(descaddr2, 8, accdesc);

if reversedescriptors then desc = accdesc = CreateAccessDescriptorPTW(acctype, secondstage, s2fs1walk, level);
desc = _Mem(descaddr2, 8, accdesc);

if reversedescriptors then desc = BigEndianReverse(desc);

if desc<0> == '0' \&\& (desc<1:0> == '01' \&\& (level == 3 \&\& (HaveBlockBBM() \&\& IsBlockDescriptorNTBitValid()) \&\& (desc<15:12> == '1'))) then
  // Fault (00), Reserved (10), Block (01) at level 3, or Block(01) with nT bit set.
  result.addrdesc.fault = AArch64.TranslationFault(ipaddress, s1_nonsecure, level, acctype, iswrite, secondstage, s2fs1walk);
  return result;
// Valid Block, Page, or Table entry
if desc<1:0> == '01' \&\& level == 3 then
  blocktranslate = TRUE;
else
  if (outputsize < 52 \&\& !IsZero(desc<15:12>)) \&\& (outputsize < 48 \&\& !IsZero(desc<15:12>)) then
    result.addrdesc.fault = AArch64.AddressSizeFault(ipaddress, s1_nonsecure, level, acctype, iswrite, secondstage, s2fs1walk);
    return result;
  // Table (11)
  if (outputsize == 52 then
    baseaddress = desc<15:12>:desc<47:grainsize>:Zeros(grainsize);
  else
    baseaddress = ZeroExtend(desc<47:grainsize>:Zeros(grainsize));
  end if
end if
// Unpack the upper and lower table attributes
ns_table = ns_table OR desc<63>;
if !secondstage && !hierattrsdisabled then
  ap_table<1> = ap_table<1> OR desc<62>; // read-only
if apply_nvnv1_effect then
  pxn_table = pxn_table OR desc<60>;
else
  xn_table = xn_table OR desc<60>;
// pxn_table and ap_table[0] apply in EL1&0 or EL2&0 translation regimes
if !singlepriv then
  if !apply_nvnv1_effect then
    pxn_table = pxn_table OR desc<59>;
ap_table<0> = ap_table<0> OR desc<61>; // privileged
level = level + 1;
addrselecttop = addrselectbottom - 1;
blocktranslate = FALSE;
until blocktranslate;

// Check block size is supported at this level
if level < firstblocklevel then
  result.addrdesc.fault = AArch64.TranslationFault(ipaddress, s1_nonsecure, level, acctype,
iswrite, secondstage, s2fs1walk);
  return result;

// Check for misprogramming of the contiguous bit
if largegrain then
  contiguousbitcheck = level == 2 && inputsize < 34;
elsif midgrain then
  contiguousbitcheck = level == 2 && inputsize < 30;
else
  contiguousbitcheck = level == 1 && inputsize < 34;
if contiguousbitcheck && desc<52> == '1' then
  if boolean IMPLEMENTATION_DEFINED "Translation fault on misprogrammed contiguous bit" then
    result.addrdesc.fault = AArch64.TranslationFault(ipaddress, s1_nonsecure, level, acctype,
iswrite, secondstage, s2fs1walk);
    return result;

// Check the output address is inside the supported range
if (outputsize < 52 && largegrain && !IsZero(desc<15:12>)) || (outputsize < 48 && !IsZero(desc<47:48>)) then
  result.addrdesc.fault = AArch64.AddressSizeFault(ipaddress,s1_nonsecure, level, acctype,
iswrite, secondstage, s2fs1walk);
  return result;

// Unpack the descriptor into address and upper and lower block attributes
if outputsize == 52 then
  outputaddress = desc<15:12>:desc<47:addrselectbottom>:inputaddr<addrselectbottom-1:0>;
else
  outputaddress = ZeroExtend(desc<47:addrselectbottom>:inputaddr<addrselectbottom-1:0>);
// Check Access Flag
if desc<10> == '0' then
  if !update_AF then
    result.addrdesc.fault = AArch64.AccessFlagFault(ipaddress,s1_nonsecure, level, acctype,
iswrite, secondstage, s2fs1walk);
    return result;
  else
    result.descupdate.AF = TRUE;
if update_AP && desc<51> == '1' then
  // If hw update of access permission field is configured consider AP[2] as '0' / S2AP[2] as '1'
  if !secondstage && desc<7> == '1' then
    desc<7> = '0';
  result.descupdate.AP = TRUE;
elsif secondstage && desc<7> == '0' then
  desc<7> = '1';
  result.descupdate.AP = TRUE;
// Required descriptor if AF or AP[2]/S2AP[2] needs update
result.descupdate.descaddr = descaddr;

if apply_nvnl1_effect then
  pxn = desc<54>;
  xn = '0';
  ap = desc<7>:'01';
else
  xn = desc<54>;
  pxn = desc<53>;
  ap = desc<7:6>:'1';
contiguousbit = desc<52>;
ng = desc<11>;
sh = desc<9:8>;
memattr = desc<5:2>;
result.domain = bits(4) UNKNOWN;
result.level = level;
result.blocksize = 2^((3-level)*stride + grainsize);

// Stage 1 translation regimes also inherit attributes from the tables
if !secondstage then
  result.perms.xn = xn OR xn_table;
  result.perms.ap<2> = ap<2> OR ap_table<1>; // Force read-only
  /\ PXN, nG and AP[1] apply in EL1&0 or EL2&0 stage 1 translation regimes
if !singlepriv then
  result.perms.ap<1> = ap<1> AND NOT(ap_table<0>); // Force privileged only
  result.perms.pxn = pxn OR pxn_table;
  // Pages from Non-secure tables are marked non-global in Secure EL1&0
  if IsSecure() then
    result.ng = nG OR ns_table;
  else
    result.ng = nG;
else
  result.perms.ap<1> = '1';
  result.perms.pxn = '0';
  result.ng = '0';
result.GP = desc<50>;
// Stage 1 block or pages might be guarded
result.perms.ap<0> = '1';
result.addrdesc.memattrs = AArch64.S1AttrDecode(sh, memattr<2:0>, acctype);
result.addrdesc.paddress.NS = memattr<3> OR ns_table;
else
  result.perms.ap<2:1> = ap<2:1>;
  result.perms.ap<0> = '1';
  result.perms.xn = xn;
  if HaveExtendedExecuteNeverExt() then result.perms.xxn = desc<53>;
  result.perms.pxn = '0';
  result.ng = '0';
if s2fs1walk then
  result.addrdesc.memattrs = S2AttrDecode(sh, memattr, AccType_PTW);
else
  result.addrdesc.memattrs = S2AttrDecode(sh, memattr, acctype);
  result.addrdesc.paddress.NS = nsaccess;
result.addrdesc.paddress.address = outputaddress;
result.addrdesc.fault = AArch64.NoFault();
result.contiguous = contiguousbit == '1';
if HaveCommonNotPrivateTransExt() then result.CnP = baseregister<0>;
return result;
// ClearStickyErrors()
// ===============

ClearStickyErrors()

EDSCR.TXU = '0'; // Clear TX underrun flag
EDSCR.RXO = '0'; // Clear RX overrun flag

if Halted() then // in Debug state
    ESCR.ITO = '0'; // Clear ITR overrun flag

// If halted and the ITR is not empty then it is UNPREDICTABLE whether the ESCR.ERR is cleared.
// The UNPREDICTABLE behavior also affects the instructions in flight, but this is not described
// in the pseudocode.
if Halted() && ESCR.ITE == '0' && ConstrainUnpredictableBool(Unpredictable_CLEARERRR) then
    return;

EDSCR.ERR = '0'; // Clear cumulative error flag
return;

---

// DebugTarget()
// =============

// Returns the debug exception target Exception level

bits(2) DebugTarget()
secure = IsSecure();
return DebugTargetFrom(secure);

---

// DebugTargetFrom()
// ===============

bits(2) DebugTargetFrom(boolean secure)
if HaveEL(EL2) && !secure then
    if ELUsingAArch32(EL2) then
        route_to_el2 = (HDCR.TDE == '1' || HCR.TGE == '1');
    else
        route_to_el2 = (MDCR_EL2.TDE == '1' || HCR_EL2.TGE == '1');
    else
        route_to_el2 = FALSE;

if route_to_el2 then
    target = EL2;
elsif HaveEL(EL3) && HighestELUsingAArch32() && secure then
    target = EL3;
else
    target = EL1;
return target;
// DoubleLockStatus()
// -------------------
// Returns the state of the OS Double Lock.
// FALSE if OSDLR_EL1.DLK == 0 or DBGPRCR_EL1.CORENPDQR == 1 or the PE is in Debug state.
// TRUE if OSDLR_EL1.DLK == 1 and DBGPRCR_EL1.CORENPDQR == 0 and the PE is in Non-debug state.

boolean DoubleLockStatus()
    if !HaveDoubleLock() then
        return FALSE;
    elsif ELUsingAArch32(EL1) then
        return DBGOSDLR.DLK == '1' && DBGPRCR.CORENPDQR == '0' && !Halted();
    else
        return OSDLR_EL1.DLK == '1' && DBGPRCR_EL1.CORENPDQR == '0' && !Halted();

// AllowExternalDebugAccess()
// -------------------------
// Returns TRUE if the External Debugger access is allowed.
// Returns the status of EDPRSR.EDAD.

boolean AllowExternalDebugAccess(boolean access_is_secure)
    AllowExternalDebugAccess()
        // The access may also be subject to OS lock, power-down, etc.
        if HaveSecureExtDebugView() || ExternalInvasiveDebugEnabled() then
            if ExternalDebugEnabled() then
                allow_secure = access_is_secure;
            elsif HaveSecureExtDebugView() then
                allow_secure = ExternalSecureDebugEnabled();
            else
                allow_secure = !IsSecure();
            fi
        else
            return FALSE;
        fi

// AllowExternalPMUAccess()
// ------------------------
// Returns TRUE if the External Debugger access is allowed.
// Returns the status of EDPRSR.EPMAD.

boolean AllowExternalPMUAccess(boolean access_is_secure)
    AllowExternalPMUAccess()
        // The access may also be subject to OS lock, power-down, etc.
        if HaveSecureExtDebugView() || ExternalNoninvasiveDebugEnabled() then
            if HaveSecureExtDebugView() then
                allow_secure = access_is_secure;
            elseif HaveSecureExtDebugView() then
                allow_secure = ExternalSecureNoninvasiveDebugEnabled();
            else
                allow_secure = !IsSecure();
            fi
        else
            return FALSE;
        fi

Shared Pseudocode Functions
Library pseudocode for shared/debug/authentication/Debug_authentication

```c
signal DBGEN;
signal NIDEN;
signal SPIDEN;
signal SPNIDEN;
```

Library pseudocode for shared/debug/authentication/ExternalDebugEnabled

```c
// ExternalDebugEnabled()
// ======================

// ExternalInvasiveDebugEnabled()
// ==============================

boolean ExternalDebugEnabled()

// The definition of this function is IMPLEMENTATION DEFINED.
// In the recommended interface, this function returns the state of the DBGEN signal.
return DBGEN == HIGH;
```

Library pseudocode for shared/debug/authentication/ExternalHypInvasiveDebugEnabled

```c
// ExternalHypInvasiveDebugEnabled()
// =================================

boolean ExternalHypInvasiveDebugEnabled()

// In the recommended interface, ExternalHypInvasiveDebugEnabled returns the state of the
// (DBGEN AND HIDEN) signal.
return ExternalDebugEnabled() && HIDEN == HIGH;
```

Library pseudocode for shared/debug/authentication/ExternalHypNoninvasiveDebugEnabled

```c
// ExternalHypNoninvasiveDebugEnabled()
// ====================================

boolean ExternalHypNoninvasiveDebugEnabled()

// The definition of this function is IMPLEMENTATION DEFINED.
// In the recommended interface, ExternalHypNoninvasiveDebugEnabled returns the state of the
// (DBGEN OR NIDEN) AND (HIDEN OR HNIDEN) signal.
return ExternalNoninvasiveDebugEnabled() && (HIDEN == HIGH || HNIDEN == HIGH);
```

Library pseudocode for shared/debug/authentication/ExternalNoninvasiveDebugAllowed

```c
// ExternalNoninvasiveDebugAllowed()
// =================================

boolean ExternalNoninvasiveDebugAllowed()

// Return TRUE if Trace and PC Sample-based Profiling are allowed
return (ExternalNoninvasiveDebugEnabled() &&
(!IsSecure() || ExternalSecureNoninvasiveDebugEnabled() ||
(ELUsingAArch32(EL1) && PSTATE.EL == EL0 && SDER.SUNIDEN == '1')));
```

Library pseudocode for shared/debug/authentication/ExternalNoninvasiveDebugEnabled

```c
// ExternalNoninvasiveDebugEnabled()
// =================================

boolean ExternalNoninvasiveDebugEnabled()

// This function returns TRUE if the v8.4 Debug relaxations are implemented, otherwise this
// function is IMPLEMENTATION DEFINED.
// In the recommended interface, ExternalNoninvasiveDebugEnabled returns the state of the (DBGEN
// OR NIDEN) signal.
return !HaveNoninvasiveDebugAuthExternalInvasiveDebugEnabled() || ExternalDebugEnabled();
```
// ExternalSecureDebugEnabled()
// ------------------------------------------

boolean ExternalSecureDebugEnabled()

// The definition of this function is IMPLEMENTATION DEFINED.
// In the recommended interface, ExternalSecureDebugEnabled returns the state of the
// (DBGEN AND SPIDEN) signal.
if !HaveEL(EL3) && !IsSecure() then return FALSE;

// The definition of this function is IMPLEMENTATION DEFINED.
// In the recommended interface, this function returns the state of the (DBGEN AND SPIDEN) signal.
// CoreSight allows asserting SPIDEN without also asserting DBGEN, but this is not recommended.
return ExternalDebugEnabled() && SPIDEN == HIGH;

// ExternalSecureNoninvasiveDebugEnabled()
// ---------------------------------------

boolean ExternalSecureNoninvasiveDebugEnabled()

// The definition of this function is IMPLEMENTATION DEFINED.
// In the recommended interface, ExternalSecureNoninvasiveDebugEnabled returns the state of the
// (DBGEN OR NIDEN) AND (SPIDEN OR SPNIDEN) signal.
if !HaveEL(EL3) && !IsSecure() then return FALSE;

// If the v8.4 Debug relaxations are implemented, this function returns the value of
// ExternalSecureDebugEnabled(). Otherwise the definition of this function is
// IMPLEMENTATION DEFINED.
// In the recommended interface, this function returns the state of the (DBGEN OR NIDEN) AND
// (SPIDEN OR SPNIDEN) signal.
if return HaveNoninvasiveDebugAuth() then
    return ExternalNoninvasiveDebugEnabled() && (SPIDEN == HIGH || SPNIDEN == HIGH);
else
    return ExternalSecureDebugEnabled() && (SPIDEN == HIGH || SPNIDEN == HIGH);

// Set a Cross Trigger multi-cycle input event trigger to the specified level.
CTI_SetEventLevel(CrossTriggerIn id, signal level);

// Signal a discrete event on a Cross Trigger input event trigger.
CTI_SignalEvent(CrossTriggerIn id);

// Cross Trigger Out enumeration
CrossTriggerOut_DebugRequest, CrossTriggerOut_IRQ, CrossTriggerOut_TraceExtOut0, CrossTriggerOut_TraceExtOut1, CrossTriggerOut_TraceExtOut2, CrossTriggerOut_TraceExtOut3;

// Cross Trigger In enumeration
CrossTriggerIn_CrossHalt, CrossTriggerIn_PMUOverflow, CrossTriggerIn_RSVD2, CrossTriggerIn_TraceExtOut0, CrossTriggerIn_TraceExtOut1, CrossTriggerIn_TraceExtOut2, CrossTriggerIn_TraceExtOut3;
// CheckForDCCInterrupts()
// -----------------------

CheckForDCCInterrupts()
commrx = (EDSCR.RXfull == '1');
commtx = (EDSCR.TXfull == '0');

// COMMRX and COMMTX support is optional and not recommended for new designs.
// SetInterruptRequestLevel(InterruptID_COMMRX, if commrx then HIGH else LOW);
// SetInterruptRequestLevel(InterruptID_COMMTX, if commtx then HIGH else LOW);

// The value to be driven onto the common COMMIRQ signal.
if ELUsingAArch32(EL1) then
    commirq = (commrx && DBGDCCINT.RX == '1') ||
               (commtx && DBGDCCINT.TX == '1'));
else
    commirq = (commrx && MDCCINT_EL1.RX == '1') ||
               (commtx && MDCCINT_EL1.TX == '1'));
SetInterruptRequestLevel(InterruptID_COMMIRQ, if commirq then HIGH else LOW);
return;
Library pseudocode for shared/debug/dccanditr/DBGDTRRX_EL0

// DBGDTRRX_EL0[] (external write)
// ----------------------------------------------------------
// Called on writes to debug register 0x08C.
DBGDTRRX_EL0[boolean memory_mapped] = bits(32) value

    if EDPSR<6:5,0> != '001' then /* Check DLK, OSLK and PU bits */
        IMPLEMENTATION_DEFINED "signal slave-generated error";
        return;
    end

    if EDSCR.ERR == '1' then return; /* Error flag set: ignore write */

    // The Software lock is OPTIONAL.
    if memory_mapped && EDLSR.SLK == '1' then return; /* Software lock locked: ignore write */

    if EDSCR.RXfull == '1' || (Halted() && EDSCR.MA == '1' && EDSCR.ITE == '0') then
        EDSCR.RXO = '1';  EDSCR.ERR = '1'; /* Overrun condition: ignore write */
        return;

    EDSCR.RXfull = '1';
    DTRRX = value;

    if Halted() && EDSCR.MA == '1' then /* See comments in EDITR[] (external write) */
        EDSCR.ITE = '0';

    if !UsingAArch32() then
        ExecuteA64(0xD5330501<31:0>); /* A64 "MRS X1,DBGDTRRX_EL0" */
        ExecuteA64(0x88004401<31:0>); /* A64 "STR W1,[X0],#4" */
        X[1] = bits(64) UNKNOWN;
    else
        ExecuteT32(0xEE10<15:0> /*hw1*/, 0x1E15<15:0> /*hw2*/); /* T32 "MRS R1,DBGDTRRXint" */
        ExecuteT32(0xF840<15:0> /*hw1*/, 0x1B04<15:0> /*hw2*/); /* T32 "STR R1,[R0],#4" */
        R[1] = bits(32) UNKNOWN;

    // If the store aborts, the Data Abort exception is taken and EDSCR.ERR is set to 1
    if EDSCR.ERR == '1' then
        EDSCR.RXfull = bit UNKNOWN;
        DBGDTRRX_EL0 = bits(32) UNKNOWN;
    else
        // "MRS X1,DBGDTRRX_EL0" calls DBGDTR_EL0[] (read) which clears RXfull.
        assert EDSCR.RXfull == '0';
        EDSCR.ITE = '1'; /* See comments in EDITR[] (external write) */
        return;

    if !UsingAArch32() then
        ExecuteA64(0xD5330501<31:0>); /* A64 "MRS X1,DBGDTRRX_EL0" */
        ExecuteA64(0x88004401<31:0>); /* A64 "STR W1,[X0],#4" */
        X[1] = bits(64) UNKNOWN;
    else
        ExecuteT32(0xEE10<15:0> /*hw1*/, 0x1E15<15:0> /*hw2*/); /* T32 "MRS R1,DBGDTRRXint" */
        ExecuteT32(0xF840<15:0> /*hw1*/, 0x1B04<15:0> /*hw2*/); /* T32 "STR R1,[R0],#4" */
        R[1] = bits(32) UNKNOWN;

    // DBGDTRRX_EL0[] (external read)
    // ----------------------------------------------------------

    bits(32) DBGDTRRX_EL0[boolean memory_mapped]
    return DTRRX;
// DBGDTRTX_EL0[] (external read)
// ==============================
// Called on reads of debug register 0x080.

bits(32) DBGDTRTX_EL0[boolean memory_mapped]

if EDPRSR<6:5,0> != '001' then                      // Check DLK, OSLK and PU bits
    IMPLEMENTATION_DEFINED "signal slave-generated error";
    return bits(32) UNKNOWN;

underrun = EDSCR.TXfull == '0' || (Halted() && EDSCR.MA == '1' && EDSCR.ITE == '0');
value = if underrun then bits(32) UNKNOWN else DTRTX;
if EDSCR.ERR == '1' then return value;              // Error flag set: no side-effects

if memory_mapped && EDLSR.SLK == '1' then           // Software lock locked: no side-effects
    return value;
if underrun then
    EDSCR.TXU = '1';  EDSCR.ERR = '1';              // Underrun condition: block side-effects
    return value;                                   // Return UNKNOWN
    EDSCR.TXfull = '0';
if Halted() && EDSCR.MA == '1' then
    EDSCR.ITE = '0';                                // See comments in EDITR[] (external write)

    if UsingAArch32() then
        ExecuteA64(0xB8404401<31:0>);               // A64 "LDR W1,[X0],#4"
    else
        ExecuteT32(0xF850<15:0> /*hw1*/, 0x1B04<15:0> /*hw2*/);      // T32 "LDR R1,[R0],#4"
        // If the load aborts, the Data Abort exception is taken and EDSCR.ERR is set to 1
    if EDSCR.ERR == '1' then
        EDSCR.TXfull = bit UNKNOWN;
        DBGDTRTX_EL0 = bits(32) UNKNOWN;
    else
        if UsingAArch32() then
            ExecuteA64(0xD5130501<31:0>);       // A64 "MSR DBGDTRTX_EL0,X1"
        else
            ExecuteT32(0xEE00<15:0> /*hw1*/, 0x1E15<15:0> /*hw2*/);  // T32 "MSR DBGDTRTXint,R1"
            // "MSR DBGDTRTX_EL0,X1" calls DBGDTR_ELO[] (write) which sets TXfull.
            assert EDSCR.TXfull == '1';

        if UsingAArch32() then
            X[1] = bits(64) UNKNOWN;
        else
            R[1] = bits(32) UNKNOWN;
        EDSCR.ITE = '1';                                // See comments in EDITR[] (external write)

    return value;

// DBGDTRTX_EL0[] (external write)
// ===============================
DBGDTRTX_EL0[boolean memory_mapped] = bits(32) value
// The Software lock is OPTIONAL.
if memory_mapped && EDLSR.SLK == '1' then return; // Software lock locked: ignore write
DTRTX = value;
return;
Library pseudocode for shared/debug/dccanditr/DBGDTR_EL0

// DBGDTR_EL0[] (write)
// ====================
// System register writes to DBGDTR_EL0, DBGDTRRX_EL0 (AArch64) and DBGDTRTXint (AArch32)

DBGDTR_EL0[] = bits(N) value
// For MSR DBGDTRTX_EL0,<Rt>  N=32, value=X[t]<31:0>, X[t]<63:32> is ignored
// For MSR DBGDTR_EL0,<Xt>    N=64, value=X[t]<63:0>
assert N IN {32,64};
if EDSCR.TXfull == '1' then
    value = bits(N) UNKNOWN;
// On a 64-bit write, implement a half-duplex channel
if N == 64 then DTRRX = value<63:32>;
DTRTX = value<31:0>;       // 32-bit or 64-bit write
EDSCR.TXfull = '1';
return;

// DBGDTR_EL0[] (read)
// ====================
// System register reads of DBGDTR_EL0, DBGDTRRX_EL0 (AArch64) and DBGDTRRXint (AArch32)

bits(N) DBGDTR_EL0[]
// For MRS <Rt>,DBGDTRTX_EL0  N=32, X[t]=Zeros(32):result
// For MRS <Xt>,DBGDTR_EL0    N=64, X[t]=result
assert N IN {32,64};
bits(N) result;
if EDSCR.RXfull == '0' then
    result = bits(N) UNKNOWN;
else
    // On a 64-bit read, implement a half-duplex channel
    // NOTE: the word order is reversed on reads with regards to writes
    if N == 64 then result<63:32> = DTRTX;
    result<31:0> = DTRRX;
    EDSCR.RXfull = '0';
return result;

Library pseudocode for shared/debug/dccanditr/DTR

bits(32) DTRRX;
basis(32) DTRTX;
// EDITR[] (external write)
// ================
// Called on writes to debug register 0x084.

EDITR[boolean memory_mapped] = bits(32) value
if EDPRSR<6:5,0> != '001' then  // Check DLK, OSLK and PU bits
  IMPLEMENTATION_DEFINED "signal slave-generated error";
  return;
if EDSCR.ERR == '1' then return;  // Error flag set: ignore write
if memory_mapped && EDLSR.SLK == '1' then return;  // Software lock locked: ignore write
if !Halted() then return;  // Non-debug state: ignore write
if EDSCR.ITE == '0' || EDSCR.MA == '1' then
  EDSCR.ITO = '1';  EDSCR.ERR = '1';  // Overrun condition: block write
  return;

  // ITE indicates whether the processor is ready to accept another instruction; the processor
  // may support multiple outstanding instructions. Unlike the "InstrCompl" flag in [v7A] there
  // is no indication that the pipeline is empty (all instructions have completed). In this
  // pseudocode, the assumption is that only one instruction can be executed at a time,
  // meaning ITE acts like "InstrCompl".
  EDSCR.ITE = '0';
  if !UsingAArch32() then
    ExecuteA64(value);
  else
    ExecuteT32(value<15:0>/"hw1*", value<31:16> /*hw2*/);

  EDSCR.ITE = '1';
  return;
DCPSInstruction(bits(2) target_el)

    SynchronizeContext();

case target_el of
    when EL1
        if PSTATE.EL == EL2 || (PSTATE.EL == EL3 && !UsingAArch32()) then handle_el = PSTATE.EL;
        elsif EL2Enabled() && HCR_EL2.TGE == '1' then UndefinedFault();
        else handle_el = EL1;
    when EL2
        if !HaveEL(EL2) then UndefinedFault();
        elsif PSTATE.EL == EL3 && !UsingAArch32() then UndefinedFault();
        else handle_el = EL2;
    when EL3
        if EDSCR.SDD == '1' || !HaveEL(EL3) then UndefinedFault();
        handle_el = EL3;
    otherwise
        Unreachable();

    from_secure = IsSecure();
    if ELUsingAArch32(handle_el) then
        if PSTATE.M == M32_Monitor then SCR.NS = '0';
        assert UsingAArch32(); // Cannot move from AArch64 to AArch32
        case handle_el of
            when EL1
                AArch32.WriteMode(M32_Svc);
            when EL2
                AArch32.WriteMode(M32_Hyp);
            when EL3
                AArch32.WriteMode(M32_Monitor);
            if HavePANExt() then
                if !from_secure then
                    PSTATE.PAN = '0';
                elsif SCTLR.SPAN == '0' then
                    PSTATE.PAN = '1';
                if handle_el == EL2 then
                    ELR_hyp = bits(32) UNKNOWN;  HSR = bits(32) UNKNOWN;
                else
                    LR = bits(32) UNKNOWN;
                    SPSR[] = bits(32) UNKNOWN;
                    PSTATE.E = SCTLR[].EE;
                    DLR = bits(32) UNKNOWN;  DSPSR = bits(32) UNKNOWN;
            else
                // Targeting AArch64
                if UsingAArch32() then
                    AArch64.MaybeZeroRegisterUppers();
                    MaybeZeroSVEUppers(target_el);
                    PSTATE.nRW = '0';  PSTATE.SP = '1';  PSTATE.EL = handle_el;
                    if HavePANExt() && ((handle_el == EL1 && SCTLR.EL1.SPAN == '0') || (handle_el == EL2 && HCR_EL2.EH == '1' && HCR_EL2.TGE == '1' && SCTLR_EL2.SPAN == '0')) then
                        PSTATE.PAN = '1';
                    ELR[] = bits(64) UNKNOWN;  SPSR[] = bits(32) UNKNOWN;  ESR[] = bits(32) UNKNOWN;
                    DLR_EL0 = bits(64) UNKNOWN;  DSPSR_EL0 = bits(32) UNKNOWN;
                    if HaveUAOExt() then PSTATE.UAO = '0';
                UpdateEDSCRFields(); // Update EDSCR PE state flags
                sync_errors = 0;
            end

            if !HaveIESB() && SCTLR[].IESB == '1';
    if HaveDoubleFaultExt() then
        sync_errors = sync_errors || (SCR_EL3.EA == '1' && SCR_EL3.NMEA == '1' && PSTATE.EL == EL3);
    // SCTLR[].IESB might be ignored in Debug state.
    if []IESB == '1' then ConstrainUnpredictableBool(IESB, IESBinDebug) then

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sync_errors = FALSE;
if sync_errors then then
    SynchronizeErrors();
return;

Library pseudocode for shared/debug/halting/DRPSInstruction

// DRPSInstruction()
// ================
// Operation of the A64 DRPS and T32 ERET instructions in Debug state
DRPSInstruction()

    SynchronizeContext();
    sync_errors = FALSE; // SCTLR[].IESB might be ignored in Debug state.
    if HaveIESBHaveRASExt() && SCTLR[].IESB == '1';
    if HaveDoubleFaultExt() && !UsingAArch32() then
        sync_errors = sync_errors || (SCR_EL3.EA == '1' && SCR_EL3.NMEA == '1' && PSTATE.EL == EL3);
    // SCTLR[].IESB might be ignored in Debug state.
    if !SCTLR[].IESB == '1' && ConstrainUnpredictableBool(Unpredictable_ENESBinDebug) then
        sync_errors = FALSE;
    if sync_errors then then
        SynchronizeErrors();
    SetPSTATEFromPSR(PSR[]);
    // PSTATE.(N,Z,C,V,GE,SS,D,A,I,F) are not observable and ignored in Debug state, so
    // behave as if UNKNOWN.
    if UsingAArch32() then
        PSTATE.<N,Z,C,V,GE,SS,D,A,I,F> = bits(13) UNKNOWN;
    // In AArch32, all instructions are T32 and unconditional.
    // PSTATE.IT = '00000000'; PSTATE.T = '1'; // PSTATE.J is RES0
    DLR = bits(32) UNKNOWN; DSPSR = bits(32) UNKNOWN;
    else
        PSTATE.<N,Z,C,V,SS,D,A,I,F> = bits(9) UNKNOWN;
        DLR_EL0 = bits(64) UNKNOWN; DSPSR_EL0 = bits(32) UNKNOWN;
    UpdateEDSCRFields(); // Update EDSCR PE state flags
    return;

Library pseudocode for shared/debug/halting/DebugHalt

constant bits(6) DebugHalt_Breakpoint = '000111';
countant bits(6) DebugHalt_EDBGRQ = '010011';
countant bits(6) DebugHalt_Step_Normal = '011011';
countant bits(6) DebugHalt_Step_Exclusive = '011111';
countant bits(6) DebugHalt_OSUnlockCatch = '100011';
countant bits(6) DebugHalt_ResetCatch = '100111';
countant bits(6) DebugHalt_Watchpoint = '101011';
countant bits(6) DebugHalt_HaltInstruction = '101111';
countant bits(6) DebugHalt_SoftwareAccess = '110011';
countant bits(6) DebugHalt_ExceptionCatch = '110111';
countant bits(6) DebugHalt_Step_NoSyndrome = '111011';

Library pseudocode for shared/debug/halting/DisableITRAndResumeInstructionPrefetch

DisableITRAndResumeInstructionPrefetch();

Library pseudocode for shared/debug/halting/ExecuteA64

// Execute an A64 instruction in Debug state.
ExecuteA64(bits(32) instr);
Library pseudocode for shared/debug/halting/ExecuteT32

// Execute a T32 instruction in Debug state.
ExecuteT32(bits(16) hw1, bits(16) hw2);

Library pseudocode for shared/debug/halting/ExitDebugState

// ExitDebugState()
// ================
ExitDebugState()
assert Halted();
SynchronizeContext();

// Although EDSCR.STATUS signals that the PE is restarting, debuggers must use EDPRSR.SDR to
detect that the PE has restarted.
EDSCR.STATUS = '000001';                           // Signal restarting
EDESR<2:0> = '000';                                // Clear any pending Halting debug events
bits(64) new_pc;
bits(32) spsr;
if UsingAArch32() then
  new_pc = ZeroExtend(DLR);
  spsr = DSPSR;
else
  new_pc = DLR_EL0;
  spsr = DSPSR_EL0;
// If this is an illegal return, SetPSTATEFromPSR() will set PSTATE.IL.
SetPSTATEFromPSR(spsr);                            // Can update privileged bits, even at EL0
if UsingAArch32() then
  if ConstrainUnpredictableBool(Unpredictable_RESTARTALIGNPC) then new_pc<0> = '0';
  BranchTo(new_pc<31:0>, BranchType_DBGEXIT BranchType_UNKNOWN);    // AArch32 branch
else
  // If targeting AArch32 then possibly zero the 32 most significant bits of the target PC
  if spsr<4> == '1' & ConstrainUnpredictableBool(Unpredictable_RESTARTZEROUPPERPC) then
    new_pc<63:32> = Zeros();
  BranchTo(new_pc, BranchType_DBGEXIT);    // A type of branch that is never predicted
(EDSCR.STATUS,EDPRSR.SDR) = ('000010','1');        // Atomically signal restarted
UpdateEDSCRFields();                               // Stop signalling PE state
DisableITRAndResumeInstructionPrefetch();
return;
Library pseudocode for shared/debug/halting/Halt

// Halt()
// ======

Halt(bits(6) reason)

  CTI_SignalEvent(CrossTriggerIn_CrossHalt);  // Trigger other cores to halt
if UsingAArch32() then
  DLR = ThisInstrAddr();
  DSPSR = GetPSRFromPSTATE();
  DSPSR.SS = PSTATE.SS;  // Always save PSTATE.SS
else
  DLR_EL0 = ThisInstrAddr();
  DSPSR_EL0 = GetPSRFromPSTATE();
  DSPSR_EL0.SS = PSTATE.SS;  // Always save PSTATE.SS

EDSCR.ITE = '1';  EDSCR.ITO = '0';
if IsSecure() then
  EDSR.IDD = '0';  // If entered in Secure state, allow debug
elsif HaveEL(EL3) then
  EDSR.IDD = if ExternalSecureDebugEnabled & ExternalInvasiveDebugEnabled() then '0' else '1';
else
  assert EDSR.IDD == '1';  // Otherwise EDSR.IDD is RES1

EDSCR.MA = '0';
// PSTATE.<SS,D,A,I,F> are not observable and ignored in Debug state, so behave as if
// UNKNOWN. PSTATE.<E,M,nRW,EL,SP> are unchanged. PSTATE.IL is set to 0.
if UsingAArch32() then
  PSTATE.<SS,A,I,F> = bits(4) UNKNOWN;
// In AArch32, all instructions are T32 and unconditional.
  PSTATE.IT = '00000000';  PSTATE.T = '1';  // PSTATE.J is RES0
else
  PSTATE.<SS,D,A,I,F> = bits(5) UNKNOWN;
  PSTATE.IL = '0';

StopInstructionPrefetchAndEnableITR();
EDSCR.STATUS = reason;  // Signal entered Debug state
UpdateEDSCRFields();  // Update EDSR PE state flags.

return;

Library pseudocode for shared/debug/halting/HaltOnBreakpointOrWatchpoint

// HaltOnBreakpointOrWatchpoint()
// -----------------------------
// Returns TRUE if the Breakpoint and Watchpoint debug events should be considered for Debug
// state entry, FALSE if they should be considered for a debug exception.

boolean HaltOnBreakpointOrWatchpoint()
return HaltingAllowed() \&\& EDSR.HDE == '1' \&\& OSLSR_EL1.OSLK == '0';

Library pseudocode for shared/debug/halting/Halted

// Halted()
// -------

boolean Halted()
return !(EDSCR.STATUS IN {'000001', '000010'});  // Halted
Library pseudocode for shared/debug/halting/HaltingAllowed

// HaltingAllowed()
// ================
// Returns TRUE if halting is currently allowed, FALSE if halting is prohibited.

boolean HaltingAllowed()
if Halted() || DoubleLockStatus() then
    return FALSE;
elseif IsSecure() then
    return ExternalSecureDebugEnabled
        ExternalInvasiveDebugEnabled();
else
    return ExternalDebugEnabled
        ExternalInvasiveDebugEnabled();

Library pseudocode for shared/debug/halting/Restarting

// Restarting()
// ============

boolean Restarting()
return EDSCR.STATUS == '00001'; // Restarting

Library pseudocode for shared/debug/halting/StopInstructionPrefetchAndEnableITR

StopInstructionPrefetchAndEnableITR();

Library pseudocode for shared/debug/halting/UpdateEDSCRFields

// UpdateEDSCRFields()
// ===================
// Update EDSCR PE state fields

UpdateEDSCRFields()
if !Halted() then
    EDSCR.EL = '00';
    EDSCR.NS = bit UNKNOWN;
    EDSCR.RW = '1111';
else
    EDSCR.EL = PSTATE.EL;
    EDSCR.NS = if IsSecure() then '0' else '1';
    bits(4) RW;
    RW<1> = if ELUsingAArch32(EL1) then '0' else '1';
    if PSTATE.EL != EL0 then
        RW<0> = RW<1>;
    else
        RW<0> = if UsingAArch32() then '0' else '1';
        if !HaveEL(EL2) || (HaveEL(EL3) && SCR_GEN[].NS == '0' && !IsSecureEL2Enabled()) then
            RW<2> = RW<1>;
        else
            RW<2> = if ELUsingAArch32(EL2) then '0' else '1';
        if !HaveEL(EL3) then
            RW<3> = RW<2>;
        else
            RW<3> = if ELUsingAArch32(EL3) then '0' else '1';
    // The least-significant bits of EDSCR.RW are UNKNOWN if any higher EL is using AArch32.
    if RW<3> == '0' then RW<2:0> = bits(3) UNKNOWN;
elsesif RW<2> == '0' then RW<1:0> = bits(2) UNKNOWN;
elsesif RW<1> == '0' then RW<0> = bit UNKNOWN;
    EDSCR.RW = RW;
    return;
Library pseudocode for shared/debug/haltingevents/CheckExceptionCatch

// CheckExceptionCatch()
// ---------------------
// Check whether an Exception Catch debug event is set on the current Exception level

CheckExceptionCatch(boolean exception_entry)
// Called after an exception entry or exit, that is, such that IsSecure() and PSTATE.EL are correct for the exception target.
base = if IsSecure() then 0 else 4;
if HaltingAllowed() then
  if HaveExtendedECDebugEvents() then
    exception_exit = !exception_entry;
    ctrl = EDECCR<UInt>(PSTATE.EL) + base + 8>:EDECCR<UInt>(PSTATE.EL) + base>:
    case ctrl of
      when '00'  halt = FALSE;
      when '01'  halt = TRUE;
      when '10'  halt = (exception_exit == TRUE);
      when '11'  halt = (exception_entry == TRUE);
    else
      halt = (EDECCR<UInt>(PSTATE.EL) + base> == '1');
  if halt then Halt(DebugHalt_ExceptionCatch);

Library pseudocode for shared/debug/haltingevents/CheckHaltingStep

// CheckHaltingStep()
// -------------------
// Check whether EDESR.SS has been set by Halting Step

CheckHaltingStep()
if HaltingAllowed() && EDESR.SS == '1' then
  // The STATUS code depends on how we arrived at the state where EDESR.SS == 1.
  if HaltingStep_DidNotStep() then
    Halt(DebugHalt_Step_NoSyndrome);
  elsif HaltingStep_SteppedEX() then
    Halt(DebugHalt_Step_Exclusive);
  else
    Halt(DebugHalt_Step_Normal);

Library pseudocode for shared/debug/haltingevents/CheckOSUnlockCatch

// CheckOSUnlockCatch()
// ---------------------
// Called on unlocking the OS Lock to pend an OS Unlock Catch debug event

CheckOSUnlockCatch()
if EDECR.OSUCE == '1' && !Halted() then EDESR.OSUC = '1';

Library pseudocode for shared/debug/haltingevents/CheckPendingOSUnlockCatch

// CheckPendingOSUnlockCatch()
// ----------------------------
// Check whether EDESR.OSUC has been set by an OS Unlock Catch debug event

CheckPendingOSUnlockCatch()
if HaltingAllowed() && EDESR.OSUC == '1' then
  Halt(DebugHalt(OSUnlockCatch);

Library pseudocode for shared/debug/haltingevents/CheckPendingResetCatch

// CheckPendingResetCatch()
// -------------------------
// Check whether EDESR.RC has been set by a Reset Catch debug event

CheckPendingResetCatch()
if HaltingAllowed() && EDESR.RC == '1' then
  Halt(DebugHalt_ResetCatch);
// CheckResetCatch()
// ------------------
// Called after reset

CheckResetCatch()
    if EDECR.RCE == '1' then
        EDESR.RC = '1';
        // If halting is allowed then halt immediately
        if HaltingAllowed() then Halt(DebugHalt_ResetCatch);

Library pseudocode for shared/debug/haltingevents/CheckSoftwareAccessToDebugRegisters

// CheckSoftwareAccessToDebugRegisters()
// -------------------------------------
// Check for access to Breakpoint and Watchpoint registers.

CheckSoftwareAccessToDebugRegisters()
    os_lock = (if ELUsingAArch32(EL1) then DBGOSLR.OSLK else OSLSR_EL1.OSLK);
    if HaltingAllowed() && EDSCR.TDA == '1' && os_lock == '0' then
        Halt(DebugHalt_SoftwareAccess);

Library pseudocode for shared/debug/haltingevents/ExternalDebugRequest

// ExternalDebugRequest()
// ----------------------

ExternalDebugRequest()
    if HaltingAllowed() then
        Halt(DebugHalt_EDBGRQ);
        // Otherwise the CTI continues to assert the debug request until it is taken.

Library pseudocode for shared/debug/haltingevents/HaltingStep_DidNotStep

// Returns TRUE if the previously executed instruction was executed in the inactive state, that is,
// if it was not itself stepped.
boolean HaltingStep_DidNotStep();

Library pseudocode for shared/debug/haltingevents/HaltingStep_SteppedEX

// Returns TRUE if the previously executed instruction was a Load-Exclusive class instruction
// executed in the active-not-pending state.
boolean HaltingStep_SteppedEX();
RunHaltingStep(boolean exception_generated, bits(2) exception_target, boolean syscall, boolean reset)

if reset then assert !Halted(); // Cannot come out of reset halted
active = EDECR.SS == '1' && !Halted();
if active && reset then // Coming out of reset with EDECR.SS set
EDESR.SS = '1';
elsif active && HaltingAllowed() then
if exception_generated && exception_target == EL3 then
advance = syscall || ExternalSecureDebugEnabled || ExternalSecureInvasiveDebugEnabled();
else
advance = TRUE;
if advance then EDESR.SS = '1';
return;

ExternalDebugInterruptsDisabled(bits(2) target)

case target of
when EL3
int_dis = EDSCR.INTdis == '11' && ExternalSecureDebugEnabled || ExternalSecureInvasiveDebugEnabled();
when EL2
int_dis = EDSCR.INTdis == '1x' && ExternalDebugEnabled || ExternalInvasiveDebugEnabled();
when EL1
if IsSecure() then
int_dis = EDSCR.INTdis == '1x' && ExternalSecureDebugEnabled || ExternalSecureInvasiveDebugEnabled();
else
int_dis = EDSCR.INTdis != '00' && ExternalDebugEnabled || ExternalInvasiveDebugEnabled();
return int_dis;

InterruptID_PMUIRQ, InterruptID_COMMIRQ, InterruptID_CTIIRQ,
InterruptID_COMMRX, InterruptID_COMMTX};

SetInterruptRequestLevel(InterruptID id, signal level);
Library pseudocode for shared/debug/samplebasedprofiling/CreatePCSample

// CreatePCSample()
// ================
CreatePCSample()
// In a simple sequential execution of the program, CreatePCSample is executed each time the PE
// executes an instruction that can be sampled. An implementation is not constrained such that
// reads of EDPCSRlo return the current values of PC, etc.

pc_sample.valid = ExternalNoninvasiveDebugAllowed() && !Halted();
pc_sample.pc = ThisInstrAddr();
pc_sample.el = PSTATE.EL;
pc_sample.rw = if UsingAArch32() then '0' else '1';
pc_sample.ns = if IsSecure() then '0' else '1';
pc_sample.contextidr = if ELUsingAArch32(EL1) then CONTEXTIDR else CONTEXTIDR_EL1;
pc_sample.has_el2 = EL2Enabled();
if EL2Enabled() then
  if ELUsingAAArch32(EL2) then
    pc_sample.vmid = ZeroExtend(VTTBR.VMID, 16);
  elsif !Have16bitVMID() || VTCR_EL2.VS == '0' then
    pc_sample.vmid = ZeroExtend(VTTBR_EL2.VMID<7:0>, 16);
  else
    pc_sample.vmid = VTTBR_EL2.VMID;
  if HaveVirtHostExt() && !ELUsingAAArch32(EL2) then
    pc_sample.contextidr_el2 = CONTEXTIDR_EL2;
  else
    pc_sample.contextidr_el2 = bits(32) UNKNOWN;
  pc_sample.el0h = PSTATE.EL == EL0 && IsInHost();
return;
// EDPCSRlo[] (read)
// -----------------

bits(32) EDPCSRlo[boolean memory_mapped]

if EDPRSR<6:5,0> != '001' then                      // Check DLK, OSLK and PU bits
  IMPLEMENTATION_DEFINED "signal slave-generated error";
  return bits(32) UNKNOWN;

// The Software lock is OPTIONAL.
update = !memory_mapped || EDLSR.SLK == '0';       // Software locked: no side-effects

if pc_sample.valid then
  sample = pc_sample.pc<31:0>;
  if update then
    if HaveVirtHostExt() && EDSCR.SC2 == '1' then
      EDPCSRhi.PC = (if pc_sample.rw == '0' then Zeros(24) else pc_sample.pc<55:32>);
      EDPCSRhi.EL = pc_sample.el;
      EDPCSRhi.NS = pc_sample.ns;
    else
      EDPCSRhi = (if pc_sample.rw == '0' then Zeros(32) else pc_sample.pc<63:32>);
      EDCIDSR = pc_sample.contextidr;
      if HaveVirtHostExt() && EDSCR.SC2 == '1' then
        EDVIDSR = (if HaveEL(EL2) && pc_sample.ns == '1' then pc_sample.contextidr_el2
                    else bits(32) UNKNOWN);
      else
        if HaveEL(EL2) && pc_sample.ns == '1' && pc_sample.el IN {EL1, EL0} then
          EDVIDSR.VMID = pc_sample.vmid;
        else
          EDVIDSR.VMID = Zeros();
        EDVIDSR.NS = pc_sample.ns;
        EDVIDSR.E2 = (if pc_sample.el == EL2 then '1' else '0');
        EDVIDSR.E3 = (if pc_sample.el == EL3 then '1' else '0') AND pc_sample.rw;
        // The conditions for setting HV are not specified if PCSRhi is zero.
        // An example implementation may be "pc_sample.rw".
        EDVIDSR.HV = (if !IsZero(EDPCSRhi) then '1' else bit IMPLEMENTATION_DEFINED "0 or 1")
      else
        sample = Ones(32);
        if update then
          EDPCSRhi = bits(32) UNKNOWN;
          EDCIDSR = bits(32) UNKNOWN;
          EDVIDSR = bits(32) UNKNOWN;
          return sample;

Library pseudocode for shared/debug/samplebasedprofiling/PCSample

type PCSVmple is (
  boolean valid,
  bits(64) pc,
  bits(2) el,
  bit rw,
  bit ns,
  boolean has_el2,
  bits(32) contextidr,
  bits(32) contextidr_el2,
  boolean el0h,
  bits(16) vmid
)

PCSample pc_sample;
// PMPCSR[] (read)
// ===============
bits(32) PMPCSR[boolean memory_mapped]

if EDPRSR<6:5,0> != '001' then  // Check DLK, OSLK and PU bits
   IMPLEMENTATION_DEFINED "signal slave-generated error";
   return bits(32) UNKNOWN;

// The Software lock is OPTIONAL.
update = 'memory_mapped || PMLSR.SLK == '0';  // Software locked: no side-effects

if pc_sample.valid then
   sample = pc_sample.pc<31:0>;
   if update then
      PMPCSR<55:32> = (if pc_sample.rw == '0' then Zeros(24) else pc_sample.pc<55:32>);
      PMPCSR.EL = pc_sample.el;
      PMPCSR.NS = pc_sample.ns;
      PMCID1SR = pc_sample.contextidr;
      PMCID2SR = if pc_sample.has_el2 then pc_sample.contextidr_el2 else bits(32) UNKNOWN;
      PMVIDSR.VMID = (if pc_sample.has_el2 && pc_sample.el IN {EL1,EL0} && !pc_sample.el0h
                      then pc_sample.vmid else bits(16) UNKNOWN);
   else
      sample = Ones(32);
      if update then
         PMPCSR<55:32> = bits(24) UNKNOWN;
         PMPCSR.EL = bits(2) UNKNOWN;
         PMPCSR.NS = bit UNKNOWN;
         PMCID1SR = bits(32) UNKNOWN;
         PMCID2SR = bits(32) UNKNOWN;
         PMVIDSR.VMID = bits(16) UNKNOWN;
   end
return sample;

Library pseudocode for shared/debug/softwarestep/CheckSoftwareStep

// CheckSoftwareStep()
// ===============
// Take a Software Step exception if in the active-pending state

CheckSoftwareStep()

// Other self-hosted debug functions will call AArch32.GenerateDebugExceptions() if called from
// AArch32 state. However, because Software Step is only active when the debug target Exception
// level is using AArch64, CheckSoftwareStep only calls AArch64.GenerateDebugExceptions().
if !ELUsingAArch32(DebugTarget()) && AArch64.GenerateDebugExceptions() then
   if MDSCR_EL1.SS == '1' && PSTATE.SS == '0' then
      AArch64.SoftwareStepException();

// DebugExceptionReturnSS()
// -----------------------------------------------
// Returns value to write to PSTATE.SS on an exception return or Debug state exit.

bit DebugExceptionReturnSS(bits(32) spsr)
assert Halted() || Restarting() || PSTATE.EL != EL0;

SS_bit = '0';
if MDSCR_EL1.SS == '1' then
    if Restarting() then
        enabled_at_source = FALSE;
    elsif UsingAArch32() then
        enabled_at_source = AArch32.GenerateDebugExceptions();
    else
        enabled_at_source = AArch64.GenerateDebugExceptions();
    endif
else
    IllegalExceptionReturn(spsr) then
        dest = PSTATE.EL;
    else
        (valid, dest) = ELFromSPSR(spsr);  assert valid;
        secure = IsSecureBelowEL3() || dest == EL3;
        if ELUsingAArch32(dest) then
            enabled_at_dest = AArch32.GenerateDebugExceptionsFrom(dest, secure);
        else
            mask = spsr<9>;
            enabled_at_dest = AArch64.GenerateDebugExceptionsFrom(dest, secure, mask);
        endif
        ELd = DebugTargetFrom(secure);
        if !ELUsingAArch32(ELd) && !enabled_at_source && enabled_at_dest then
            SS_bit = spsr<21>;
        endif
    return SS_bit;
endif

Library pseudocode for shared/debug/softwarestep/SSAdvance

// SSAdvance()
// -------------
// Advance the Software Step state machine.

SSAdvance()

// A simpler implementation of this function just clears PSTATE.SS to zero regardless of the
// current Software Step state machine. However, this check is made to illustrate that the
// processor only needs to consider advancing the state machine from the active-not-pending
// state.

target = DebugTarget();
step_enabled = !ELUsingAArch32(target) && MDSCR_EL1.SS == '1';
active_not_pending = step_enabled && PSTATE.SS == '1';

if active_not_pending then PSTATE.SS = '0';
return;

Library pseudocode for shared/debug/softwarestep/SoftwareStep_DidNotStep

// Returns TRUE if the previously executed instruction was executed in the inactive state, that is,
// if it was not itself stepped.

boolean SoftwareStep_DidNotStep();

Library pseudocode for shared/debug/softwarestep/SoftwareStep_SteppedEX

// Returns TRUE if the previously executed instruction was a Load-Exclusive class instruction
// executed in the active-not-pending state.

boolean SoftwareStep_SteppedEX();
// ConditionSyndrome()
// ===================
// Return CV and COND fields of instruction syndrome

bits(5) ConditionSyndrome()

    bits(5) syndrome;

    if UsingAArch32() then
        cond = AArch32.CurrentCond();
        if PSTATE.T == '0' then  // A32
            syndrome<4> = '1';
            // A conditional A32 instruction that is known to pass its condition code check
            // can be presented either with COND set to 0xE, the value for unconditional, or
            // the COND value held in the instruction.
            if ConditionHolds(cond) && ConstrainUnpredictableBool(Unpredictable_ESRCONDPASS) then
                syndrome<3:0> = '1110';
            else
                syndrome<3:0> = cond;
        else
            // When a T32 instruction is trapped, it is IMPLEMENTATION DEFINED whether:
            //  * CV set to 0 and COND is set to an UNKNOWN value
            //  * CV set to 1 and COND is set to the condition code for the condition that
            //    applied to the instruction.
            if boolean IMPLEMENTATION_DEFINED "Condition valid for trapped T32" then
                syndrome<4> = '1';
                syndrome<3:0> = cond;
            else
                syndrome<4> = '0';
                syndrome<3:0> = bits(4) UNKNOWN;
        else
            syndrome<4> = '1';
            syndrome<3:0> = '1110';
    else
        syndrome<4> = '1';
        syndrome<3:0> = '1110';

    return syndrome;
```
// Library pseudocode for shared/exceptions/exceptions/Exception

enumeration Exception {
    Exception_Uncategorized,       // Uncategorized or unknown reason
    Exception_WFXTrap,             // Trapped WFI or WFE instruction
    Exception_CPI5RTTrap,          // Trapped AArch32 MCR or MRC access to CP15
    Exception_CPI5RRTrap,          // Trapped AArch32 MCRR or MRRC access to CP15
    Exception_CPI4RTTrap,          // Trapped AArch32 MCR or MRC access to CP14
    Exception_CPI4DTTrap,          // Trapped AArch32 LDC or STC access to CP14
    Exception_AdvSIMDFPAccessTrap, // HCPTR-trapped access to SIMD or FP
    Exception_FPIDTrap,            // Trapped access to SIMD or FP ID register
    Exception_PACTrap,             // Trapped invalid PAC use
    Exception_CP14RRTrap,          // Trapped MRRC access to CP14 from AArch32
    Exception_IllegalState,        // Illegal Execution state
    Exception_SupervisorCall,      // Supervisor Call
    Exception_HypervisorCall,      // Hypervisor Call
    Exception_MonitorCall,         // Monitor Call or Trapped SMC instruction
    Exception_SystemRegisterTrap,  // Trapped MRS or MSR system register access
    Exception_ERetTrap,            // Trapped invalid ERET use
    Exception_InstructionAbort,    // Instruction Abort or Prefetch Abort
    Exception_PCAlignment,         // PC alignment fault
    Exception_DataAbort,           // Data Abort
    Exception_NV2DataAbort,        // Data abort at EL1 reported as being from EL2
    Exception_SPAlignment,         // SP alignment fault
    Exception_FPTrappedException,  // IEEE trapped FP exception
    Exception_SError,              // SError interrupt
    Exception_Breakpoint,          // (Hardware) Breakpoint
    Exception_SoftwareStep,        // Software Step
    Exception_Watchpoint,          // Watchpoint
    Exception_SoftwareBreakpoint,  // Software Breakpoint Instruction
    Exception_VectorCatch,         // AArch32 Vector Catch
    Exception_IRQ,                 // IRQ interrupt
    Exception_SVEAccessTrap,       // HCPTR trapped access to SVE
    Exception_BranchTarget,        // Branch Target Identification
    Exception_FIQ);                // FIQ interrupt
}
```

```
// Library pseudocode for shared/exceptions/exceptions/ExceptionRecord

type ExceptionRecord is (
    Exception type,              // Exception class
    bits(25) syndrome,           // Syndrome record
    bits(64) vaddress,           // Virtual fault address
    boolean ipavalid,            // Physical fault address for second stage faults
    bits(1) NS,                  // Physical fault address for second stage faults
    bits(52) ipaddress)          // Physical fault address for second stage faults
)

// ExceptionSyndrome()
// -------------------
// Return a blank exception syndrome record for an exception of the given type.

ExceptionRecord ExceptionSyndrome(Exception type)
{
    ExceptionRecord r;
    r.type = type;

    // Initialize all other fields
    r.syndrome = Zeros();
    r.vaddress = Zeros();
    r.ipavalid = FALSE;
    r.NS = '0';
    r.ipaddress = Zeros();

    return r;
}
```
Library pseudocode for shared/exceptions/traps/ReservedValue

```c
// ReservedValue()
// ==============

ReservedValue()
    if UsingAArch32() && !AArch32.GeneralExceptionsToAArch64() then
        AArch32.TakeUndefInstrException();
    else
        AArch64.UndefinedFault();
```

Library pseudocode for shared/exceptions/traps/SystemAccessType

```c
enumeration SystemAccessType { SystemAccessType_RT, SystemAccessType_RRT, SystemAccessType_DT };
```

Library pseudocode for shared/exceptions/traps/UnallocatedEncoding

```c
// UnallocatedEncoding()
// ================

UnallocatedEncoding()
    if UsingAArch32() && AArch32.ExecutingCP10or11Instr() then
        FPEXC.DEX = '0';
    if UsingAArch32() && !AArch32.GeneralExceptionsToAArch64() then
        AArch32.TakeUndefInstrException();
    else
        AArch64.UndefinedFault();
```

Library pseudocode for shared/functions/aborts/EncodeLDFSC

```c
// EncodeLDFSC()
// =============

// Function that gives the Long-descriptor FSC code for types of Fault

bits(6) EncodeLDFSC(Fault type, integer level)
    bits(6) result;
    case type of
        when Fault_AddressSize result = '0000':level<1:0>; assert level IN {0,1,2,3};
        when Fault_AccessFlag result = '0010':level<1:0>; assert level IN {1,2,3};
        when Fault_Permission result = '0011':level<1:0>; assert level IN {1,2,3};
        when Fault_Translation result = '0001':level<1:0>; assert level IN {0,1,2,3};
        when Fault_SyncExternal result = '010000';
        when Fault_SyncExternalOnWalk result = '0111':level<1:0>; assert level IN {0,1,2,3};
        when Fault_SyncParity result = '011000';
        when Fault_SyncParityOnWalk result = '0111':level<1:0>; assert level IN {0,1,2,3};
        when Fault_AsyncParity result = '011001';
        when Fault_AsyncExternal result = '010001';
        when Fault_Alignment result = '100001';  // IMPLEMENTATION DEFINED
        when Fault_Debug result = '100010';
        when Fault_TLBConflict result = '110000';
        when Fault_HWUpdateAccessFlag result = '110001';
        when Fault_Exclusive result = '110101';  // IMPLEMENTATION DEFINED
        otherwise
            Unreachable();
    return result;
```
Library pseudocode for shared/functions/aborts/IPAValid

```c
// IPAValid()  
// ===========  
// Return TRUE if the IPA is reported for the abort

boolean IPAValid(FaultRecord fault)  
assert fault.type != Fault_None;
  
if fault.s2fs1walk then  
return fault.type IN {Fault_AccessFlag, Fault_Permission, Fault_Translation, Fault_AddressSize};
elsif fault.secondstage then  
return fault.type IN {Fault_AccessFlag, Fault_Translation, Fault_AddressSize};
else  
return FALSE;
```

Library pseudocode for shared/functions/aborts/IsAsyncAbort

```c
// IsAsyncAbort()  
// ==============  
// Returns TRUE if the abort currently being processed is an asynchronous abort, and FALSE otherwise.

boolean IsAsyncAbort(Fault type)  
assert type != Fault_None;
return (type IN {Fault_AsyncExternal, Fault_AsyncParity});
```

Library pseudocode for shared/functions/aborts/IsDebugException

```c
// IsDebugException()  
// ===================  

boolean IsDebugException(FaultRecord fault)  
assert fault.type != Fault_None;
return fault.type == Fault_Debug;
```

Library pseudocode for shared/functions/aborts/IsExternalAbort

```c
// IsExternalAbort()  
// =================  
// Returns TRUE if the abort currently being processed is an external abort and FALSE otherwise.

boolean IsExternalAbort(Fault type)  
assert type != Fault_None;
return (type IN {Fault_SyncExternal, Fault_SyncParity, Fault_SyncExternalOnWalk, Fault_SyncParityOnWalk, Fault_AsyncExternal, Fault_AsyncParity});
```

```c
// IsExternalAbort()  
// ================  

boolean IsExternalAbort(FaultRecord fault)  
return IsExternalAbort(fault.type);
```
Library pseudocode for shared/functions/aborts/IsExternalSyncAbort

```
// IsExternalSyncAbort()
// =====================
// Returns TRUE if the abort currently being processed is an external synchronous abort and FALSE otherwise.

boolean IsExternalSyncAbort(Fault type)
    assert type != Fault_None;
    return (type IN {Fault_SyncExternal, Fault_SyncParity, Fault_SyncExternalOnWalk, Fault_SyncParityOnWalk});

// IsExternalSyncAbort()
// =====================

boolean IsExternalSyncAbort(FaultRecord fault)
    return IsExternalSyncAbort(fault.type);
```

Library pseudocode for shared/functions/aborts/IsFault

```
// IsFault()
// =========
// Return TRUE if a fault is associated with an address descriptor

boolean IsFault(AddressDescriptor addrdesc)
    return addrdesc.fault.type != Fault_None;
```

Library pseudocode for shared/functions/aborts/IsSErrorInterrupt

```
// IsSErrorInterrupt()
// ===================
// Returns TRUE if the abort currently being processed is an SError interrupt, and FALSE otherwise.

boolean IsSErrorInterrupt(Fault type)
    assert type != Fault_None;
    return (type IN {Fault_AsyncExternal, Fault_AsyncParity});

// IsSErrorInterrupt()
// ===================

boolean IsSErrorInterrupt(FaultRecord fault)
    return IsSErrorInterrupt(fault.type);
```

Library pseudocode for shared/functions/aborts/IsSecondStage

```
// IsSecondStage()
// ===============

boolean IsSecondStage(FaultRecord fault)
    assert fault.type != Fault_None;
    return fault.secondstage;
```

Library pseudocode for shared/functions/aborts/LSInstructionSyndrome

```
bits(11) LSInstructionSyndrome();
```
Library pseudocode for shared/functions/common/ASR

```c
// ASR()
// =====

bits(N) ASR(bits(N) x, integer shift)
assert shift >= 0;
if shift == 0 then
    result = x;
else
    (result, -) = ASR_C(x, shift);
return result;
```

Library pseudocode for shared/functions/common/ASR_C

```c
// ASR_C()
// ========

(bits(N), bit) ASR_C(bits(N) x, integer shift)
assert shift > 0;
shift = if shift > N then N else shift;
extended_x = SignExtend(x, shift+N);
result = extended_x<shift+N-1:shift>;
carry_out = extended_x<shift-1>;
return (result, carry_out);
```

Library pseudocode for shared/functions/common/Abs

```c
// Abs()
// =====

integer Abs(integer x)
return if x >= 0 then x else -x;
```

Library pseudocode for shared/functions/common/Abs

```c
// Abs()
// =====

real Abs(real x)
return if x >= 0.0 then x else -x;
```

Library pseudocode for shared/functions/common/Align

```c
// Align()
// ========

integer Align(integer x, integer y)
return y * (x DIV y);
```

Library pseudocode for shared/functions/common/Align

```c
// Align()
// ========

bits(N) Align(bits(N) x, integer y)
return Align(UInt(x), y)<N-1:0>;
```

Library pseudocode for shared/functions/common/BitCount

```c
// BitCount()
// =========

integer BitCount(bits(N) x)
integer result = 0;
for i = 0 to N-1
    if x<i> == '1' then
        result = result + 1;
return result;
```
Library pseudocode for shared/functions/common/CountLeadingSignBits

```plaintext
// CountLeadingSignBits()
// ======================

integer CountLeadingSignBits(bits(N) x)
    return CountLeadingZeroBits(x<N-1:1> EOR x<N-2:0>);
```

Library pseudocode for shared/functions/common/CountLeadingZeroBits

```plaintext
// CountLeadingZeroBits()
// ======================

integer CountLeadingZeroBits(bits(N) x)
    return N - (HighestSetBit(x) + 1);
```

Library pseudocode for shared/functions/common/Elem

```plaintext
// Elem[] - non-assignment form
// -----------------------------

bits(size) Elem[bits(N) vector, integer e, integer size]
    assert e >= 0 && (e+1)*size <= N;
    return vector<e*size+size-1 : e*size>;

// Elem[] - non-assignment form
// -----------------------------

bits(size) Elem[bits(N) vector, integer e]
    return Elem[vector, e, size];

// Elem[] - assignment form
// -------------------------

Elem[bits(N) &vector, integer e, integer size] = bits(size) value
    assert e >= 0 && (e+1)*size <= N;
    vector<(e+1)*size-1:e*size> = value;
    return;

// Elem[] - assignment form
// -------------------------

Elem[bits(N) &vector, integer e] = bits(size) value
    Elem[vector, e, size] = value;
    return;
```

Library pseudocode for shared/functions/common/Extend

```plaintext
// Extend()
// -------

bits(N) Extend(bits(M) x, integer N, boolean unsigned)
    return if unsigned then ZeroExtend(x, N) else SignExtend(x, N);

// Extend()
// -------

bits(N) Extend(bits(M) x, boolean unsigned)
    return Extend(x, N, unsigned);
```
// HighestSetBit()
// ===============
integer HighestSetBit(bits(N) x)
    for i = N-1 downto 0
        if x<i> == '1' then return i;
    return -1;

// Int()
// ======
integer Int(bits(N) x, boolean unsigned)
    result = if unsigned then UInt(x) else SInt(x);
    return result;

// IsOnes()
// ========
boolean IsOnes(bits(N) x)
    return x == Ones(N);

// IsZero()
// ========
boolean IsZero(bits(N) x)
    return x == Zeros(N);

// IsZeroBit()
// ===========
bit IsZeroBit(bits(N) x)
    return if IsZero(x) then '1' else '0';

// LSL()
// ======
bits(N) LSL(bits(N) x, integer shift)
    assert shift >= 0;
    if shift == 0 then
        result = x;
    else
        (result, -) = LSL_C(x, shift);
    return result;
Library pseudocode for shared/functions/common/LSL_C

// LSL_C()
// =======

<bits(N), bit> LSL_C(bits(N) x, integer shift)
assert shift > 0;
shift = if shift > N then N else shift;
extended_x = x : Zeros(shift);
result = extended_x[N-1:0];
carry_out = extended_x[N];
return (result, carry_out);

Library pseudocode for shared/functions/common/LSR

// LSR()
// =====

<bits(N) LSR(bits(N) x, integer shift)
assert shift >= 0;
if shift == 0 then
    result = x;
else
    (result, -) = LSR_C(x, shift);
return result;

Library pseudocode for shared/functions/common/LSR_C

// LSR_C()
// =======

<bits(N), bit> LSR_C(bits(N) x, integer shift)
assert shift > 0;
shift = if shift > N then N else shift;
extended_x = ZeroExtend(x, shift+N);
result = extended_x[shift+N-1:shift];
carry_out = extended_x[shift-1];
return (result, carry_out);

Library pseudocode for shared/functions/common/LowestSetBit

// LowestSetBit()
// ==============

integer LowestSetBit(bits(N) x)
for i = 0 to N-1
    if x[i] == '1' then return i;
return N;

Library pseudocode for shared/functions/common/Max

// Max()
// =====

integer Max(integer a, integer b)
return if a >= b then a else b;

// Max()
// =====

real Max(real a, real b)
return if a >= b then a else b;
Library pseudocode for shared/functions/common/Min

```plaintext
// Min()
// ======

integer Min(integer a, integer b)
    return if a <= b then a else b;

// Min()
// ======

real Min(real a, real b)
    return if a <= b then a else b;
```

Library pseudocode for shared/functions/common/Ones

```plaintext
// Ones()
// ======

bits(N) Ones(integer N)
    return Replicate('1',N);

// Ones()
// ======

bits(N) Ones()
    return Ones(N);
```

Library pseudocode for shared/functions/common/ROR

```plaintext
// ROR()
// ======

bits(N) ROR(bits(N) x, integer shift)
    assert shift >= 0;
    if shift == 0 then
        result = x;
    else
        (result, -) = ROR_C(x, shift);
    return result;
```

Library pseudocode for shared/functions/common/ROR_C

```plaintext
// ROR_C()
// ======

(bits(N), bit) ROR_C(bits(N) x, integer shift)
    assert shift != 0;
    m = shift MOD N;
    result = LSR(x,m) OR LSL(x,N-m);
    carry_out = result<N-1>
    return (result, carry_out);
```

Library pseudocode for shared/functions/common/Replicate

```plaintext
// Replicate()
// =============

bits(N) Replicate(bits(M) x)
    assert N MOD M == 0;
    return Replicate(x, N DIV M);

bits(M*N) Replicate(bits(M) x, integer N);
```
Library pseudocode for shared/functions/common/RoundDown

```plaintext
integer RoundDown(real x);
```

Library pseudocode for shared/functions/common/RoundTowardsZero

```plaintext
// RoundTowardsZero()
// ---------------
integer RoundTowardsZero(real x)
    return if x == 0.0 then 0 else if x >= 0.0 then RoundDown(x) else RoundUp(x);
```

Library pseudocode for shared/functions/common/RoundUp

```plaintext
integer RoundUp(real x);
```

Library pseudocode for shared/functions/common/SInt

```plaintext
// SInt()
// ------
integer SInt(bits(N) x)
    result = 0;
    for i = 0 to N-1
        if x<i> == '1' then result = result + 2^i;
        if x<N-1> == '1' then result = result - 2^N;
    return result;
```

Library pseudocode for shared/functions/common/SignExtend

```plaintext
// SignExtend()
// ============
bits(N) SignExtend(bits(M) x, integer N)
    assert N >= M;
    return Replicate(x<M-1>, N-M) : x;

// SignExtend()
// ============
bits(N) SignExtend(bits(M) x)
    return SignExtend(x, N);
```

Library pseudocode for shared/functions/common/UInt

```plaintext
// UInt()
// ------
integer UInt(bits(N) x)
    result = 0;
    for i = 0 to N-1
        if x<i> == '1' then result = result + 2^i;
    return result;
```
Library pseudocode for shared/functions/common/ZeroExtend

```c
// ZeroExtend()
// ============
bits(N) ZeroExtend(bits(M) x, integer N)
    assert N >= M;
    return Zeros(N-M) : x;
// ZeroExtend()
// ============
bits(N) ZeroExtend(bits(M) x)
    return ZeroExtend(x, N);
```

Library pseudocode for shared/functions/common/Zeros

```c
// Zeros()
// ========
bits(N) Zeros(integer N)
    return Replicate('0',N);
// Zeros()
// ========
bits(N) Zeros()
    return Zeros(N);
```

Library pseudocode for shared/functions/crc/BitReverse

```c
// BitReverse()
// ===========
bits(N) BitReverse(bits(N) data)
    bits(N) result;
    for i = 0 to N-1
        result<N-i-1> = data<i>;
    return result;
```

Library pseudocode for shared/functions/crc/HaveCRCExt

```c
// HaveCRCExt()
// ===========
boolean HaveCRCExt()
    return HasArchVersion(ARMv8p1) || boolean IMPLEMENTATION_DEFINED "Have CRC extension";
```

Library pseudocode for shared/functions/crc/Poly32Mod2

```c
// Poly32Mod2()
// ===========
// Poly32Mod2 on a bitstring does a polynomial Modulus over {0,1} operation
bits(32) Poly32Mod2(bits(N) data, bits(32) poly)
    assert N > 32;
    for i = N-1 downto 32
        if data<i> == '1' then
            data<i-1:0> = data<i-1:0> EOR (poly:Zeros(i-32));
        end
    return data<31:0>;
```

Library pseudocode for shared/functions/crypto/AESInvMixColumns

```c
bits(128) AESInvMixColumns(bits (128) op);
```
Library pseudocode for shared/functions/crypto/AESInvShiftRows

```plaintext
bits(128) AESInvShiftRows(bits(128) op);
```

Library pseudocode for shared/functions/crypto/AESInvSubBytes

```plaintext
bits(128) AESInvSubBytes(bits(128) op);
```

Library pseudocode for shared/functions/crypto/AESMixColumns

```plaintext
bits(128) AESMixColumns(bits (128) op);
```

Library pseudocode for shared/functions/crypto/AESShiftRows

```plaintext
bits(128) AESShiftRows(bits(128) op);
```

Library pseudocode for shared/functions/crypto/AESSubBytes

```plaintext
bits(128) AESSubBytes(bits(128) op);
```

Library pseudocode for shared/functions/crypto/HaveAESExt

```plaintext
// HaveAESExt()
// ============
// TRUE if AES cryptographic instructions support is implemented,
// FALSE otherwise.
boolean HaveAESExt()
    return boolean IMPLEMENTATION_DEFINED "Has AES Crypto instructions";
```

Library pseudocode for shared/functions/crypto/HaveBit128PMULLExt

```plaintext
// HaveBit128PMULLExt()
// ==============
// TRUE if 128 bit form of PMULL instructions support is implemented,
// FALSE otherwise.
boolean HaveBit128PMULLExt()
    return boolean IMPLEMENTATION_DEFINED "Has 128-bit form of PMULL instructions";
```

Library pseudocode for shared/functions/crypto/HaveSHA1Ext

```plaintext
// HaveSHA1Ext()
// =============
// TRUE if SHA1 cryptographic instructions support is implemented,
// FALSE otherwise.
boolean HaveSHA1Ext()
    return boolean IMPLEMENTATION_DEFINED "Has SHA1 Crypto instructions";
```

Library pseudocode for shared/functions/crypto/HaveSHA256Ext

```plaintext
// HaveSHA256Ext()
// ===============
// TRUE if SHA256 cryptographic instructions support is implemented,
// FALSE otherwise.
boolean HaveSHA256Ext()
    return boolean IMPLEMENTATION_DEFINED "Has SHA256 Crypto instructions";
```
Library pseudocode for shared/functions/crypto/HaveSHA3Ext

// HaveSHA3Ext()
// =============
// TRUE if SHA3 cryptographic instructions support is implemented,
// and when SHA1 and SHA2 basic cryptographic instructions support is implemented,
// FALSE otherwise.

boolean HaveSHA3Ext()
if !HasArchVersion(ARMv8p2) || !(HaveSHA1Ext() && HaveSHA256Ext()) then
    return FALSE;
return boolean IMPLEMENTATION_DEFINED "Has SHA3 Crypto instructions";

Library pseudocode for shared/functions/crypto/HaveSHA512Ext

// HaveSHA512Ext()
// ===============
// TRUE if SHA512 cryptographic instructions support is implemented,
// and when SHA1 and SHA2 basic cryptographic instructions support is implemented,
// FALSE otherwise.

boolean HaveSHA512Ext()
if !HasArchVersion(ARMv8p2) || !(HaveSHA1Ext() && HaveSHA256Ext()) then
    return FALSE;
return boolean IMPLEMENTATION_DEFINED "Has SHA512 Crypto instructions";

Library pseudocode for shared/functions/crypto/HaveSM3Ext

// HaveSM3Ext()
// ============
// TRUE if SM3 cryptographic instructions support is implemented,
// FALSE otherwise.

boolean HaveSM3Ext()
if !HasArchVersion(ARMv8p2) then
    return FALSE;
return boolean IMPLEMENTATION_DEFINED "Has SM3 Crypto instructions";

Library pseudocode for shared/functions/crypto/HaveSM4Ext

// HaveSM4Ext()
// ============
// TRUE if SM4 cryptographic instructions support is implemented,
// FALSE otherwise.

boolean HaveSM4Ext()
if !HasArchVersion(ARMv8p2) then
    return FALSE;
return boolean IMPLEMENTATION_DEFINED "Has SM4 Crypto instructions";

Library pseudocode for shared/functions/crypto/ROL

// ROL()
// =====

bits(N) ROL(bits(N) x, integer shift)
assert shift >= 0 && shift <= N;
if (shift == 0) then
    return x;
return ROR(x, N-shift);
Library pseudocode for shared/functions/crypto/SHA256hash

// SHA256hash()
// ============

bits(128) SHA256hash(bits(128) X, bits(128) Y, bits(128) W, boolean part1)
    bits(32) chs, maj, t;
    for e = 0 to 3
        chs = SHAchoose(Y<31:0>, Y<63:32>, Y<95:64>);
        maj = SHAmajority(X<31:0>, X<63:32>, X<95:64>);
        t = Y<127:96> + SHAhashSIGMA1(Y<31:0>) + chs + Elem[W, e, 32];
        X<127:96> = t + X<127:96>;
        Y<127:96> = t + SHAhashSIGMA0(X<31:0>) + maj;
        <Y, X> = ROL(Y : X, 32);
    return (if part1 then X else Y);

Library pseudocode for shared/functions/crypto/SHAchoose

// SHAchoose()
// ===========

bits(32) SHAchoose(bits(32) x, bits(32) y, bits(32) z)
    return (((y EOR z) AND x) EOR z);

Library pseudocode for shared/functions/crypto/SHAhashSIGMA0

// SHAhashSIGMA0()
// ===============

bits(32) SHAhashSIGMA0(bits(32) x)
    return ROR(x, 2) EOR ROR(x, 13) EOR ROR(x, 22);

Library pseudocode for shared/functions/crypto/SHAhashSIGMA1

// SHAhashSIGMA1()
// ===============

bits(32) SHAhashSIGMA1(bits(32) x)
    return ROR(x, 6) EOR ROR(x, 11) EOR ROR(x, 25);

Library pseudocode for shared/functions/crypto/SHAmajority

// SHAmajority()
// =============

bits(32) SHAmajority(bits(32) x, bits(32) y, bits(32) z)
    return ((x AND y) OR ((x OR y) AND z));

Library pseudocode for shared/functions/crypto/SHAparity

// SHAparity()
// ===========

bits(32) SHAparity(bits(32) x, bits(32) y, bits(32) z)
    return (x EOR y EOR z);
Library pseudocode for shared/functions/crypto/Sbox

// Sbox()
// ======
// Used in SM4E crypto instruction

bits(8) Sbox(bits(8) sboxin)
  bits(8) sboxout;
  bits(2048) sboxstring = ... f11d95c411f105ad80ac13188a5cd7bbd2d74d012b8e5b4b08969974a0c96777e65b9f109c56ec68418f07dec3adc4d2079ee5f3ed7cb3948<2047:0>;
  sboxout = sboxstring<(255-UInt(sboxin))*8+7:(255-UInt(sboxin))*8>;
return sboxout;

Library pseudocode for shared/functions/exclusive/ClearExclusiveByAddress

// Clear the global Exclusives monitors for all PEs EXCEPT processorid if they
// record any part of the physical address region of size bytes starting at paddress.
// It is IMPLEMENTATION DEFINED whether the global Exclusives monitor for processorid
// is also cleared if it records any part of the address region.
ClearExclusiveByAddress(FullAddress paddress, integer processorid, integer size);

Library pseudocode for shared/functions/exclusive/ClearExclusiveLocal

// Clear the local Exclusives monitor for the specified processorid.
ClearExclusiveLocal(integer processorid);

Library pseudocode for shared/functions/exclusive/ClearExclusiveMonitors

// ClearExclusiveMonitors()
// ========================
// Clear the local Exclusives monitor for the executing PE.
ClearExclusiveMonitors()
  ClearExclusiveLocal(ProcessorID());

Library pseudocode for shared/functions/exclusive/ExclusiveMonitorsStatus

// Returns '0' to indicate success if the last memory write by this PE was to
// the same physical address region endorsed by ExclusiveMonitorsPass().
// Returns '1' to indicate failure if address translation resulted in a different
// physical address.
bit ExclusiveMonitorsStatus();

Library pseudocode for shared/functions/exclusive/IsExclusiveGlobal

// Return TRUE if the global Exclusives monitor for processorid includes all of
// the physical address region of size bytes starting at paddress.
boolean IsExclusiveGlobal(FullAddress paddress, integer processorid, integer size);

Library pseudocode for shared/functions/exclusive/IsExclusiveLocal

// Return TRUE if the local Exclusives monitor for processorid includes all of
// the physical address region of size bytes starting at paddress.
boolean IsExclusiveLocal(FullAddress paddress, integer processorid, integer size);

Library pseudocode for shared/functions/exclusive/MarkExclusiveGlobal

// Record the physical address region of size bytes starting at paddress in
// the global Exclusives monitor for processorid.
MarkExclusiveGlobal(FullAddress paddress, integer processorid, integer size);
Library pseudocode for shared/functions/exclusive/MarkExclusiveLocal

```c
// Record the physical address region of size bytes starting at paddress in
// the local Exclusives monitor for processorid.
MarkExclusiveLocal(FullAddress paddress, integer processorid, integer size);
```

Library pseudocode for shared/functions/exclusive/ProcessorID

```c
// Return the ID of the currently executing PE.
integer ProcessorID();
```

Library pseudocode for shared/functions/extension/AArch32.HaveHPDExt

```c
// AArch32.HaveHPDExt()
// ---------------------
boolean AArch32.HaveHPDExt()
return HasArchVersion(ARMv8p2);
```

Library pseudocode for shared/functions/extension/AArch64.HaveHPDExt

```c
// AArch64.HaveHPDExt()
// ---------------------
boolean AArch64.HaveHPDExt()
return HasArchVersion(ARMv8p1);
```

Library pseudocode for shared/functions/extension/Have52BitPAExt

```c
// Have52BitPAExt()
// ----------------
boolean Have52BitPAExt()
return HasArchVersion(ARMv8p2);
```

Library pseudocode for shared/functions/extension/Have52BitVAExt

```c
// Have52BitVAExt()
// ----------------
boolean Have52BitVAExt()
return HasArchVersion(ARMv8p2);
```

Library pseudocode for shared/functions/extension/HaveAtomicExt

```c
// HaveAtomicExt()
// ----------------
boolean HaveAtomicExt()
return HasArchVersion(ARMv8p1);
```

Library pseudocode for shared/functions/extension/HaveBTIExt

```c
// HaveBTIExt()
// ------------
// Returns TRUE if BTI implemented and FALSE otherwise
boolean HaveBTIExt()
return HasArchVersion(ARMv8p5);
```
Library pseudocode for shared/functions/extension/HaveBlockBBM

```java
// HaveBlockBBM()
// ==============
// Returns TRUE if support for changing block size without requring break-before-make is implemented.
boolean HaveBlockBBM()
return HasArchVersion(ARMv8p4);
```

Library pseudocode for shared/functions/extension/HaveCommonNotPrivateTransExt

```java
// HaveCommonNotPrivateTransExt()
// ==============================
boolean HaveCommonNotPrivateTransExt()
return HasArchVersion(ARMv8p2);
```

Library pseudocode for shared/functions/extension/HaveDITExt

```java
// HaveDITExt()
// ============
boolean HaveDITExt()
return HasArchVersion(ARMv8p4);
```

Library pseudocode for shared/functions/extension/HaveDOTPExt

```java
// HaveDOTPExt()
// =============
// Returns TRUE if has Dot Product feature support, and FALSE otherwise.
boolean HaveDOTPExt()
return HasArchVersion(ARMv8p4) || (HasArchVersion(ARMv8p2) && boolean IMPLEMENTATION_DEFINED "Has Dot Product extension");
```

Library pseudocode for shared/functions/extension/HaveDoubleFaultExt

```java
// HaveDoubleFaultExt()
// ====================
boolean HaveDoubleFaultExt()
return (HasArchVersion(ARMv8p4) && HaveEL(EL3) && !ELUsingAArch32(EL3) && HaveIESB());
```

Library pseudocode for shared/functions/extension/HaveDoubleLock

```java
// HaveDoubleLock()
// ================
// Returns TRUE if support for the OS Double Lock is implemented
boolean HaveDoubleLock()
return !HasArchVersion(ARMv8p4) || boolean IMPLEMENTATION_DEFINED "OS Double Lock is implemented";
```

Library pseudocode for shared/functions/extension/HaveE0PDExt

```java
// HaveE0PDExt()
// =============
// Returns TRUE if support for constant fault times for unprivileged accesses
// to the memory map is implemented.
boolean HaveE0PDExt()
return HasArchVersion(ARMv8p5);
```
Library pseudocode for shared/functions/extension/HaveExtendedCacheSets

```java
// HaveExtendedCacheSets()
// =======================
boolean HaveExtendedCacheSets()
    return HasArchVersion(ARMv8p3);
```

Library pseudocode for shared/functions/extension/HaveExtendedECDebugEvents

```java
// HaveExtendedECDebugEvents()
// ===========================
boolean HaveExtendedECDebugEvents()
    return HasArchVersion(ARMv8p2);
```

Library pseudocode for shared/functions/extension/HaveExtendedExecuteNeverExt

```java
// HaveExtendedExecuteNeverExt()
// =============================
boolean HaveExtendedExecuteNeverExt()
    return HasArchVersion(ARMv8p2);
```

Library pseudocode for shared/functions/extension/HaveFCADDExt

```java
// HaveFCADDExt()
// ==============
boolean HaveFCADDExt()
    return HasArchVersion(ARMv8p3);
```

Library pseudocode for shared/functions/extension/HaveFJCVTZSExt

```java
// HaveFJCVTZSExt()
// ================
boolean HaveFJCVTZSExt()
    return HasArchVersion(ARMv8p3);
```

Library pseudocode for shared/functions/extension/HaveFP16MulNoRoundingToFP32Ext

```java
// HaveFP16MulNoRoundingToFP32Ext()
// =================================
// Returns TRUE if has FP16 multiply with no intermediate rounding accumulate to FP32 instructions,
// and FALSE otherwise
boolean HaveFP16MulNoRoundingToFP32Ext()
    if !HaveFP16Ext() then return FALSE;
    if HasArchVersion(ARMv8p4) then return TRUE;
    return (HasArchVersion(ARMv8p2) &&
        boolean IMPLEMENTATION_DEFINED "Has accumulate FP16 product into FP32 extension");
```

Library pseudocode for shared/functions/extension/HaveFlagFormatExt

```java
// HaveFlagFormatExt()
// ===================
// Returns TRUE if flag format conversion instructions implemented
// and FALSE otherwise
boolean HaveFlagFormatExt()
    return HasArchVersion(ARMv8p5);
```
// HaveFlagManipulateExt()
// ----------------------
// Returns TRUE if has flag manipulate instructions, and FALSE otherwise

boolean HaveFlagManipulateExt()
    return HasArchVersion(ARMv8p4);

// HaveFrintExt()
// ==============
// Returns TRUE if FRINT instructions are implemented and FALSE otherwise

boolean HaveFrintExt()
    return HasArchVersion(ARMv8p5);

// HaveHPMDExt()
// =============

boolean HaveHPMDExt()
    return HasArchVersion(ARMv8p1);

// HaveIESB()
// ===========

boolean HaveIESB()
    return (HaveRASExt() &&
            boolean IMPLEMENTATION_DEFINED "Has Implicit Error Synchronization Barrier");

// HaveMPAMExt()
// =============

boolean HaveMPAMExt()
    return (HasArchVersion(ARMv8p2) &&
            boolean IMPLEMENTATION_DEFINED "Has MPAM extension");

// HaveMTEExt()
// ============

boolean HaveMTEExt()
    if !HasArchVersion(ARMv8p5) then
        return FALSE;
    return boolean IMPLEMENTATION_DEFINED "Has MTE extension";

// HaveNV2Ext()
// ============

boolean HaveNV2Ext()
    return HasArchVersion(ARMv8p4);
Library pseudocode for shared/functions/extension/HaveNVExt

```java
// HaveNVExt()
// ============

boolean HaveNVExt()
    return HasArchVersion(ARMv8p3);
```

Library pseudocode for shared/functions/extension/HaveNoSecurePMUDisableOverride

```java
// HaveNoSecurePMUDisableOverride()
// =================================

boolean HaveNoSecurePMUDisableOverride()
    return HasArchVersion(ARMv8p2);
```

Library pseudocode for shared/functions/extension/HaveNoninvasiveDebugAuth

```java
// HaveNoninvasiveDebugAuth()
// ===========================

// Returns FALSE if support for the removal of the non-invasive Debug controls is implemented.

boolean HaveNoninvasiveDebugAuth()
    return !HasArchVersion(ARMv8p4);
```

Library pseudocode for shared/functions/extension/HavePANExt

```java
// HavePANExt()
// ============

boolean HavePANExt()
    return HasArchVersion(ARMv8p1);
```

Library pseudocode for shared/functions/extension/HavePageBasedHardwareAttributes

```java
// HavePageBasedHardwareAttributes()
// =================================

boolean HavePageBasedHardwareAttributes()
    return HasArchVersion(ARMv8p2);
```

Library pseudocode for shared/functions/extension/HavePrivATExt

```java
// HavePrivATExt()
// ===============

boolean HavePrivATExt()
    return HasArchVersion(ARMv8p2);
```

Library pseudocode for shared/functions/extension/HaveQRDMLAHExt

```java
// HaveQRDMLAHExt()
// ================

boolean HaveQRDMLAHExt()
    return HasArchVersion(ARMv8p1);

boolean HaveAccessFlagUpdateExt()
    return HasArchVersion(ARMv8p1);

boolean HaveDirtyBitModifierExt()
    return HasArchVersion(ARMv8p1);
```
// HaveRASExt()
// ============
boolean HaveRASExt()
return (HasArchVersion(ARMv8p2) || boolean IMPLEMENTATION_DEFINED "Has RAS extension");

// HaveSBExt()
// ===========
// Returns TRUE if has SB feature support, and FALSE otherwise.
boolean HaveSBExt()
return HasArchVersion(ARMv8p5) || boolean IMPLEMENTATION_DEFINED "Has SB extension");

// HaveSSBSExt()
// =============
// Returns TRUE if has SSBS feature support, and FALSE otherwise.
boolean HaveSSBSExt()
return HasArchVersion(ARMv8p5) || boolean IMPLEMENTATION_DEFINED "Has SSBS extension");

// HaveSecureEL2Ext()
// ==================
// Returns TRUE if has Secure EL2, and FALSE otherwise.
boolean HaveSecureEL2Ext()
return HasArchVersion(ARMv8p4);

// HaveSecureExtDebugView()
// =========================
// Returns TRUE if supports Secure and Non-secure views of debug peripherals is implemented.
boolean HaveSecureExtDebugView()
return HasArchVersion(ARMv8p4);

// HaveSelfHostedTrace()
// =====================
boolean HaveSelfHostedTrace()
return HasArchVersion(ARMv8p4);

// HaveSmallPageTblExt()
// ======================
// Returns TRUE if has Small Page Table Support, and FALSE otherwise.
boolean HaveSmallPageTblExt()
return HasArchVersion(ARMv8p4) && boolean IMPLEMENTATION_DEFINED "Has Small Page Table extension";
// HaveStage2MemAttrControl()
// =========================
// Returns TRUE if support for Stage2 control of memory types and cacheability attributes is implemented.

boolean HaveStage2MemAttrControl()
return HasArchVersion(ARMv8p4);

// HaveStatisticalProfiling()
// ==========================

boolean HaveStatisticalProfiling()
return HasArchVersion(ARMv8p2);

// HaveTrapLoadStoreMultipleDeviceExt()
// ====================================

boolean HaveTrapLoadStoreMultipleDeviceExt()
return HasArchVersion(ARMv8p2);

// HaveUA16Ext()
// =============

// Returns TRUE if has extended unaligned memory access support, and FALSE otherwise

boolean HaveUA16Ext()
return HasArchVersion(ARMv8p4);

// HaveUAOExt()
// ============

boolean HaveUAOExt()
return HasArchVersion(ARMv8p2);

// HaveVirtHostExt()
// =================

boolean HaveVirtHostExt()
return HasArchVersion(ARMv8p1);

// InsertIESBBeforeException()
// If SCTLR_ELx.IESB is 1 when an exception is generated to ELx, any pending Unrecoverable
// SError interrupt must be taken before executing any instructions in the exception handler.
// However, this can be before the branch to the exception handler is made.

boolean InsertIESBBeforeException(bits(2) el);
Library pseudocode for shared/functions/float/fixedtofp/FixedToFP

```plaintext
// FixedToFP()
// ===========
// Convert M-bit fixed point OP with FBITS fractional bits to
// N-bit precision floating point, controlled by UNSIGNED and ROUNDDING.

// (bits(N) FixedToFP(bits(M) op, integer fbits, boolean unsigned, FPCRType fpcr, FPRounding rounding)
assert N IN {16,32,64};
assert M IN {16,32,64};
bits(N) result;
assert fbits >= 0;
assert rounding != FPRounding_ODD;
// Correct signed-ness
int_operand = Int(op, unsigned);
// Scale by fractional bits and generate a real value
real_operand = Real(int_operand) / 2.0^fbits;
if real_operand == 0.0 then
  result = FPZero('0');
else
  result = FPRound(real_operand, fpcr, rounding);
return result;
```

Library pseudocode for shared/functions/float/fpabs/FPAbs

```plaintext
// FPAbs()
// =======
// bits(N) FPAbs(bits(N) op)
assert N IN {16,32,64};
return '0' : op<N-2:0>;
```

Library pseudocode for shared/functions/float/fpadd/FPAdd

```plaintext
// FPAdd()
// =======
// bits(N) FPAdd(bits(N) op1, bits(N) op2, FPCRType fpcr)
assert N IN {16,32,64};
rounding = FPRoundingMode(fpcr);
(type1,sign1,value1) = FPUnpack(op1, fpcr);
(type2,sign2,value2) = FPUnpack(op2, fpcr);
(done,result) = FPProcessNaNs(type1, type2, op1, op2, fpcr);
if !done then
  inf1 = (type1 == FPType_Infinity); inf2 = (type2 == FPType_Infinity);
  zero1 = (type1 == FPType_Zero); zero2 = (type2 == FPType_Zero);
  if inf1 && inf2 && sign1 == NOT(sign2) then
    result = FPDefaultNaN();
    FPProcessException(FPExc_InvalidOp, fpcr);
  elsif (inf1 && sign1 == '0') || (inf2 && sign2 == '0') then
    result = FPInfinity('0');
  elsif (inf1 && sign1 == '1') || (inf2 && sign2 == '1') then
    result = FPInfinity('1');
  elsif zero1 && zero2 && sign1 == sign2 then
    result = FPZero(sign1);
  else
    result_value = value1 + value2;
    if result_value == 0.0 then // Sign of exact zero result depends on rounding mode
      result_sign = if rounding == FPRounding_NEGINF then '1' else '0';
      result = FPZero(result_sign);
    else
      result = FPRound(result_value, fpcr, rounding);
  endif
else
  result = FPZero(sign1);
endif
return result;
```
Library pseudocode for shared/functions/float/fpcompare/FPCompare

```c
// FPCompare()
// ===========

bits(4) FPCompare(bits(N) op1, bits(N) op2, boolean signal_nans, FPCRType fpcr)
assert N IN {16,32,64};
(type1,sign1,value1) = FPUnpack(op1, fpcr);
(type2,sign2,value2) = FPUnpack(op2, fpcr);
if type1==FPType_SNaN || type1==FPType_QNaN || type2==FPType_SNaN || type2==FPType_QNaN then
    result = '0011';
else
    if type1==FPType_SNaN || type2==FPType_SNaN || signal_nans then
        FPProcessException(FPExc_InvalidOp, fpcr);
    else
        // All non-NaN cases can be evaluated on the values produced by FPUnpack()
        if value1 == value2 then
            result = '0110';
        elsif value1 < value2 then
            result = '1000';
        else  // value1 > value2
            result = '0010';
    end
return result;
```

Library pseudocode for shared/functions/float/fpcompareeq/FPCompareEQ

```c
// FPCompareEQ()
// =============

boolean FPCompareEQ(bits(N) op1, bits(N) op2, FPCRType fpcr)
assert N IN {16,32,64};
(type1,sign1,value1) = FPUnpack(op1, fpcr);
(type2,sign2,value2) = FPUnpack(op2, fpcr);
if type1==FPType_SNaN || type1==FPType_QNaN || type2==FPType_SNaN || type2==FPType_QNaN then
    result = FALSE;
else
    // All non-NaN cases can be evaluated on the values produced by FPUnpack()
    result = (value1 == value2);
return result;
```

Library pseudocode for shared/functions/float/fpcomparege/FPCompareGE

```c
// FPCompareGE()
// =============

boolean FPCompareGE(bits(N) op1, bits(N) op2, FPCRType fpcr)
assert N IN {16,32,64};
(type1,sign1,value1) = FPUnpack(op1, fpcr);
(type2,sign2,value2) = FPUnpack(op2, fpcr);
if type1==FPType_SNaN || type1==FPType_QNaN || type2==FPType_SNaN || type2==FPType_QNaN then
    result = FALSE;
else
    // All non-NaN cases can be evaluated on the values produced by FPUnpack()
    result = (value1 >= value2);
return result;
```
// FPCompareGT()
// =============

boolean FPCompareGT(bits(N) op1, bits(N) op2, FPCRType fpcr)
assert N IN {16,32,64};
(type1,sign1,value1) = FPUnpack(op1, fpcr);
(type2,sign2,value2) = FPUnpack(op2, fpcr);
if type1==FPType_SNaN || type1==FPType_QNaN || type2==FPType_SNaN || type2==FPType_QNaN then
    result = FALSE;
    FPProcessException(FPExc_InvalidOp, fpcr);
else
    // All non-NaN cases can be evaluated on the values produced by FPUnpack()
    result = (value1 > value2);
    return result;

// FPConvert()
// ===========

bits(M) FPConvert(bits(N) op, FPCRType fpcr, FPRounding rounding)
assert M IN {16,32,64};
assert N IN {16,32,64};
bits(M) result;

// Unpack floating-point operand optionally with flush-to-zero.
(type,sign,value) = FPUnpackCV(op, fpcr);
alt_hp = (M == 16) && (fpcr.AHP == '1');
if type == FPType_SNaN || type == FPType_QNaN then
    if alt_hp then
        result = FPZero(sign);
    elsif fpcr.DN == '1' then
        result = FPDefaultNaN();
    else
        result = FPConvertNaN(op);
    if type == FPType_SNaN || alt_hp then
        FPProcessException(FPExc_InvalidOp, fpcr);
    elsif type == FPType_Infinity then
        if alt_hp then
            result = sign:Ones(M-1);
            FPProcessException(FPExc_InvalidOp, fpcr);
        else
            result = FPInfinity(sign);
        elsif type == FPType_Zero then
            result = FPZero(sign);
        else
            result = FPRoundCV(value, fpcr, rounding);
        return result;
    // FPConvert()
    // ===========

bits(M) FPConvert(bits(N) op, FPCRType fpcr)
return FPConvert(op, fpcr, FPRoundingMode(fpcr));
Library pseudocode for shared/functions/float/fpconvertnan/FPConvertNaN

```plaintext
// FPConvertNaN()
// ==============
// Converts a NaN of one floating-point type to another

bits(M) FPConvertNaN(bits(N) op)
assert N IN {16,32,64};
assert M IN {16,32,64};
bits(M) result;
bits(51) frac;

sign = op<N-1>;

// Unpack payload from input NaN
case N of
  when 64 frac = op<50:0>;
  when 32 frac = op<21:0>: Zeros(29);
  when 16 frac = op<8:0>: Zeros(42);
// Repack payload into output NaN, while
// converting an SNaN to a QNaN.
case M of
  when 64 result = sign:Ones(M-52):frac;
  when 32 result = sign:Ones(M-23):frac<50:29>;
  when 16 result = sign:Ones(M-10):frac<50:42>;
return result;
```

Library pseudocode for shared/functions/float/fpcrtype/FPCRType

```plaintext
type FPCRType;
```

Library pseudocode for shared/functions/float/fpdecoderm/FPDecodeRM

```plaintext
// FPDecodeRM()
// ============
// Decode most common AArch32 floating-point rounding encoding.

FPRounding FPDecodeRM(bits(2) rm)
case rm of
  when '00' return FPRounding_TIEAWAY; // A
  when '01' return FPRounding_TIEEVEN; // N
  when '10' return FPRounding_POSINF; // P
  when '11' return FPRounding_NEGINF; // M
```

Library pseudocode for shared/functions/float/fpdecoderounding/FPDecodeRounding

```plaintext
// FPDecodeRounding()
// ================
// Decode floating-point rounding mode and common AArch64 encoding.

FPRounding FPDecodeRounding(bits(2) rmode)
case rmode of
  when '00' return FPRounding_TIEEVEN; // N
  when '01' return FPRounding_POSINF; // P
  when '10' return FPRounding_NEGINF; // M
  when '11' return FPRounding_ZERO; // Z
```
Library pseudocode for shared/functions/float/fpdefaultnan/FPDefaultNaN

```pseudocode
// FPDefaultNaN()
// ===============
bits(N) FPDefaultNaN()
assert N IN {16,32,64};
constant integer E = (if N == 16 then 5 elsif N == 32 then 8 else 11);
constant integer F = N - (E + 1);
sign = '0';
exp = Ones(E);
frac = '1':Zeros(F-1);
return sign : exp : frac;
```

Library pseudocode for shared/functions/float/fpdiv/FPDiv

```pseudocode
// FPDiv()
// ========
bits(N) FPDiv(bits(N) op1, bits(N) op2, FPCRType fpcr)
assert N IN {16,32,64};
(type1,sign1,value1) = FPUnpack(op1, fpcr);
(type2,sign2,value2) = FPUnpack(op2, fpcr);
(done,result) = FPProcessNaNs(type1, type2, op1, op2, fpcr);
if !done then
    inf1 = (type1 == FPType_Infinity);
    inf2 = (type2 == FPType_Infinity);
    zero1 = (type1 == FPType_Zero);
    zero2 = (type2 == FPType_Zero);
    if (inf1 && inf2) || (zero1 && zero2) then
        result = FPDefaultNaN();
    else
        result = FPInfinity(sign1 EOR sign2);
    endif
elsif inf1 || zero2 then
    result = FPInfinity(sign1 EOR sign2);
else
    result = FPZero(sign1 EOR sign2);
else
    result = FPRound(value1/value2, fpcr);
return result;
```

Library pseudocode for shared/functions/float/fpexc/FPExc

```pseudocode
enumeration FPExc {FPExc_InvalidOp, FPExc_DivideByZero, FPExc_Overflow, FPExc_Underflow, FPExc_Inexact, FPExc_InputDenorm};
```

Library pseudocode for shared/functions/float/fpinfinity/FPInfinity

```pseudocode
// FPInfinity()
// ============
bits(N) FPInfinity(bit sign)
assert N IN {16,32,64};
constant integer E = (if N == 16 then 5 elsif N == 32 then 8 else 11);
constant integer F = N - (E + 1);
exp = Ones(E);
frac = Zeros(F);
return sign : exp : frac;
```
Library pseudocode for shared/functions/float/fpmax/FPMax

```c
// FPMax()
// =========

bits(N) FPMax(bits(N) op1, bits(N) op2, FPCRType fpcr)
assert N IN {16,32,64};
(type1,sign1,value1) = FPUnpack(op1, fpcr);
(type2,sign2,value2) = FPUnpack(op2, fpcr);
(done,result) = FPProcessNaNs(type1, type2, op1, op2, fpcr);
if !done then
  if value1 > value2 then
    (type,sign,value) = (type1,sign1,value1);
  else
    (type,sign,value) = (type2,sign2,value2);
  if type == FPType_Infinity then
    result = FPInfinity(sign);
  elsif type == FPType_Zero then
    sign = sign1 AND sign2; // Use most positive sign
    result = FPZero(sign);
  else
    // The use of FPRound() covers the case where there is a trapped underflow exception
    // for a denormalized number even though the result is exact.
    result = FPRound(value, fpcr);
  return result;
```

Library pseudocode for shared/functions/float/fpmaxnormal/FPMaxNormal

```c
// FPMaxNormal()
// =============

bits(N) FPMaxNormal(bit sign)
assert N IN {16,32,64};
constant integer E = (if N == 16 then 5 elsif N == 32 then 8 else 11);
constant integer F = N - (E + 1);
exp = Ones(E-1):'0';
frac = Ones(F);
return sign : exp : frac;
```

Library pseudocode for shared/functions/float/fpmaxnum/FPMaxNum

```c
// FPMaxNum()
// ===========

bits(N) FPMaxNum(bits(N) op1, bits(N) op2, FPCRType fpcr)
assert N IN {16,32,64};
(type1,~,~) = FPUnpack(op1, fpcr);
(type2,~,~) = FPUnpack(op2, fpcr);
// treat a single quiet-NaN as -Infinity
if type1 == FPType_QNaN && type2 != FPType_QNaN then
  op1 = FPInfinity('1');
elsif type1 != FPType_QNaN && type2 == FPType_QNaN then
  op2 = FPInfinity('1');
return FPMax(op1, op2, fpcr);
```
// FPMin()
// ========

bits(N) FPMin(bits(N) op1, bits(N) op2, FPCRType fpcr)
assert N IN {16,32,64};
(type1,sign1,value1) = FPUnpack(op1, fpcr);
(type2,sign2,value2) = FPUnpack(op2, fpcr);
(done,result) = FPProcessNaNs(type1, type2, op1, op2, fpcr);
if !done then
  if value1 < value2 then
    (type,sign,value) = (type1,sign1,value1);
  else
    (type,sign,value) = (type2,sign2,value2);
  if type == FPType_Infinity then
    result = FPInfinity(sign);
  elsif type == FPType_Zero then
    sign = sign1 OR sign2; // Use most negative sign
    result = FPZero(sign);
  else
    // The use of FPRound() covers the case where there is a trapped underflow exception
    // for a denormalized number even though the result is exact.
    result = FPRound(value, fpcr);
  return result;

// FPMinNum()
// ===========

bits(N) FPMinNum(bits(N) op1, bits(N) op2, FPCRType fpcr)
assert N IN {16,32,64};
(type1,_,_) = FPUnpack(op1, fpcr);
(type2,_,_) = FPUnpack(op2, fpcr);

// Treat a single quiet-NaN as +Infinity
if type1 == FPType_QNaN && type2 != FPType_QNaN then
  op1 = FPInfinity('0');
elsif type1 != FPType_QNaN && type2 == FPType_QNaN then
  op2 = FPInfinity('0');
return FPMin(op1, op2, fpcr);
// FPMul()  
// ========

bits(N) FPMul(bits(N) op1, bits(N) op2, FPCRType fpcr)  
assert N IN {16,32,64};  
(type1,sign1,value1) = FPUnpack(op1, fpcr);  
(type2,sign2,value2) = FPUnpack(op2, fpcr);  
(done,result) = FPProcessNaNs(type1, type2, op1, op2, fpcr);  
if !done then
  inf1 = (type1 == FPType_Infinity);  
  inf2 = (type2 == FPType_Infinity);  
  zero1 = (type1 == FPType_Zero);  
  zero2 = (type2 == FPType_Zero);  
  if (inf1 && zero2) || (zero1 && inf2) then
    result = FPDefaultNaN();  
    FPProcessException(FPExc_InvalidOp, fpcr);  
  elsif inf1 || inf2 then
    result = FPInfinity(sign1 EOR sign2);  
  elsif zero1 || zero2 then
    result = FPZero(sign1 EOR sign2);  
  else
    result = FPRound(value1*value2, fpcr);  
return result;
Library pseudocode for shared/functions/float/fpmuladd/FPMulAdd

```plaintext
// FPMulAdd()
// ============
// Calculates addend + op1*op2 with a single rounding.

bits(N) FPMulAdd(bits(N) addend, bits(N) op1, bits(N) op2, FPCRType fpcr)
assert N IN {16,32,64};
rounding = FPRoundingMode(fpcr);
(typeA,signA,valueA) = FPUnpack(addend, fpcr);
(type1,sign1,value1) = FPUnpack(op1, fpcr);
(type2,sign2,value2) = FPUnpack(op2, fpcr);
inf1 = (type1 == FPType_Infinity);
zero1 = (type1 == FPType_Zero);
inf2 = (type2 == FPType_Infinity);
zero2 = (type2 == FPType_Zero);
(done,result) = FPProcessNaNs3(typeA, type1, type2, addend, op1, op2, fpcr);

if typeA == FPType_QNaN && ((inf1 && zero2) || (zero1 && inf2)) then
    result = FPDefaultNaN();
    FPProcessException(FPExc_InvalidOp, fpcr);
if !done then
    infA = (typeA == FPType_Infinity);
    zeroA = (typeA == FPType_Zero);
    // Determine sign and type product will have if it does not cause an Invalid Operation.
    signP = sign1 EOR sign2;
    infP  = inf1 || inf2;
    zeroP = zero1 || zero2;
    // Non SNaN-generated Invalid Operation cases are multiplies of zero by infinity and additions of opposite-signed infinities.
    if (inf1 && zero2) || (zero1 && inf2) || (infA && infP && signA != signP) then
        result = FPDefaultNaN();
        FPProcessException(FPExc_InvalidOp, fpcr);
    elseif (infA && signA == '0') || (infP && signP == '0') then
        result = FPInfinity('0');
    elseif (infA && signA == '1') || (infP && signP == '1') then
        result = FPInfinity('1');
    // Cases where the result is exactly zero and its sign is not determined by the rounding mode are additions of same-signed zeros.
    elseif zeroA && zeroP && signA == signP then
        result = FPZero(signA);
    // Otherwise calculate numerical result and round it.
    else
        result_value = valueA + (value1 * value2);
        if result_value == 0.0 then // Sign of exact zero result depends on rounding mode
            result_sign = if rounding == FPRounding_NEGINF then '1' else '0';
        result = FPRound(result_sign);
        else
            result = FPRound(result_value, fpcr);
    return result;
```

Shared Pseudocode Functions
Library pseudocode for shared/functions/float/fpmuladdh/FPMulAddH

bits(N) FPMulAddH(bits(N) addend, bits(N DIV 2) op1, bits(N DIV 2) op2, FPCRType fpcr)
assert N IN {32,64};
rounding = FPRoundingMode(fpcr);
(typeA,signA,valueA) = FPUnpack(addend, fpcr);
(type1,sign1,value1) = FPUnpack(op1, fpcr);
(type2,sign2,value2) = FPUnpack(op2, fpcr);
inf1 = (type1 == FPType_Infinity); zero1 = (type1 == FPType_Zero);
inf2 = (type2 == FPType_Infinity); zero2 = (type2 == FPType_Zero);
(done,result) = FPProcessNaNs3H(typeA, type1, type2, addend, op1, op2, fpcr);
if typeA == FPType_QNaN && ((inf1 && zero2) || (zero1 && inf2)) then
  result = FPDefaultNaN();
  FPProcessException(FPExc_InvalidOp, fpcr);
if !done then
  infA = (typeA == FPType_Infinity); zeroA = (typeA == FPType_Zero);
  // Determine sign and type product will have if it does not cause an Invalid
  // Operation.
  signP = sign1 EOR sign2;
  infP = inf1 || inf2;
  zeroP = zero1 || zero2;
  // Non SNaN-generated Invalid Operation cases are multiplies of zero by infinity and
  // additions of opposite-signed infinities.
  if (inf1 && zero2) || (zero1 && inf2) || (infA && infP && signA != signP) then
    result = FPDefaultNaN();
    FPProcessException(FPExc_InvalidOp, fpcr);
  // Other cases involving infinities produce an infinity of the same sign.
  elsif (infA && signA == '0') || (infP && signP == '0') then
    result = FPInfinity('0');
  elsif (infA && signA == '1') || (infP && signP == '1') then
    result = FPInfinity('1');
  // Cases where the result is exactly zero and its sign is not determined by the
  // rounding mode are additions of same-signed zeros.
  elsif zeroA && zeroP && signA == signP then
    result = FPZero(signA);
  // Otherwise calculate numerical result and round it.
  else
    result_value = valueA + (value1 * value2);
    if result_value == 0.0 then // Sign of exact zero result depends on rounding mode
      result_sign = if rounding == FPRounding_NEGINF then '1' else '0';
      result = FPZero(result_sign);
    else
      result = FPRound(result_value, fpcr);
  return result;
Library pseudocode for shared/functions/float/fpmuladdh/FPProcessNaNs3H

```c
// FPProcessNaNs3H()
//
(boolean, bits(N)) FPProcessNaNs3H(FPType type1, FPType type2, FPType type3, bits(N) op1, bits(N DIV 2) op2, bits(N DIV 2) op3, FPCRType fpcr)
assert N IN {32,64};
bits(N) result;
if type1 == FPTYPE_SNaN then
done = TRUE; result = FPProcessNaN(type1, op1, fpcr);
elsif type2 == FPTYPE_SNaN then
done = TRUE; result = FPConvertNaN(FPProcessNaN(type2, op2, fpcr));
elsif type3 == FPTYPE_SNaN then
done = TRUE; result = FPConvertNaN(FPProcessNaN(type3, op3, fpcr));
elsif type1 == FPTYPE_QNaN then
done = TRUE; result = FPProcessNaN(type1, op1, fpcr);
elsif type2 == FPTYPE_QNaN then
done = TRUE; result = FPConvertNaN(FPProcessNaN(type2, op2, fpcr));
elsif type3 == FPTYPE_QNaN then
done = TRUE; result = FPConvertNaN(FPProcessNaN(type3, op3, fpcr));
else

done = FALSE; result = Zeros(); // 'Don't care' result
return (done, result);
```

Library pseudocode for shared/functions/float/fpmulx/FPMulX

```c
// FPMulX()
//

bits(N) FPMulX(bits(N) op1, bits(N) op2, FPCRType fpcr)
assert N IN {16,32,64};
bits(N) result;
(type1,sign1,value1) = FPUnpack(op1, fpcr);
(type2,sign2,value2) = FPUnpack(op2, fpcr);
(done,result) = FPProcessNaNs(type1, type2, op1, op2, fpcr);
if !done then
inf1 = (type1 == FPTYPE_Infinity);
inf2 = (type2 == FPTYPE_Infinity);
zero1 = (type1 == FPTYPE_Zero);
zero2 = (type2 == FPTYPE_Zero);
if (inf1 && zero2) || (zero1 && inf2) then
result = FPTwo(sign1 EOR sign2);
elsif inf1 || inf2 then
result = FPInfinity(sign1 EOR sign2);
elsif zero1 || zero2 then
result = FPZero(sign1 EOR sign2);
else
result = FPRound(value1*value2, fpcr);
return result;
```

Library pseudocode for shared/functions/float/fpneg/FPNeg

```c
// FPNeg()
//
bits(N) FPNeg(bits(N) op)
assert N IN {16,32,64};
return NOT(op<N-1>) : op<N-2:0>;
```
Library pseudocode for shared/functions/float/fponepointfive/FPOnePointFive

```
// FPOnePointFive()
// ===============
bits(N) FPOnePointFive(bit sign)
  assert N IN {16,32,64};
  constant integer E = (if N == 16 then 5 elsif N == 32 then 8 else 11);
  constant integer P = N - (E + 1);
  exp = '0':Ones(E-1);
  frac = '1':Zeros(F-1);
  return sign : exp : frac;
```

Library pseudocode for shared/functions/float/fpprocessexception/FPProcessException

```
// FPProcessException()
// ====================
// The 'fpcr' argument supplies FPCR control bits. Status information is
// updated directly in the FPSR where appropriate.
FPProcessException(FPExc exception, FPCRType fpcr)
  // Determine the cumulative exception bit number
  case exception of
    when FPExc_InvalidOp   cumul = 0;
    when FPExc_DivideByZero cumul = 1;
    when FPExc_Overflow     cumul = 2;
    when FPExc_Underflow    cumul = 3;
    when FPExc_Inexact     cumul = 4;
    when FPExc_InputDenorm cumul = 7;
  enable = cumul + 8;
  if fpcr<enable> == '1' then
    // Trapping of the exception enabled.
    // It is IMPLEMENTATION DEFINED whether the enable bit may be set at all, and
    // if so then how exceptions may be accumulated before calling FPTrapException()
    IMPLEMENTATION_DEFINED "floating-point trap handling";
  elsif UsingAArch32() then
    // Set the cumulative exception bit
    FPSCR<cumul> = '1';
  else
    // Set the cumulative exception bit
    FPSR<cumul> = '1';
  return;
```

Library pseudocode for shared/functions/float/fpprocessnan/FPProcessNaN

```
// FPProcessNaN()
// ==============
bits(N) FPProcessNaN(FPType type, bits(N) op, FPCRType fpcr)
  assert N IN {16,32,64};
  assert type IN {FPType_QNaN, FPType_SNaN};
  case N of
    when 16 topfrac = 9;
    when 32 topfrac = 22;
    when 64 topfrac = 51;
  result = op;
  if type == FPType_SNaN then
    result<topfrac> = '1';
    FPProcessException(FPExc_InvalidOp, fpcr);
  if fpcr.DN == '1' then  // DefaultNaN requested
    result = FPDefaultNaN();
  return result;
```
FPProcessNaNs()  // The boolean part of the return value says whether a NaN has been found and  // processed. The bits(N) part is only relevant if it has and supplies the  // result of the operation.  // The 'fpcr' argument supplies FPCR control bits. Status information is  // updated directly in the FPSR where appropriate.

(boolean, bits(N)) FPProcessNaNs(FPTYPE type1, FPTYPE type2,  
bits(N) op1, bits(N) op2,  
FPCRType fpcr)

assert N IN {16,32,64};
if type1 == FPTYPE_SNaN then
    done = TRUE; result = FPProcessNaN(type1, op1, fpcr);
elseif type2 == FPTYPE_SNaN then
    done = TRUE; result = FPProcessNaN(type2, op2, fpcr);
elseif type1 == FPTYPE_QNaN then
    done = TRUE; result = FPProcessNaN(type1, op1, fpcr);
elseif type2 == FPTYPE_QNaN then
    done = TRUE; result = FPProcessNaN(type2, op2, fpcr);
else
    done = FALSE; result = Zeros(); // 'Don't care' result
return (done, result);

FPProcessNaNs3()  // The boolean part of the return value says whether a NaN has been found and  // processed. The bits(N) part is only relevant if it has and supplies the  // result of the operation.  // The 'fpcr' argument supplies FPCR control bits. Status information is  // updated directly in the FPSR where appropriate.

(boolean, bits(N)) FPProcessNaNs3(FPTYPE type1, FPTYPE type2, FPTYPE type3,  
bits(N) op1, bits(N) op2, bits(N) op3,  
FPCRType fpcr)

assert N IN {16,32,64};
if type1 == FPTYPE_SNaN then
    done = TRUE; result = FPProcessNaN(type1, op1, fpcr);
elseif type2 == FPTYPE_SNaN then
    done = TRUE; result = FPProcessNaN(type2, op2, fpcr);
elseif type3 == FPTYPE_SNaN then
    done = TRUE; result = FPProcessNaN(type3, op3, fpcr);
elseif type1 == FPTYPE_QNaN then
    done = TRUE; result = FPProcessNaN(type1, op1, fpcr);
elseif type2 == FPTYPE_QNaN then
    done = TRUE; result = FPProcessNaN(type2, op2, fpcr);
elseif type3 == FPTYPE_QNaN then
    done = TRUE; result = FPProcessNaN(type3, op3, fpcr);
else
    done = FALSE; result = Zeros(); // 'Don't care' result
return (done, result);
FPRecipEstimate(bits(N) operand, FPCRType fpcr)
assert N IN {16,32,64};
(type,sign,value) = FPUnpack(operand, fpcr);
if type == FPType_SNaN || type == FPType_QNaN then
  result = FPProcessNaN(type, operand, fpcr);
elseif type == FPType_Infinity then
  result = FPZero(sign);
elseif type == FPType_Zero then
  result = FPInfinity(sign);
  FPProcessException(FPExc_DivideByZero, fpcr);
else if (
    (N == 16 && Abs(value) < 2.0^-16) ||
    (N == 32 && Abs(value) < 2.0^-128) ||
    (N == 64 && Abs(value) < 2.0^-1024)
  ) then
  case FPRoundingMode(fpcr) of
    when FPRounding_TIEEVEN
      overflow_to_inf = TRUE;
    when FPRounding_POSINF
      overflow_to_inf = (sign == '0');
    when FPRounding_NEGINF
      overflow_to_inf = (sign == '1');
    when FPRounding_ZERO
      overflow_to_inf = FALSE;
  result = if overflow_to_inf then FPInfinity(sign) else FMaxNormal(sign);  
  end;
  else
    // Result flushed to zero of correct sign
    result = FPZero(sign);
    if UsingAArch32() then
      FPSR.UFC = '1';
    else
      FPSR.UFC = '1';
    end;
  end;
else
  // Scale to a fixed point value in the range 0.5 <= x < 1.0 in steps of 1/512, and
  // calculate result exponent. Scaled value has copied sign bit,
  // exponent = 1022 = double-precision biased version of -1,
  // fraction = original fraction
  case N of
    when 16
      fraction = operand<9:0> : Zeros(42);
      exp = Uint(operand<14:10>);
    when 32
      fraction = operand<22:0> : Zeros(29);
      exp = Uint(operand<30:23>);
    when 64
      fraction = operand<51:0>;
      exp = Uint(operand<62:52>);
  if exp == 0 then
    if fraction<51> == 0 then
      exp = -1;
      fraction = fraction<49:0>:'00';
    else
      fraction = fraction<50:0>:'0';
  integer scaled = Uint('1':fraction<51:44>);
  end;
  case N of
    when 16 result_exp = 29 - exp; // In range 29-30 = -1 to 29+1 = 30
    when 32 result_exp = 253 - exp; // In range 253-254 = -1 to 253+1 = 254
Shared Pseudocode Functions
when 64 result_exp = 2045 - exp; // In range 2045=2046 = -1 to 2045+1 = 2046
// scaled is in range 256..511 representing a fixed-point number in range [0.5..1.0)
estimate = RecipEstimate(scaled);
// estimate is in the range 256..511 representing a fixed point result in the range [1.0..2.0)
// Convert to scaled floating point result with copied sign bit,
// high-order bits from estimate, and exponent calculated above.

define fraction = estimate<7:0> : Zeros(44);
if result_exp == 0 then
    fraction = '1' : fraction<51:1>;
elsif result_exp == -1 then
    fraction = '01' : fraction<51:2>;
    result_exp = 0;
end if

case N of
    when 16 result = sign : result_exp<N-12:0> : fraction<51:42>;
    when 32 result = sign : result_exp<N-25:0> : fraction<51:29>;
    when 64 result = sign : result_exp<N-54:0> : fraction<51:0>;
end case

return result;

// Compute estimate of reciprocal of 9-bit fixed-point number
// a is in range 256 .. 511 representing a number in the range 0.5 <= x < 1.0.
// result is in the range 256 .. 511 representing a number in the range 1.0 to 511/256.

define integer RecipEstimate(integer a)
    assert 256 <= a && a < 512;
a = a*2+1; // round to nearest
integer b = (2 ^ 19) DIV a;
r = (b+1) DIV 2; // round to nearest
assert 256 <= r && r < 512;
return r;
/ FPRecpX() 
// =========

bits(N) FPRecpX(bits(N) op, FPCRType fpcr)
assert N IN {16,32,64};

    case N of
        when 16 esize = 5;
        when 32 esize = 8;
        when 64 esize = 11;

    bits(N)           result;
    bits(esize)       exp;
    bits(esize)       max_exp;
    bits(N-(esize+1)) frac = Zeros();

    case N of
        when 16 exp = op<10+esize-1:10>;
        when 32 exp = op<23+esize-1:23>;
        when 64 exp = op<52+esize-1:52>;

    max_exp = Ones(esize) - 1;

    (type,sign,value) = FPUnpack(op, fpcr);
    if type == FPType_SNaN || type == FPType_QNaN then
        result = FPProcessNaN(type, op, fpcr);
    else
        if IsZero(exp) then // Zero and denormals
            result = sign:max_exp:frac;
        else // Infinities and normals
            result = sign:NOT(exp):frac;

    return result;
// FPRound()
// =========
// Used by data processing and int/fixed <-> FP conversion instructions.
// For half-precision data it ignores AHP, and observes FZ16.

bits(N) FPRound(real op, FPCRType fpcr, FPRounding rounding)
    fpcr.AHP = '0';
    return FPRoundBase(op, fpcr, rounding);

// Convert a real number OP into an N-bit floating-point value using the
// supplied rounding mode RMODE.

bits(N) FPRoundBase(real op, FPCRType fpcr, FPRounding rounding)
    assert N IN {16,32,64};
    assert op != 0.0;
    assert rounding != FPRounding_TIEAWAY;
    bits(N) result;

    // Obtain format parameters - minimum exponent, numbers of exponent and fraction bits.
    if N == 16 then
        minimum_exp = -14;  E = 5;  F = 10;
    elsif N == 32 then
        minimum_exp = -126;  E = 8;  F = 23;
    else  // N == 64
        minimum_exp = -1022;  E = 11;  F = 52;

    // Split value into sign, unrounded mantissa and exponent.
    if op < 0.0 then
        sign = '1';  mantissa = -op;
    else
        sign = '0';  mantissa = op;
    exponent = 0;
    while mantissa < 1.0 do
        mantissa = mantissa * 2.0;  exponent = exponent - 1;
    while mantissa >= 2.0 do
        mantissa = mantissa / 2.0;  exponent = exponent + 1;

    // Deal with flush-to-zero.
    if ((fpcr.FZ == '1' && N != 16) || (fpcr.FZ16 == '1' && N == 16)) && exponent < minimum_exp then
        // Flush-to-zero never generates a trapped exception
        if UsingAArch32() then
            FPSCR.UFC = '1';
        else
            FPSR.UFC = '1';
        return FPZero(sign);
    // Start creating the exponent value for the result. Start by biasing the actual exponent
    // so that the minimum exponent becomes 1, lower values 0 (indicating possible underflow).
    biased_exp = Max(exponent - minimum_exp + 1, 0);
    if biased_exp == 0 then mantissa = mantissa / 2.0^(minimum_exp - exponent);

    // Get the unrounded mantissa as an integer, and the "units in last place" rounding error.
    int_mant = RoundDown(mantissa * 2.0^F);  // < 2.0^F if biased_exp == 0, >= 2.0^F if not
    error = mantissa * 2.0^F - Real(int_mant);

    // Underflow occurs if exponent is too small before rounding, and result is inexact or
    // the Underflow exception is trapped.
    if biased_exp == 0 && (error != 0.0 || fpcr.UFE == '1') then
        FPProcessException(FPExc_Underflow, fpcr);
    // Round result according to rounding mode.
    case rounding of
    when FPRounding_TIEEVEN
        round_up = (error > 0.5 || (error == 0.5 && int_mant<0> == '1'));
        overflow_to_inf = TRUE;
    when FPRounding_POSINF
        round_up = (error != 0.0 && sign == '0');
        overflow_to_inf = (sign == '0');
    when FPRounding_NEGINF
        round_up = (error != 0.0 && sign == '1');

overflow_to_inf = (sign == '1');

when FPRounding_ZERO, FPRounding_ODD
  round_up = FALSE;
  overflow_to_inf = FALSE;

if round_up then
  int_mant = int_mant + 1;
  if int_mant == 2^F then    // Rounded up from denormalized to normalized
    biased_exp = 1;
  if int_mant == 2^(F+1) then // Rounded up to next exponent
    biased_exp = biased_exp + 1;  int_mant = int_mant DIV 2;

  // Handle rounding to odd aka Von Neumann rounding
  if error != 0.0 && rounding == FPRounding_ODD then
    int_mant<0> = '1';

  // Deal with overflow and generate result.
  if N != 16 || fpcr.AHP == '0' then    // Single, double or IEEE half precision
    if biased_exp >= 2^E - 1 then
      result = if overflow_to_inf then
               FPInfinity(sign) else
               FPMaxNormal(sign);
      FPProcessException(FPExc_Overflow, fpcr);
      error = 1.0;  // Ensure that an Inexact exception occurs
    else
      biased_exp = biased_exp<F-1:0> : int_mant<F-1:0>;
      // Alternative half precision
    if error != 0.0 then
      FPProcessException(FPExc_Inexact, fpcr);
      return result;

// FPround()
// =========

bits(N) FPround(real op, FPCRTyp fpcr)
  return FPround(op, fpcr, FPRoundingMode(fpcr));

Library pseudocode for shared/functions/float/fpround/FPRoundCV

// FPRoundCV()
// ===========
// Used for FP <-> FP conversion instructions.
// For half-precision data ignores FZ16 and observes AHP.

bits(N) FPRoundCV(real op, FPCRTyp fpcr, FPRounding rounding)
  fpcr.FZ16 = '0';
  return FPRoundBase(op, fpcr, rounding);

Library pseudocode for shared/functions/float/fpround/FPRounding

enumeration FPRounding  {FPRounding_TIEEVEN, FPRounding_POSINF,
                        FPRounding_NEGINF,  FPRounding_ZERO,
                        FPRounding_TIEAWAY, FPRounding_ODD);
// FPRoundingMode()
// ================
// Return the current floating-point rounding mode.

FPRounding FPRoundingMode(FPCRType fpcr)
return FPDecodeRounding(fpcr.RMode);

// FPRoundInt()
// ============
// Round OP to nearest integral floating point value using rounding mode ROUNDED.
// If EXACT is TRUE, set FPSR.IXC if result is not numerically equal to OP.

bits(N) FPRoundInt(bits(N) op, FPCRType fpcr, FPRounding rounding, boolean exact)
assert rounding != FPRounding_ODD;
assert N IN {16,32,64};
assert rounding != FPRounding_ODD;

// Unpack using FPCR to determine if subnormals are flushed-to-zero
(type,sign,value) = FPUnpack(op, fpcr);

if type == FPTYPE_SNaN || type == FPTYPE_QNaN then
    result = FPProcessNaN(type, op, fpcr);
elsif type == FPTYPE_Infinity then
    result = FPInfinity(sign);
elsif type == FPTYPE_Zero then
    result = FPZero(sign);
else
    // extract integer component
    int_result = RoundDown(value);
    error = value - Real(int_result);

    // Determine whether supplied rounding mode requires an increment
    case rounding of
        when FPRounding_TIEEVEN
            round_up = (error > 0.5 || (error == 0.5 && int_result < 0));
        when FPRounding_POSINF
            round_up = (error != 0.0);
        when FPRounding_NEGINF
            round_up = FALSE;
        when FPRounding_ZERO
            round_up = (error != 0.0 && int_result < 0);
        when FPRounding_TIEAWAY
            round_up = (error > 0.5 || (error == 0.5 && int_result >= 0));
    if round_up then int_result = int_result + 1;

    // Convert integer value into an equivalent real value
    real_result = Real(int_result);

    // Re-encode as a floating-point value, result is always exact
    if real_result == 0.0 then
        return result;
    else
        result = FPRound(real_result, fpcr, FPRounding_ZERO);

    // Generate inexact exceptions
    if error != 0.0 && exact then
        FPProcessException(FPExc_Inexact, fpcr);

    return result;
Library pseudocode for shared/functions/float/fproundintn/FPRoundIntN
// FPRoundIntN
// =============

bits(N) FPRoundIntN(bits(N) op, FPCRType fpcr, FPRounding rounding, integer intsize)
assert rounding != FPRounding_ODD;
assert N IN [32,64];
assert intsize IN [32, 64];
integer exp;
constant integer E = (if N == 32 then 8 else 11);
constant integer F = N - (E + 1);

// Unpack using FPCR to determine if subnormals are flushed-to-zero
(type,sign,value) = FPUnpack(op, fpcr);
if type IN {
  FPType_SNaN, FPType_QNaN, FPType_Infinity
} then
  if N == 32 then
    exp = 126 + intsize;
    result = '1':exp<(E-1):0>:Zeros(F);
  else
    exp = 1022+intsize;
    result = '1':exp<(E-1):0>:Zeros(F);
  FPProcessException(FPExc_InvalidOp, fpcr);
elsif type == FPType_Zero then
  result = FPZero(sign);
else
  // Extract integer component
  int_result = RoundDown(value);
  error = value - Real(int_result);
  // Determine whether supplied rounding mode requires an increment
  case rounding of
    when FPRounding_TIEEVEN
      round_up = error > 0.5 || (error == 0.5 && int_result<0> == '1');
    when FPRounding_POSINF
      round_up = error != 0.0;
    when FPRounding_NEGINF
      round_up = FALSE;
    when FPRounding_ZERO
      round_up = error != 0.0 && int_result < 0;
    when FPRounding_TIEAWAY
      round_up = error > 0.5 || (error == 0.5 && int_result >= 0);
  if round_up then
    int_result = int_result + 1;
    if int_result > 2^(intsize-1)-1 || int_result < -1*2^(intsize-1) then
      if N == 32 then
        exp = 126 + intsize;
        result = '1':exp<(E-1):0>:Zeros(F);
      else
        exp = 1022 + intsize;
        result = '1':exp<(E-1):0>:Zeros(F);
      FPProcessException(FPExc_InvalidOp, fpcr);
      // this case shouldn't set Inexact
      error = 0.0;
    else
      // Convert integer value into an equivalent real value
      real_result = Real(int_result);
      // Re-encode as a floating-point value, result is always exact
      if real_result == 0.0 then
        result = FPZero(sign);
      else
        result = FPRound(real_result, fpcr, FPRounding_ZERO);
      // Generate inexact exceptions
      if error != 0.0 then
        FPProcessException(FPExc_Inexact, fpcr);
  // Generate inexact exceptions
  if error != 0.0 then
    FPProcessException(FPExc_Inexact, fpcr);
  return result;
// FPRSqrtEstimate()
// =================

bits(N) FPRSqrtEstimate(bits(N) operand, FPCRType fpcr)
assert N IN {16,32,64};
(type,sign,value) = FPUnpack(operand, fpcr);
if type == FPType_SNan || type == FPType_QNaN then
    result = FPProcessNaN(type, operand, fpcr);
elsif type == FPType_Zero then
    result = FPInfinity(sign);
elsif sign == '1' then
    result = FPDefaultNaN();
    FPProcessException(FPExc_DivideByZero, fpcr);
elsif type == FPType_Infinity then
    result = FPZero('0');
else
    // Scale to a fixed-point value in the range 0.25 <= x < 1.0 in steps of 512, with the
    // evenness or oddness of the exponent unchanged, and calculate result exponent.
    // Scaled value has copied sign bit, exponent = 1022 or 1021 = double-precision
    // biased version of -1 or -2, fraction = original fraction extended with zeros.

    case N of
        when 16
            fraction = operand<9:0> : Zeros(42);
            exp = UInt(operand<14:10>);
        when 32
            fraction = operand<22:0> : Zeros(29);
            exp = UInt(operand<30:23>);
        when 64
            fraction = operand<51:0>;
            exp = UInt(operand<62:52>);
    if exp == 0 then
        while fraction<51> == 0 do
            fraction = fraction<50:0> : '0';
            exp = exp - 1;
            fraction = fraction<50:0> : '0';
    if exp<0> == '0' then
        scaled = UInt('1':fraction<51:44>);
    else
        scaled = UInt('01':fraction<51:45>);
    case N of
        when 16 result_exp = ( 44 - exp) DIV 2;
        when 32 result_exp = ( 380 - exp) DIV 2;
        when 64 result_exp = (3068 - exp) DIV 2;
    estimate = RecipSqrtEstimate(scaled);
    // estimate is in the range 256..511 representing a fixed point result in the range [1.0..2.0)
    // Convert to scaled floating point result with copied sign bit and high-order
    // fraction bits, and exponent calculated above.
    case N of
        when 16 result = '0' : result_exp<N=12:0> : estimate<7:0>:Zeros( 2);
        when 32 result = '0' : result_exp<N=25:0> : estimate<7:0>:Zeros(15);
        when 64 result = '0' : result_exp<N=54:0> : estimate<7:0>:Zeros(44);
    return result;
Library pseudocode for shared/functions/float/fprsqrtestimate/RecipSqrtEstimate

```plaintext
// Compute estimate of reciprocal square root of 9-bit fixed-point number
// a is in range 128 .. 511 representing a number in the range 0.25 <= x < 1.0.
// result is in the range 256 .. 511 representing a number in the range in the range 1.0 to 511/256.

integer RecipSqrtEstimate(integer a)
assert 128 <= a && a < 512;
if a < 256 then // 0.25 .. 0.5
    a = a*2+1;     // a in units of 1/512 rounded to nearest
else // 0.5 .. 1.0
    a = (a >> 1) << 1;  // discard bottom bit
    a = (a+1)*2;  // a in units of 1/256 rounded to nearest
integer b = 512;
while a*(b+1)*(b+1) < 2^28 do
    b = b+1;
// b = largest b such that b < 2^14 / sqrt(a) do
r = (b+1) DIV 2;  // round to nearest
assert 256 <= r && r < 512;
return r;
```

Library pseudocode for shared/functions/float/fpsqrt/FPSqrt

```plaintext
// FPSqrt()
// ========

bits(N) FPSqrt(bits(N) op, FPCRTYPE fpcr)
assert N IN {16,32,64};
(type,sign,value) = FPUnpack(op, fpcr);
if type == FPType_SNaN || type == FPType_QNaN then
    result = FPProcessNaN(type, op, fpcr);
elif type == FPType_Zero then
    result = FPZero(sign);
elif type == FPType_Infinity && sign == '0' then
    result = FPIInfinity(sign);
elif sign == '1' then
    result = FPDefaultNaN();
    FPProcessException(FPEx_InvalidOp, fpcr);
else
    result = FPRound(Sqrt(value), fpcr);
return result;
```
/**
 * FPSub()
 */

bits(N) FPSub(bits(N) op1, bits(N) op2, FPCRType fpcr)
assert N IN {16,32,64};
rounding = FPRoundingMode(fpcr);
(type1,sign1,value1) = FPUnpack(op1, fpcr);
(type2,sign2,value2) = FPUnpack(op2, fpcr);
(done,result) = FPProcessNaNs(type1, type2, op1, op2, fpcr);
if !done then
  inf1 = (type1 == FPType_Infinity);
  inf2 = (type2 == FPType_Infinity);
  zero1 = (type1 == FPType_Zero);
  zero2 = (type2 == FPType_Zero);
  if inf1 && inf2 && sign1 == sign2 then
    result = FPDefaultNaN();
    FPProcessException(FPExc_InvalidOp, fpcr);
  elsif (inf1 && sign1 == '0') || (inf2 && sign2 == '1') then
    result = FPInfinity('0');
  elsif (inf1 && sign1 == '1') || (inf2 && sign2 == '0') then
    result = FPInfinity('1');
  elsif zero1 && zero2 && sign1 == NOT(sign2) then
    result = FPZero(sign1);
  else
    result_value = value1 - value2;
    if result_value == 0.0 then // Sign of exact zero result depends on rounding mode
      result_sign = if rounding == FPRounding_NEGINF then '1' else '0';
      result = FPZero(result_sign);
    else
      result = FPRound(result_value, fpcr, rounding);
  return result;

/**
 * FPThree()
 */

bits(N) FPThree(bit sign)
assert N IN {16,32,64};
constant integer E = (if N == 16 then 5 elsif N == 32 then 8 else 11);
constant integer F = N - (E + 1);
exp = '1':Zeros(E-1);
frac = '1':Zeros(F-1);
return sign : exp : frac;
Library pseudocode for shared/functions/float/fptofixed/FPTofixed

```plaintext
// FPTofixed()
// ===========
// Convert N-bit precision floating point OP to M-bit fixed point with
// FBITS fractional bits, controlled by UNSIGNED and ROUNDD.

bit(M) FPTofixed(bits(N) op, integer fbits, boolean unsigned, FPCRType fpcr, FPRounding rounding)
assert N IN {16,32,64};
assert M IN {16,32,64};
assert fbits >= 0;
assert rounding != FPRounding_ODD;

// Unpack using fpcr to determine if subnormals are flushed-to-zero
(type,sign,value) = FPUnpack(op, fpcr);

// If NaN, set cumulative flag or take exception
if type == FPType_SNaN || type == FPType_QNaN then
  FPProcessException(FPExc_InvalidOp, fpcr);

// Scale by fractional bits and produce integer rounded towards minus-infinity
value = value * 2.0^fbits;
int_result = RoundDown(value);
error = value - Real(int_result);

// Determine whether supplied rounding mode requires an increment
case rounding of
  when FPRounding_TIEEVEN
    round_up = (error > 0.5 || (error == 0.5 && int_result<0> == '1'));
  when FPRounding_POSINF
    round_up = (error != 0.0);
  when FPRounding_NEGINF
    round_up = FALSE;
  when FPRounding_ZERO
    round_up = (error != 0.0 && int_result < 0);
  when FPRounding_TIEAWAY
    round_up = (error > 0.5 || (error == 0.5 && int_result >= 0));
if round_up then int_result = int_result + 1;

// Generate saturated result and exceptions
(result, overflow) = SatQ(int_result, M, unsigned);
if overflow then
  FPProcessException(FPExc_InvalidOp, fpcr);
elsif error != 0.0 then
  FPProcessException(FPExc_Inexact, fpcr);
return result;
```

Shared Pseudocode Functions
Library pseudocode for shared/functions/float/fptofixedjs/FPToFixedJS

// FPToFixedJS()
// =============

// Converts a double precision floating point input value
// to a signed integer, with rounding to zero.

bits(N) FPToFixedJS(bits(M) op, FPCRType fpcr, boolean Is64)

    assert M == 64 && N == 32;

    // Unpack using fpcr to determine if subnormals are flushed-to-zero
    (type,sign,value) = FPUnpack(op, fpcr);

    Z = '1';

    // If NaN, set cumulative flag or take exception
    if type == FPType_SNaN || type == FPType_QNaN then
        FPProcessException(FPE_exc_InvalidOp, fpcr);
        Z = '0';

    int_result = RoundDown(value);
    error = value - Real(int_result);

    // Determine whether supplied rounding mode requires an increment
    round_it_up = (error != 0.0 && int_result < 0);
    if round_it_up then int_result = int_result + 1;

    if int_result < 0 then
        result = int_result - 2^32*RoundUp(Real(int_result)/Real(2^32));
    else
        result = int_result - 2^32*RoundDown(Real(int_result)/Real(2^32));

    // Generate exceptions
    if int_result < -(2^31) || int_result > (2^31)-1 then
        FPProcessException(FPE_exc_InvalidOp, fpcr);
        Z = '0';
    elsif error != 0.0 then
        FPProcessException(FPE_exc_Inexact, fpcr);
        Z = '0';
    if sign == '1' && value == 0.0 then
        Z = '0';
    if type == FPType_Infinity then result = 0;

    if Is64 then
        PSTATE.<N,Z,C,V> = '0':Z:'00';
    else
        FPSCR<31:28> = '0':Z:'00';

    return result<N-1:0>;

Library pseudocode for shared/functions/float/fptwo/FPTwo

// FPTwo()
// ========

bits(N) FPTwo(bit sign)

    assert N IN {16,32,64};
    constant integer E = (if N == 16 then 5 elsif N == 32 then 8 else 11);
    constant integer F = N - (E + 1);
    exp = '1':Zeros(E-1);
    frac = Zeros(F);
    return sign : exp : frac;
Library pseudocode for shared/functions/float/fptype/FPType

```c
enum FPTYPE      {FPTYPE_Nonzero, FPTYPE_Zero, FPTYPE_Infinity,
                 FPTYPE_QNaN, FPTYPE_SNaN};
```

Library pseudocode for shared/functions/float/fpunpack/FPUnpack

```c
// FPUnpack()
// =========
//
// Used by data processing and int/fixed <-> FP conversion instructions.
// For half-precision data it ignores AHP, and observes FZ16.

(FPTYPE, bit, real) FPUnpack(bits(N) fpval, FPCRType fpcr)
    fpcr.AHP = '0';
    (fp_type, sign, value) = FPUnpackBase(fpval, fpcr);
    return (fp_type, sign, value);
```
Library pseudocode for shared/functions/float/fpunpack/FPUnpackBase
// FPUnpackBase()
// ==============
// Unpack a floating-point number into its type, sign bit and the real number
// that it represents. The real number result has the correct sign for numbers
// and infinities, is very large in magnitude for infinities, and is 0.0 for
// NaNs. (These values are chosen to simplify the description of comparisons
// and conversions.)
// The 'fpcr' argument supplies FPCR control bits. Status information is
// updated directly in the FPSR where appropriate.

(FPType, bit, real) FPUnpackBase(bits(N) fpval, FPCRType fpcr) {
  assert N IN {16,32,64};

  if N == 16 then
    sign   = fpval<15>;
    exp16  = fpval<14:10>;
    frac16 = fpval<9:0>;
    if IsZero(exp16) then
      // Produce zero if value is zero or flush-to-zero is selected
      if IsZero(frac16) || fpcr.FZ16 == '1' then
        type = FPTyp.Zero; value = 0.0;
      else
        type = FPTyp.Nonzero; value = 2.0^-14 * (Real(UInt(frac16)) * 2.0^-10);
    elsif IsOnes(exp16) && fpcr.AHP == '0' then  // Infinity or NaN in IEEE format
      if IsZero(frac16) then
        type = FPTyp.Infinity; value = 2.0^1000000;
      else
        type = if frac16<9> == '1' then FPTyp.QNaN else FPTyp.SNaN;
        value = 0.0;
    else
      type = FPTyp.Nonzero;
      value = 2.0^((UInt(exp16)-15) * (1.0 + Real(UInt(frac16)) * 2.0^-10));
  elsif N == 32 then
    sign   = fpval<31>;
    exp32  = fpval<30:23>;
    frac32 = fpval<22:0>;
    if IsZero(exp32) then
      // Produce zero if value is zero or flush-to-zero is selected.
      if IsZero(frac32) || fpcr.FZ == '1' then
        type = FPTyp.Zero; value = 0.0;
      else
        type = if frac32<22> == '1' then FPTyp.QNaN else FPTyp.SNaN;
        value = 0.0;
    elsif IsOnes(exp32) then
      if IsZero(frac32) then
        type = FPTyp.Infinity; value = 2.0^1000000;
      else
        type = if frac32<22> == '1' then FPTyp.QNaN else FPTyp.SNaN;
        value = 0.0;
    else
      type = FPTyp.Nonzero;
      value = 2.0^((UInt(exp32)-127) * (1.0 + Real(UInt(frac32)) * 2.0^-23));
  else // N == 64
    sign   = fpval<63>;
    exp64  = fpval<62:52>;
    frac64 = fpval<51:0>;
    if IsZero(exp64) then
      // Produce zero if value is zero or flush-to-zero is selected.
      if IsZero(frac64) || fpcr.FZ == '1' then
        type = FPTyp.Zero; value = 0.0;
      else
        type = FPTyp.QNaN else FPTyp.SNaN;
        value = 0.0;
      // Denormalized input flushed to zero
      FPProcessException(FPExc_InputDenorm, fpcr);
    else
      Shared Pseudocode Functions
Library pseudocode for shared/functions/float/fpunpack/FPUnpackCV

```c
// FPUnpackCV()
// ============
// Used for FP <-> FP conversion instructions.
// For half-precision data ignores FZ16 and observes AHP.

(FPType, bit, real) FPUnpackCV(bits(N) fpval, FPCRType fpcr)
    fpcr.FZ16 = '0';
    (fp_type, sign, value) = FPUnpackBase(fpval, fpcr);
    return (fp_type, sign, value);
```

Library pseudocode for shared/functions/float/fpzero/FPZero

```c
// FPZero()
// =========

bits(N) FPZero(bit sign)
    assert N IN {16,32,64};
    constant integer E = (if N == 16 then 5 elsif N == 32 then 8 else 11);
    constant integer F = N - (E + 1);
    exp = Zeros(E);
    frac = Zeros(F);
    return sign : exp : frac;
```

Library pseudocode for shared/functions/float/vfexpandimm/VFPExpandImm

```c
// VFPExpandImm()
// ===============

bits(N) VFPExpandImm(bits(8) imm8)
    assert N IN {16,32,64};
    constant integer E = (if N == 16 then 5 elsif N == 32 then 8 else 11);
    constant integer F = N - E - 1;
    sign = imm8<7>;
    exp = NOT(imm8<6>):Replicate(imm8<6>,E-3):imm8<5:4>;
    frac = imm8<3:0>:Zeros(F-4);
    return sign : exp : frac;
```
// AddWithCarry()
// ==============
// Integer addition with carry input, returning result and NZCV flags

(bits(N), bits(4)) AddWithCarry(bits(N) x, bits(N) y, bit carry_in)
integer unsigned_sum = UInt(x) + UInt(y) + UInt(carry_in);
integer signed_sum = SInt(x) + SInt(y) + UInt(carry_in);
bits(N) result = unsigned_sum<N-1:0>; // same value as signed_sum<N-1:0>
bit n = result<N-1>;
bit z = if IsZero(result) then '1' else '0';
bit c = if UInt(result) == unsigned_sum then '0' else '1';
bit v = if SInt(result) == signed_sum then '0' else '1';
return (result, n:z:c:v);
Library pseudocode for shared/functions/memory/AddrTop

// AddrTop()
// =========
// Return the MSB number of a virtual address in the stage 1 translation regime for "el".
// If EL1 is using AArch64 then addresses from EL0 using AArch32 are zero-extended to 64 bits.
integer AddrTop(bits(64) address, boolean IsInstr, bits(2) el)

assert HaveEL(el);
regime = S1TranslationRegime(el);
if ELUsingAArch32(regime) then
    // AArch32 translation regime.
    return 31;
else
    // AArch64 translation regime.
    case regime of
        when EL1
            tbi = (if address<55> == '1' then TCR_EL1.TBI1 else TCR_EL1.TBI0);
        when EL2
            if HavePACExt() then
                tbid = if address<55> == '1' then TCR_EL1.TBID1 else TCR_EL1.TBID0;
            else
                tbi = TCR_EL2.TBI;
        when EL3
            tbi = TCR_EL3.TBI;
        return (if tbi == '1' && (!HavePACExt() || tbid == '0' || !IsInstr ) then 55 else 63);

Library pseudocode for shared/functions/memory/AddressDescriptor

type AddressDescriptor is {
    FaultRecord fault,      // fault.type indicates whether the address is valid
    MemoryAttributes memattrs,
    FullAddress paddress,
    bits(64) vaddress
}

Library pseudocode for shared/functions/memory/AddressWithAllocationTag

// AddressWithAllocationTag()
// ==========================
// Generate a 64-bit value containing a Logical Address Tag from a 64-bit virtual address and an Allocation Tag.
// If the extension is disabled, treats the Allocation Tag as "0000".
bits(64) AddressWithAllocationTag(bits(64) address, bits(4) allocation_tag)
    bits(64) result = address;
    bits(4) tag = allocation_tag - ('000':address<55>);
    result<59:56> = tag;
    return result;

Library pseudocode for shared/functions/memory/Allocation

constant bits(2) MemHint_No = '00';  // No Read-Allocate, No Write-Allocate
constant bits(2) MemHint_WA = '01';  // No Read-Allocate, Write-Allocate
constant bits(2) MemHint_RA = '10';  // Read-Allocate, No Write-Allocate
constant bits(2) MemHint_RWA = '11'; // Read-Allocate, Write-Allocate
// AllocationTagFromAddress()
// =========================
// Generate a Tag from a 64-bit value containing a Logical Address Tag.
// If access to Allocation Tags is disabled, this function returns '0000'.

bits(4) AllocationTagFromAddress(bits(64) tagged_address)
    bits(4) logical_tag = tagged_address<59:56>
    bits(4) tag = logical_tag + ('000':tagged_address<55>)
    return tag;

// BigEndian()
// ============

boolean BigEndian()
    boolean bigend;
    if UsingAArch32() then
        bigend = (PSTATE.E != '0');
    elsif PSTATE.EL == EL0 then
        bigend = (SCTLR[].E0E != '0');
    else
        bigend = (SCTLR[].EE != '0');
    return bigend;

// BigEndianReverse()
// =================

bits(width) BigEndianReverse (bits(width) value)
    assert width IN {8, 16, 32, 64, 128};
    integer half = width DIV 2;
    if width == 8 then return value;
    return BigEndianReverse(value<half-1:0>) : BigEndianReverse(value<width-1:half>);

// MemAttr_NC = '00';     // Non-cacheable
// MemAttr_WT = '10';     // Write-through
// MemAttr_WB = '11';     // Write-back

// CheckTag()          // Performs a Tag Check operation for a memory access and returns
// whether the check passed
// CreateAccessDescriptor()          //

boolean AccessDescriptorCheckTag(
    CreateAccessDescriptor(AddressDescriptor AccType memaddrdesc, bits(4) ptag, boolean write)
    if memaddrdesc.memattrs.tagged then
        bits(64) paddress = accdesc.memaddrdesc.paddress.address);
        return ptag == MemTag[paddress];
    else
        return TRUE;
    accdesc.acctype = accdesc.acctype;
    accdesc.page_table_walk = FALSE;
    return accdesc;
Library pseudocode for shared/functions/memory/CreateAccessDescriptor

```
// CreateAccessDescriptor()
// ========================
// CreateAccessDescriptorPTW()
// ===========================

AccessDescriptor CreateAccessDescriptor(AccessDescriptor accdesc)

accdesc.acctype = acctype;
accdesc.mpam = GenMPAMcurEL(acctype IN {AccType_IFETCH, AccType_IC});
accdesc.page_table_walk = FALSE;
accdesc.secondstage = s2fs1walk;
accdesc.level = level;
return accdesc;
```

Library pseudocode for shared/functions/memory/CreateAccessDescriptorPTW

```
// CreateAccessDescriptorPTW()
// ===========================

AccessDescriptor CreateAccessDescriptorPTW(AccType acctype, boolean secondstage, boolean s2fs1walk, integer level)

accdesc.acctype = acctype;
accdesc.mpam = GenMPAMcurEL(acctype IN {AccType_IFETCH, AccType_IC});
accdesc.page_table_walk = TRUE;
accdesc.secondstage = s2fs1walk;
accdesc.level = level;
return accdesc;
```

Library pseudocode for shared/functions/memory/DataMemoryBarrier

```
DataMemoryBarrier(MBReqDomain domain, MBReqTypes types);
```

Library pseudocode for shared/functions/memory/DataSynchronizationBarrier

```
DataSynchronizationBarrier(MBReqDomain domain, MBReqTypes types);
```

Library pseudocode for shared/functions/memory/DescriptorUpdate

```
type DescriptorUpdate is  
    boolean AF,      // AF needs to be set
    AddressDescriptor descaddr  // Descriptor to be updated
)
```

Library pseudocode for shared/functions/memory/DeviceType

```
enumeration DeviceType {DeviceType_GRE, DeviceType_nGRE, DeviceType_nGnRE, DeviceType_nGnRnE};
```
Library pseudocode for shared/functions/memory/EffectiveTBI

```c
// EffectiveTBI()
// ==============
// Returns the effective TBI in the AArch64 stage 1 translation regime for "el".

bit enumeration EffectiveTBI(bits(64) address, boolean IsInstr, bits(2) el)
assert(Fault, HaveEL(el));
regime = Fault_AccessFlag, S1TranslationRegime(el);
assert(!Fault_AccessFlag, ELUsingAArch32(regime));

    case regime of
        when Fault_Alignment, EL1
            if address<55> == '1' then TCR_EL1.TBI1 else TCR_EL1.TBI0;
        when Fault_Background, EL1
            if address<55> == '1' then TCR_EL1.TBID1 else TCR_EL1.TBID0;
        when Fault_Domain, EL2
            if Fault_Permission, HavePACExt() then
                if address<55> == '1' then TCR_EL2.TBI1 else TCR_EL2.TBI0;
            else
                tbi = TCR_EL2.TBI;
        when Fault_SyncExternal, EL3
            if Fault_SyncParity, HavePACExt() then
                tbid = TCR_EL3.TBID;
        when Fault_SyncExternalOnWalk, EL3
            tbi = TCR_EL3.TBI;
    else
        tbi = TCR_EL3.TBI;

return (if tbi == '1' && (!Fault_SyncParityOnWalk, Fault_AsyncParity, Fault_AsyncExternal, Fault_Debug, Fault_TLBConflict, Fault_HWUpdateAccessFlag, Fault_Lockdown, Fault_Exclusive, HavePACExt()) then '1' else '0');
```

Library pseudocode for shared/functions/memory/EffectiveTCMA

```c
// EffectiveTCMA()
// ===============
// Returns the effective TCMA of a virtual address in the stage 1 translation regime for "el".

bit type EffectiveTCMA(bits(64) address, bits(2) el)
assert(FaultRecord is (HaveELFault(el));
regime = type, // Fault Status S1TranslationRegimeAccType(el);
assert(!acctype, // Type of access that faulted ELUsingAArch32FullAddress(regime));

    case regime of
        when EL1
            tcma = if address<55> == '1' then TCR_EL1.TCMA1 else TCR_EL1.TCMA0;
        when EL2
            if HaveVirtHostExt() && ELIsInHost(el) then
                tcma = if address<55> == '1' then TCR_EL2.TCMA1 else TCR_EL2.TCMA0;
            else
                tcma = TCR_EL2.TCMA;
        when EL3
            tcma = TCR_EL3.TCMA;
    else
        tcma = TCR_EL3.TCMA;

return tcma;
```

Shared Pseudocode Functions
Library pseudocode for shared/functions/memory/Fault

```plaintext
```

Library pseudocode for shared/functions/memory/FaultRecord

```plaintext
type FaultRecord is (Fault type, // Fault Status
AccType acctype, // Type of access that faulted
FullAddress ipaddress, // Intermediate physical address
boolean s2fs1walk, // Is on a Stage 1 page table walk
boolean write, // TRUE for a write, FALSE for a read
integer level, // For translation, access flag and permission faults
bit extflag, // IMPLEMENTATION DEFINED syndrome for external aborts
boolean secondstage, // Is a Stage 2 abort
bit(4) domain, // Domain number, AArch32 only
bit(2) errortype, // [ARMv8.2 RAS] AArch32 AET or AArch64 SET
d...} debugmoe) // Debug method of entry, from AArch32 only

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```

Library pseudocode for shared/functions/memory/FullAddress

```plaintext
type FullAddress is (bits(52) address, // '0' = Secure, '1' = Non-secure
bit NS)
```
Library pseudocode for shared/functions/memory/Hint_Prefetch

```c
Hint_Prefetch(bits(64) address, PrefetchHint hint, integer target, boolean stream);
```

Library pseudocode for shared/functions/memory/MBReqDomain

```c
enumeration MBReqDomain {MBReqDomain_Nonshareable, MBReqDomain_InnerShareable, MBReqDomain_OuterShareable, MBReqDomain_FullSystem};
```

Library pseudocode for shared/functions/memory/MBReqTypes

```c
enumeration MBReqTypes {MBReqTypes_Reads, MBReqTypes_Writes, MBReqTypes_All};
```

Library pseudocode for shared/functions/memory/MemAttrHints

```c
type MemAttrHints is {
    bits(2) attrs, // See MemAttr_*, Cacheability attributes
    bits(2) hints, // See MemHint_*, Allocation hints
    boolean transient
}
```
// MemTag[] - non-assignment (read) form
// =====================================
// Load an Allocation Tag from memory.

bits(4) MemTag[bits(64) address]
    AddressDescriptor memaddrdesc;
    bits(4) value;
    iswrite = FALSE;

    memaddrdesc = AArch64.TranslateAddress(address, AccType_NORMAL, iswrite, TRUE, TAG_GRANULE);

    // Check for aborts or debug exceptions
    if IsFault(memaddrdesc) then
        AArch64.Abort(address, memaddrdesc.fault);

    // Return the granule tag if tagging is enabled...
    if AllocationTagAccessIsEnabled() then
        return _MemTag[memaddrdesc];
    else
        // ...otherwise read tag as zero.
        return '0000';

// MemTag[] - assignment (write) form
// ==================================
// Store an Allocation Tag to memory.

MemTag[bits(64) address] = bits(4) value
    AddressDescriptor memaddrdesc;
    iswrite = TRUE;

    // Stores of allocation tags must be aligned
    if address != Align(address, TAG_GRANULE) then
        boolean secondstage = FALSE;
        AArch64.Abort(address, AArch64.AlignmentFault(AccType_NORMAL, iswrite, secondstage));
    wasaligned = TRUE;
    memaddrdesc = AArch64.TranslateAddress(address, AccType_NORMAL, iswrite, wasaligned, TAG_GRANULE);

    // Check for aborts or debug exceptions
    if IsFault(memaddrdesc) then
        AArch64.Abort(address, memaddrdesc.fault);

    // Memory array access
    if AllocationTagAccessIsEnabled() then
        _MemTag[memaddrdesc] = value;

Library pseudocode for shared/functions/memory/MemTag

// Library pseudocode for shared/functions/memory/MemType

enumeration MemType {MemType_Normal, MemType_Device};

// Library pseudocode for shared/functions/memory/MemoryAttributes

type MemoryAttributes is (  
    MemType type,
    DeviceType device,  // For Device memory types
    MemAttrHints inner, // Inner hints and attributes
    MemAttrHints outer, // Outer hints and attributes
    boolean tagged,  // Tagged access
    boolean shareable,
    boolean outershareable
  )
Library pseudocode for shared/functions/memory/Permissions

```c
typedef Permissions {
    bits(3) ap, // Access permission bits
    bit     xn, // Execute-never bit
    bit     xxn, // [ARMv8.2] Extended execute-never bit for stage 2
    bit     pxn // Privileged execute-never bit
} Permissions;
```

Library pseudocode for shared/functions/memory/PrefetchHint

```c
typedef PrefetchHint {Prefetch_READ, Prefetch_WRITE, Prefetch_EXEC};
```

Library pseudocode for shared/functions/memory/SpeculativeSynchronizationBarrierToPA

```c
SpeculativeSynchronizationBarrierToPA();
```

Library pseudocode for shared/functions/memory/SpeculativeSynchronizationBarrierToVA

```c
SpeculativeSynchronizationBarrierToVA();
```

Library pseudocode for shared/functions/memory/TLBRecord

```c
type TLBRecord is {
    Permissions perms,
    bit     nG, // '0' = Global, '1' = not Global
    bits(4) domain, // AArch32 only
    boolean contiguous, // Contiguous bit from page table
    integer level, // AArch32 Short-descriptor format: Indicates Section/Page
    integer blocksize, // Describes size of memory translated in KBytes
    DescriptorUpdate descupdate, // [ARMv8.1] Context for h/w update of table descriptor
    bit     CnP, // [ARMv8.2] TLB entry can be shared between different PEs
    AddressDescriptor addrdesc
}
```

Library pseudocode for shared/functions/memory/TransformTag

```c
// TransformTag()
// ==============
// Apply tag transformation rules.

bits(4) TransformTag(bits(64) vaddr)
    bits(4) vtag = vaddr<59:56>;
    bits(4) tagdelta = ZeroExtend(vaddr<55>);
    bits(4) ptag = vtag + tagdelta;
    return ptag;
```

Library pseudocode for shared/functions/memory/_Mem

```c
// These two _Mem[] accessors are the hardware operations which perform single-copy atomic, // aligned, little-endian memory accesses of size bytes from/to the underlying physical // memory array of bytes. // // The functions address the array using desc.paddress which supplies: // * A 52-bit physical address // * A single NS bit to select between Secure and Non-secure parts of the array. // // The accdesc descriptor describes the access type: normal, exclusive, ordered, streaming, // etc and other parameters required to access the physical memory or for setting syndrome // register in the event of an external abort.
bits(8*size) _Mem[AddressDescriptor desc, integer size, AccessDescriptor accdesc] = bits(8*size) value;
```
// boolean AccessIsTagChecked()
// ================
// TRUE if a given access is tag-checked, FALSE otherwise.
// BranchTo()

boolean// Set program counter to a new address, which might include a tag in the top eight bits.  
// with a branch reason hint for possible use by hardware fetching the next instruction.  
AccessIsTagChecked(
    if PSTATE.M<4> == '1' then return FALSE;
    if branch_type)  EffectiveTBIHint_Branch(vaddr, FALSE, PSTATE.EL) == '0' then return FALSE;
    if branch_type)  if N == 32 then  
        assert EffectiveTCMAssignAArch32(vaddr, PSTATE.EL) == '1' && (vaddr<59:55> == '00000' || vaddr<59:55> == '11111') then return FALSE;
    if !();  _PC = AllocationTagAccessIsEnabledZeroExtend() then return FALSE;
    if acctype IN {target);  else  
        assert N == 64 && ! UsingAArch32(),();  
        _PC = ZeroExtend(target);
    if PSTATE.TCO=='1' then return FALSE;
    if IsNonTagCheckedInstruction() then return FALSE;
    return TRUE;((target<63:0>);

Library pseudocode for shared/functions: memory registers booleanchannel BranchTo

// DefaultMPAMinfo
// ============
// Returns default MPAM info.  If secure is TRUE return default Secure 
// MPAMinfo, otherwise return default Non-secure MPAMinfo.
// BranchToAddr()

MPAMinfo DefaultMPAMinfo(boolean secure)
    MPAMinfo DefaultInfo;
    DefaultInfo.mpam_ns = if secure then '0' else '1';
    DefaultInfo.partid = DefaultPARTID;
    DefaultInfo.pmg = DefaultPMG;
    return DefaultInfo;

// Set program counter to a new address, which does not include a tag in the top 
// with a branch reason hint for possible use by hardware fetching the next instruction.BranchToAddr()

// Partitioning
// =========
constant PARTIDtype DefaultPARTID = 0<15:0>;

enumeration BranchType {BranchType_CALL, BranchType_ERET, BranchType_DBGEXIT, BranchType_RET, BranchType_JMP, BranchType_EXCEPTION, BranchType_UNKNOWN};

constant PMGtype DefaultPMG = 0<7:0>;

Library pseudocode for shared/functions/mpam/DefaultPMG

Library pseudocode for shared/functions/mpam/GenMPAMcurEL

// GenMPAMcurEL
// ============
// Returns MPAMinfo for the current EL and security state.
// InD is TRUE instruction access and FALSE otherwise.
// May be called if MPAM is not implemented (but in a version that supports
// MPAM), MPAM is disabled, or in AArch32. In AArch32, convert the mode to
// EL if can and use that to drive MPAM information generation. If mode
// cannot be converted, MPAM is not implemented, or MPAM is disabled return
// default MPAM information for the current security state.

MPAMinfo GenMPAMcurEL(boolean InD)
    bits(2) mpamel;
    boolean validEL;
    boolean secure = IsSecure();
    if HaveMPAMExt() && MPAMisEnabled() then
        if UsingAArch32() then
            (validEL, mpamel) = ELFromM32(PSTATE.M);
        else
            validEL = TRUE;
            mpamel = PSTATE.EL;
        if validEL then
            return genMPAM(UInt(mpamel), InD, secure);
    return DefaultMPAMinfo(secure);
// MAP_vPARTID
// ===========
// Performs conversion of virtual PARTID into physical PARTID
// Contains all of the error checking and implementation
// choices for the conversion.

(PARTIDtype, boolean) MAP_vPARTID(PARTIDtype vpartid)
// should not ever be called if EL2 is not implemented
// or is implemented but not enabled in the current
// security state.

PARTIDtype ret;
boolean err;
integer virt    = UInt(vpartid);
integer vmprmax = UInt(MPAMIDR_EL1.VPMR_MAX);

// vpartid_max is largest vpartid supported
integer vpartid_max = 4 * vmprmax + 3;

// One of many ways to reduce vpartid to value less than vpartid_max.
if virt > vpartid_max then
  virt = virt MOD (vpartid_max+1);

// Check for valid mapping entry.
if MPAMVPMV_EL2<virt> == '1' then
  // vpartid has a valid mapping so access the map.
  ret = mapvpmw(virt);
  err = FALSE;
else
  // Is the default virtual PARTID valid?
  if MPAMVPMV_EL2<0> == '1' then
    // Yes, so use default mapping for vpartid == 0.
    ret = MPAMVPM0_EL2<0 +: 16>;
    err = FALSE;
  else
    // Neither is valid so use default physical PARTID.
    ret = DefaultPARTID;
    err = TRUE;

  // Check that the physical PARTID is in-range.
  integer partid_max = UInt(MPAMIDR_EL1.PARTID_MAX);
  if UInt(ret) > partid_max then
    // Out of range, so return default physical PARTID
    ret = DefaultPARTID;
    err = TRUE;

return (ret, err);

Library pseudocode for shared/functions/mpam/MPAMisEnabled

// MPAMisEnabled
// =============
// Returns TRUE if MPAMisEnabled.

boolean MPAMisEnabled()

el = HighestEL();
case el of
  when EL3 return MPAM3_EL3.MPAMEN == '1';
  when EL2 return MPAM2_EL2.MPAMEN == '1';
  when EL1 return MPAM1_EL1.MPAMEN == '1';
endcase;

Library pseudocode for shared/functions/mpam/MPAMisVirtual

```c
// MPAMisVirtual
// =============
// Returns TRUE if MPAM is configured to be virtual at EL.

boolean MPAMisVirtual(integer el)
    return (MPAMIDR_EL1.HAS_HCR == '1' && EL2Enabled() &&
        ((el == 0 && MPAMHCR_EL2.EL0_VPMEN == '1') ||
        (el == 1 && MPAMHCR_EL2.EL1_VPMEN == '1')));
```

Library pseudocode for shared/functions/mpam/genMPAM

```c
// genMPAM
// =========
// Returns MPAMInfo for exception level el.
// If InD is TRUE returns MPAM information using PARTID_I and PMG_I fields
// of MPAMel_ELx register and otherwise using PARTID_D and PMG_D fields.
// Produces a Secure PARTID if Secure is TRUE and a Non-secure PARTID otherwise.

MPAMinfo genMPAM(integer el, boolean InD, boolean secure)
    MPAMinfo returnInfo;
    PARTIDtype partidel;
    boolean perr;
    boolean gstplk = (el == 0 && EL2Enabled() &&
        MPAMHCR_EL2.GSTAPP_PLK == '1' && HCR_EL2.TGE == '0');
    integer eff_el = if gstplk then 1 else el;
    (partidel, perr) = genPARTID(eff_el, InD);
    PMGtype groupel = genPMG(eff_el, InD, perr);
    returnInfo.mpam_ns = if secure then '0' else '1';
    returnInfo.partid = partidel;
    returnInfo.pmg = groupel;
    return returnInfo;
```

Library pseudocode for shared/functions/mpam/genMPAMel

```c
// genMPAMel
// =========
// Returns MPAMinfo for specified EL in the current security state.
// InD is TRUE for instruction access and FALSE otherwise.

MPAMinfo genMPAMel(bits(2) el, boolean InD)
    boolean secure = IsSecure();
    if HaveMPAMExt() && MPAMisEnabled() then
        return genMPAM(UInt(el), InD, secure);
    return DefaultMPAMinfo(secure);
```

Library pseudocode for shared/functions/mpam/genPARTID

```c
// genPARTID
// =========
// Returns physical PARTID and error boolean for exception level el.
// If InD is TRUE then PARTID is from MPAMel_ELx.PARTID_I and
// otherwise from MPAMel_ELx.PARTID_D.

(PARTIDtype, boolean) genPARTID(integer el, boolean InD)
    PARTIDtype partidel = getMPAM_PARTID(el, InD);
    integer partid_max = UInt(MPAMIDR_EL1.PARTID_MAX);
    if UInt(partidel) > partid_max then
        return (DefaultPARTID, TRUE);
    if MPAMisVirtual(el) then
        return MAP_vPARTID(partidel);
    else
        return (partidel, FALSE);
```
Library pseudocode for shared/functions/mpam/genPMG

```plaintext
// genPMG
// ======
// Returns PMG for exception level el and I- or D-side (InD).
// If PARTID generation (genPARTID) encountered an error, genPMG() should be
// called with partid_err as TRUE.

PMGtype genPMG(integer el, boolean InD, boolean partid_err)
    integer pmg_max = UInt(MPAMIDR_EL1.PMG_MAX);

    // It is CONSTRAINED UNPREDICTABLE whether partid_err forces PMG to
    // use the default or if it uses the PMG from getMPAM_PMG.
    if partid_err then
        return DefaultPMG;
    PMGtype groupel = getMPAM_PMG(el, InD);
    if UInt(groupel) <= pmg_max then
        return groupel;
    return DefaultPMG;
```

Library pseudocode for shared/functions/mpam/getMPAM_PARTID

```plaintext
// getMPAM_PARTID
// ==============
// Returns a PARTID from one of the MPAMn_ELx registers.
// MPAMn selects the MPAMn_ELx register used.
// If InD is TRUE, selects the PARTID_I field of that
// register. Otherwise, selects the PARTID_D field.

PARTIDtype getMPAM_PARTID(integer MPAMn, boolean InD)
    PARTIDtype partid;
    boolean el2avail = EL2Enabled();

    if InD then
        case MPAMn of
            when 3 partid = MPAM3_EL3.PARTID_I;
            when 2 partid = if el2avail then MPAM2_EL2.PARTID_I else Zeros();
            when 1 partid = MPAM1_EL1.PARTID_I;
            when 0 partid = MPAM0_EL1.PARTID_I;
            otherwise partid = PARTIDtype UNKNOWN;
        else
            case MPAMn of
                when 3 partid = MPAM3_EL3.PARTID_D;
                when 2 partid = if el2avail then MPAM2_EL2.PARTID_D else Zeros();
                when 1 partid = MPAM1_EL1.PARTID_D;
                when 0 partid = MPAM0_EL1.PARTID_D;
                otherwise partid = PARTIDtype UNKNOWN;
        return partid;
```
Library pseudocode for shared/functions/mpam/getMPAM_PMG

```plaintext
// getMPAM_PMG
// ===========
// Returns a PMG from one of the MPAMn_ELx registers.
// MPAMn selects the MPAMn_ELx register used.
// If InD is TRUE, selects the PMG_I field of that
// register. Otherwise, selects the PMG_D field.

PMGtype getMPAM_PMG(integer MPAMn, boolean InD)
  PMGtype pmg;
  boolean el2avail = EL2Enabled();
  if InD then
    case MPAMn of
      when 3 pmg = MPAM3_EL3.PMG_I;
      when 2 pmg = if el2avail then MPAM2_EL2.PMG_I else Zeros();
      when 1 pmg = MPAM1_EL1.PMG_I;
      when 0 pmg = MPAM0_EL1.PMG_I;
    otherwise pmg = PMGtype UNKNOWN;
  else
    case MPAMn of
      when 3 pmg = MPAM3_EL3.PMG_D;
      when 2 pmg = if el2avail then MPAM2_EL2.PMG_D else Zeros();
      when 1 pmg = MPAM1_EL1.PMG_D;
      when 0 pmg = MPAM0_EL1.PMG_D;
    otherwise pmg = PMGtype UNKNOWN;
  return pmg;
```

Library pseudocode for shared/functions/mpam/mapvpmw

```plaintext
// mapvpmw
// ========
// Map a virtual PARTID into a physical PARTID using
// the MPAMVPMn_EL2 registers.
// vpartid is now assumed in-range and valid (checked by caller)
// returns physical PARTID from mapping entry.

PARTIDtype mapvpmw(integer vpartid)
  bits(64) vpmw;
  integer wd = vpartid DIV 4;
  case wd of
    when 0 vpmw = MPAMVPM0_EL2;
    when 1 vpmw = MPAMVPM1_EL2;
    when 2 vpmw = MPAMVPM2_EL2;
    when 3 vpmw = MPAMVPM3_EL2;
    when 4 vpmw = MPAMVPM4_EL2;
    when 5 vpmw = MPAMVPM5_EL2;
    when 6 vpmw = MPAMVPM6_EL2;
    when 7 vpmw = MPAMVPM7_EL2;
  otherwise vpmw = Zeros(64);
  // vpme_lsb selects LSB of field within register
  integer vpme_lsb = (vpartid REM 4) * 16;
  return vpmw<vpme_lsb +: 16>;
```
// BranchTo()
// ============
// Set program counter to a new address, with a branch type
// In AArch64 state the address might include a tag in the top eight bits.
BranchTo(bits(N) target, BranchType branch_type)
    Hint_Branch(branch_type);
    if N == 32 then
        assert UsingAArch32();
        _PC = ZeroExtend(target);
    else
        assert N == 64 && !UsingAArch32();
        _PC = AArch64.BranchAddr(target<63:0>);
    return;

// BranchToAddr()
// ===============
// Set program counter to a new address, with a branch type
// In AArch64 state the address does not include a tag in the top eight bits.
BranchToAddr(bits(N) target, BranchType branch_type)
    Hint_Branch(branch_type);
    if N == 32 then
        assert UsingAArch32();
        _PC = ZeroExtend(target);
    else
        assert N == 64 && !UsingAArch32();
        _PC = target<63:0>;
    return;

// BranchType
enum BranchType {
    BranchType_DIRCALL,     // Direct Branch with link
    BranchType_INDCALL,     // Indirect Branch with link
    BranchType_ERET,        // Exception return (indirect)
    BranchType_DBGEXIT,     // Exit from Debug state
    BranchType_RET,         // Indirect branch with function return hint
    BranchType_DIR,         // Direct branch
    BranchType_INDIR,       // Indirect branch
    BranchType_EXCEPTION,   // Exception entry
    BranchType_RESET,       // Reset
    BranchType_UNKNOWN};    // Other

// Hint_Branch
// Report the hint passed to BranchTo() and BranchToAddr(), for consideration when processing
// the next instruction.
Hint_Branch(BranchType hint);

// NextInstrAddr
// Return address of the sequentially next instruction.
// Return address of the next instruction.
bits(N) NextInstrAddr();

// ResetExternalDebugRegisters
// Reset the External Debug registers in the Core power domain.
ResetExternalDebugRegisters(boolean cold_reset);
// ThisInstrAddr()
// ===============
// Return address of the current instruction.

bits(N) ThisInstrAddr()
    assert N == 64 || (N == 32 && UsingAArch32());
    return _PC<N-1:0>;

Library pseudocode for shared/functionsregisters/_PC
bits(64) _PC;

Library pseudocode for shared/functionsregisters/_R
array bits(64) _R[0..30];

Library pseudocode for shared/functionsregisters/_V
array bits(128) _V[0..31];
bits(32) SPSR[]
  if UsingAArch32() then
    case PSTATE.M of
      when M32_FIQ    result = SPSR_fiq;
      when M32_IRQ    result = SPSR_irq;
      when M32_Svc    result = SPSR_svc;
      when M32_Monitor result = SPSR_mon;
      when M32_Abort  result = SPSR_abt;
      when M32_Hyp    result = SPSR_hyp;
      when M32_Undef  result = SPSR_und;
      otherwise       Unreachable();
    else
      case PSTATE.EL of
        when EL1        result = SPSR_EL1;
        when EL2        result = SPSR_EL2;
        when EL3        result = SPSR_EL3;
        otherwise       Unreachable();
      return result;
  return;
// AllocationTagAccessIsEnabled()
// ---------------------------------------------
// Check whether access to Allocation Tags is enabled.

boolean AllocationTagAccessIsEnabled() {
    if SCR_EL3.ATA == '0' && PSTATE.EL IN {ArchVersion {EL1, ARMv8p0, EL1, ARMv8p3}} then
        return FALSE;
    elsif HCR_EL2.ATA == '0' && HCR_EL2.<E2H,TGE> != '11' && PSTATE.EL IN {ARMv8p2, EL0, ARMv8p3, EL1} then
        return FALSE;
    elsif SCTLR_EL3.ATA == '0' && PSTATE.EL == EL3 then
        return FALSE;
    elsif SCTLR_EL2.ATA == '0' && PSTATE.EL == EL2 then
        return FALSE;
    elsif SCTLR_EL1.ATA == '0' && PSTATE.EL == EL1 then
        return FALSE;
    elsif SCTLR_EL2.ATA0 == '0' && HCR_EL2.<E2H,TGE> == '11' && PSTATE.EL == EL0 then
        return FALSE;
    elsif SCTLR_EL1.ATA0 == '0' && HCR_EL2.<E2H,TGE> != '11' && PSTATE.EL == EL0 then
        return FALSE;
    else
        return TRUE;
}

// ArchVersion

enumeration ArchVersion {
    ARMv8p0,
    ARMv8p1,
    ARMv8p2,
    ARMv8p3,
    ARMv8p4,
    ARMv8p5
}

// BranchTargetCheck()
// ---------------------
// This function is executed checks if the current instruction is a valid target for a branch
// taken into, or inside, a guarded page. It is executed on every cycle once the current
// instruction has been decoded and the values of InGuardedPage and BTypeCompatible have been
// determined for the current instruction.

BranchTargetCheck() {
    assert HaveBTIExt() && !UsingAArch32();

    // The branch target check considers two state variables:
    // * InGuardedPage, which is evaluated during instruction fetch.
    // * BTypeCompatible, which is evaluated during instruction decode.
    if InGuardedPage && PSTATE.BTYPE != '00' && !BTypeCompatible && !Halted() then
        bits(64) pc = ThisInstrAddr();
        AArch64.BranchTargetException(pc<51:0>);
    boolean branch_instr = AArch64.ExecutingBROrBLROrRetInstr();
    boolean bti_instr = AArch64.ExecutingBTIInstr();

    // PSTATE.BTYPE defaults to 00 for instructions that don't explicitly set BTYPE.
    if !(branch_instr || bti_instr) then
        BTypeNext = '00';
    }
// ChooseNonExcludedTag()
// =====================
// Return a tag derived from the start and the offset values, excluding
// any tags in the given mask.

bits(4) ChooseNonExcludedTag(bits(4) tag, bits(4) offset, bits(16) exclude)

if exclude == Ones(16) then
    return tag;

while offset != '0000' do
    offset = offset - '0001';
    tag = tag + '0001';
    while exclude<UInt(tag)> == '1' do
        tag = tag + '0001';

return tag;

// ClearEventRegister()
// ====================
// Clear the Event Register of this PE

ClearEventRegister()
    EventRegister = '0';
    return;

// ClearPendingPhysicalSError
// Clear a pending physical SError interrupt
ClearPendingPhysicalSError();

// ClearPendingVirtualSError
// Clear a pending virtual SError interrupt
ClearPendingVirtualSError();

// ConditionHolds()
// ================
// Return TRUE iff COND currently holds

boolean ConditionHolds(bits(4) cond)
    // Evaluate base condition.
    case cond<3:1> of
        when '000' result = (PSTATE.Z == '1'); // EQ or NE
        when '001' result = (PSTATE.C == '1'); // CS or CC
        when '010' result = (PSTATE.N == '1'); // MI or PL
        when '011' result = (PSTATE.V == '1'); // VS or VC
        when '100' result = (PSTATE.C == '1' && PSTATE.Z == '0'); // HI or LS
        when '101' result = (PSTATE.N == PSTATE.V); // GE or LT
        when '110' result = (PSTATE.N == PSTATE.V && PSTATE.Z == '0'); // GT or LE
        when '111' result = TRUE; // AL

    // Condition flag values in the set '111x' indicate always true
    // Otherwise, invert condition if necessary.
    if cond<0> == '1' && cond != '1111' then
        result = !result;

    return result;
Library pseudocode for shared/functions/system/ConsumptionOfSpeculativeDataBarrier

ConsumptionOfSpeculativeDataBarrier();

Library pseudocode for shared/functions/system/CurrentInstrSet

// CurrentInstrSet()
// ------------------

InstrSet CurrentInstrSet()
    if UsingAArch32() then
        result = if PSTATE.T == '0' then InstrSet_A32 else InstrSet_T32;
        // PSTATE.J is RES0. Implementation of T32EE or Jazelle state not permitted.
    else
        result = InstrSet_A64;
    return result;

Library pseudocode for shared/functions/system/CurrentPL

// CurrentPL()
// -------

PrivilegeLevel CurrentPL()
    return PLOfEL(PSTATE.EL);

Library pseudocode for shared/functions/system/EL0

constant bits(2) EL3 = '11';
constant bits(2) EL2 = '10';
constant bits(2) EL1 = '01';
constant bits(2) EL0 = '00';

Library pseudocode for shared/functions/system/EL2Enabled

// EL2Enabled()
// --------
// Returns TRUE if EL2 is present and executing in either non-Secure state when Secure EL2 is not implemented,
// or in Secure state when Secure EL2 is implemented, FALSE otherwise.

boolean EL2Enabled()
    return IsSecureEL2Enabled() || (HaveEL(EL2) & & !IsSecure());
Library pseudocode for shared/functions/system/ELFromM32

// ELFromM32()
// ===========

(boolean, bits(2)) ELFromM32(bits(5) mode)
// Convert an AArch32 mode encoding to an Exception level.
// Returns (valid, EL):
// 'valid' is TRUE if 'mode<4:0>' encodes a mode that is both valid for this implementation
// and the current value of SCR.NS/SCR_EL3.NS.
// 'EL' is the Exception level decoded from 'mode'.
bits(2) el;
boolean valid = !BadMode(mode); // Check for modes that are not valid for this implementation

// case mode of
when M32_Monitor
   el = EL3;
when M32_Hyp
   el = EL2;
when M32_FIQ, M32IRQ, M32_Svc, M32_Abort, M32_Undef, M32_System
   valid = valid && (HaveEL(EL3) || SCR_GEN[].NS == '1');
   el = (if HaveEL(EL3) && HighestEUpgradeAArch32() && SCR.NS == '0' then EL3 else EL1);
when M32_User
   el = EL0;
otherwise
   valid = FALSE; // Passed an illegal mode value
   if !valid then el = bits(2) UNKNOWN;

return (valid, el);

Library pseudocode for shared/functions/system/ELFromSPSR

// ELFromSPSR()
// ============

// Convert an SPSR value encoding to an Exception level.
// Returns (valid, EL):
// 'valid' is TRUE if 'spsr<4:0>' encodes a valid mode for the current state.
// 'EL' is the Exception level decoded from 'spsr'.

(boolean, bits(2)) ELFromSPSR(bits(32) spsr)
if spsr<4> == '0' then // AArch64 state
   el = spsr<3:2>;
   if HighestEUpgradeAArch32() then // No AArch64 support
      valid = FALSE;
   elsif !HaveEL(el) then // Exception level not implemented
      valid = FALSE;
   elsif spsr<1> == '1' then // M[1] must be 0
      valid = FALSE;
   elsif el == EL0 && spsr<0> == '1' then // for EL0, M[0] must be 0
      valid = FALSE;
   elsif el == EL2 && HaveEL(EL3) && !IsSecureEL2Enabled() && SCR_EL3.NS == '0' then
      valid = FALSE; // Unless Secure EL2 is enabled, EL2 only valid in Non-
   else
      valid = TRUE;
   elsif !HaveAnyAArch32() then // AArch32 not supported
      valid = FALSE;
   else // AArch32 state
      (valid, el) = ELFromM32(spsr<4:0>);
   if !valid then el = bits(2) UNKNOWN;

return (valid, el);
Library pseudocode for shared/functions/system/ELIsInHost

```c
// ELIsInHost()
// ============

boolean ELIsInHost(bits(2) el)
    return ((IsSecureEL2Enabled() || !IsSecureBelowEL3()) && HaveVirtHostExt() && !ELUsingAArch32(EL2)
            && HCR_EL2.E2H == '1' && (el == EL2 || (el == EL0 && HCR_EL2.TGE == '1')));
```

Library pseudocode for shared/functions/system/ELStateUsingAArch32

```c
// ELStateUsingAArch32()
// =====================

boolean ELStateUsingAArch32(bits(2) el, boolean secure)
    // See ELStateUsingAArch32K() for description. Must only be called in circumstances where
    // result is valid (typically, that means 'el IN {EL1,EL2,EL3}').
    (known, aarch32) = ELStateUsingAArch32K(el, secure);
    assert known;
    return aarch32;
```

Library pseudocode for shared/functions/system/ELStateUsingAArch32K

```c
// ELStateUsingAArch32K()
// ======================

(Boolean,Boolean) ELStateUsingAArch32K(bits(2) el, boolean secure)
    // Returns (known, aarch32):
    //   'known'   is FALSE for EL0 if the current Exception level is not EL0 and EL1 is
    //             using AArch64, since it cannot determine the state of EL0; TRUE otherwise.
    //   'aarch32' is TRUE if the specified Exception level is using AArch32; FALSE otherwise.
    boolean aarch32;
    known = TRUE;
    if !HaveAArch32EL(el) then
        aarch32 = FALSE;                           // Exception level is using AArch64
    elsif HighestELUsingAArch32() then
        aarch32 = TRUE;                            // All levels are using AArch32
    else
        aarch32_below_el3 = HaveEL(EL3) && SCR_EL3.RW == '0';
        aarch32_at_el1 = (aarch32_below_el3 || (HaveEL(EL2) &&
            (HavesecureEL2Ext() && SCR_EL3.EEL2 == '1') || !secure) && HCR_EL2.RW == '0'
            && !HCR_EL2.E2H == '1' && HCR_EL2.TGE == '1' && HaveVirtHostExt()));
        if el == EL0 && aarch32_at_el1 then       // Only know if EL0 using AArch32 from PSTATE
            if PSTATE.EL == EL0 then
                aarch32 = PSTATE.nRW == '1';       // EL0 controlled by PSTATE
            else
                known = FALSE;
                // EL0 state is UNKNOWN
        else
            aarch32 = (aarch32_below_el3 && el != EL3) || (aarch32_at_el1 && el IN {EL1,EL0});
        if !known then aarch32 = boolean UNKNOWN;
        return (known, aarch32);
    endif;
```

Library pseudocode for shared/functions/system/ELUsingAArch32

```c
// ELUsingAArch32()
// ================

boolean ELUsingAArch32(bits(2) el)
    return ELStateUsingAArch32K(el, IsSecureBelowEL3());
```
Library pseudocode for shared/functions/system/ELUsingAArch32K

```c
// ELUsingAArch32K()
// ================

(boolean,boolean) ELUsingAArch32K(bits(2) el)
return ELStateUsingAArch32K(el, IsSecureBelowEL3());
```

Library pseudocode for shared/functions/system/EndOfInstruction

```c
// Terminate processing of the current instruction.
EndOfInstruction();
```

Library pseudocode for shared/functions/system/EnterLowPowerState

```c
// PE enters a low-power state
EnterLowPowerState();
```

Library pseudocode for shared/functions/system/EventRegister

```c
bits(1) EventRegister;
```

Library pseudocode for shared/functions/system/GetPSRFromPSTATE

```c
// GetPSRFromPSTATE()
// ================

// Return a PSR value which represents the current PSTATE
bits(32) GetPSRFromPSTATE()
bits(32) spsr = Zeros();
spsr<31:28> = PSTATE.<N,Z,C,V>;
if HaveDITExt() then spsr<24> = PSTATE.DIT;
if HavePANExt() then spsr<22> = PSTATE.PAN;
spsr<21> = PSTATE.SS;
spsr<20> = PSTATE.IL;
if PSTATE.nRW == '1' then // AArch32 state
spsr<27> = PSTATE.Q;
spsr<26:25> = PSTATE.IT<1:0>;
if HaveSSBSExt() then spsr<23> = PSTATE.SSBS;
() then spsr<23> = '0';
spsr<19:16> = PSTATE.GE;
spsr<15:10> = PSTATE.IT<7:2>;
spsr<9> = PSTATE.E;
spsr<8:6> = PSTATE.<A,I,F>;
// No PSTATE.D in AArch32 state
spsr<5> = PSTATE.T;
assert PSTATE.M<4> == PSTATE.nRW; // bit [4] is the discriminator
spsr<4:0> = PSTATE.M;
else // AArch64 state
if HaveUAOExt() then spsr<23> = PSTATE.UAO;
if HaveSSBSExt() then spsr<12> = PSTATE.SSBS;
if HaveMTEExt() then spsr<25> = PSTATE.TCO;
if HaveBTIExt() then spsr<11:10> = PSTATE.BTYPE;
() then spsr<23> = PSTATE.UAO;
spsr<9:6> = PSTATE.<D,A,I,F>;
spsr<4> = PSTATE.nRW;
spsr<3:2> = PSTATE.EL;
spsr<0> = PSTATE.SP;
return spsr;
```
Library pseudocode for shared/functions/system/HasArchVersion

```plaintext
// HasArchVersion()
// ================
// Return TRUE if the implemented architecture includes the extensions defined in the specified
// architecture version.

boolean HasArchVersion(ArchVersion version)
return version == ARMv8p0 || Boolean IMPLEMENTATION_DEFINED;
```

Library pseudocode for shared/functions/system/HaveAArch32EL

```plaintext
// HaveAArch32EL()
// ===============
boolean HaveAArch32EL(bits(2) el)
// Return TRUE if Exception level 'el' supports AArch32 in this implementation
if !HaveEL(el) then
  return FALSE; // The Exception level is not implemented
elsif !HaveAnyAArch32() then
  return FALSE; // No Exception level can use AArch32
elsif HighestELUsingAArch32() then
  return TRUE; // All Exception levels are using AArch32
elsif el == HighestEL() then
  return FALSE; // The highest Exception level is using AArch64
elsif el == EL0 then
  return TRUE; // EL0 must support using AArch32 if any AArch32
return boolean IMPLEMENTATION_DEFINED;
```

Library pseudocode for shared/functions/system/HaveAnyAArch32

```plaintext
// HaveAnyAArch32()
// ================
// Return TRUE if AArch32 state is supported at any Exception level

boolean HaveAnyAArch32()
return boolean IMPLEMENTATION_DEFINED;
```

Library pseudocode for shared/functions/system/HaveAnyAArch64

```plaintext
// HaveAnyAArch64()
// ================
// Return TRUE if AArch64 state is supported at any Exception level

boolean HaveAnyAArch64()
return !HighestELUsingAArch32();
```

Library pseudocode for shared/functions/system/HaveEL

```plaintext
// HaveEL()
// =========
// Return TRUE if Exception level 'el' is supported

boolean HaveEL(bits(2) el)
if el IN {EL1,EL0} then
  return TRUE; // EL1 and EL0 must exist
return boolean IMPLEMENTATION_DEFINED;
```

Library pseudocode for shared/functions/system/HaveFP16Ext

```plaintext
// HaveFP16Ext()
// =============
// Return TRUE if FP16 extension is supported

boolean HaveFP16Ext()
return boolean IMPLEMENTATION_DEFINED;
```
Library pseudocode for shared/functions/system/HighestEL

```c
// HighestEL()
// ===========
// Returns the highest implemented Exception level.

bits(2) HighestEL()
    if HaveEL(EL3) then
        return EL3;
    elsif HaveEL(EL2) then
        return EL2;
    else
        return EL1;
```

Library pseudocode for shared/functions/system/HighestELUsingAArch32

```c
// HighestELUsingAArch32()
// =======================
// Return TRUE if configured to boot into AArch32 operation

boolean HighestELUsingAArch32()
    if !HaveAnyAArch32() then return FALSE;
    return boolean IMPLEMENTATION_DEFINED;       // e.g. CFG32SIGNAL == HIGH
```

Library pseudocode for shared/functions/system/Hint_Yield

```c
Hint_Yield();
```
// IllegalExceptionReturn()  
// ========================

boolean IllegalExceptionReturn(bits(32) spsr)

    // Check for illegal return:
    // * To an unimplemented Exception level.
    // * To EL2 in Secure state, when SecureEL2 is not enabled.
    // * To EL0 using AArch64 state, with SPSR.M[0]==1.
    // * To AArch64 state with SPSR.M[1]==1.
    // * To AArch32 state with an illegal value of SPSR.M.
    (valid, target) = ELFromSPSR(spsr);
    if !valid then return TRUE;

    // Check for return to higher Exception level
    if UInt(target) > UInt(PSTATE.EL) then return TRUE;

    spsr_mode_is_aarch32 = (spsr<4> == '1');

    // Check for illegal return:
    // * To EL1, EL2 or EL3 with register width specified in the SPSR different from the
    //   Execution state used in the Exception level being returned to, as determined by
    //   the SCR_EL3.RW or HCR_EL2.RW bits, or as configured from reset.
    // * To EL0 using AArch64 state when EL1 is using AArch32 state as determined by the
    //   SCR_EL3.RW or HCR_EL2.RW bits or as configured from reset.
    // * To AArch64 state from AArch32 state (should be caught by above)
    (known, target_el_is_aarch32) = ELUsingAArch32K(target);
    assert known || (target == EL0 && ELUsingAAArch32(EL1));
    if known && spsr_mode_is_aarch32 != target_el_is_aarch32 then return TRUE;

    // Check for illegal return from AArch32 to AArch64
    if UsingAArch32() && !spsr_mode_is_aarch32 then return TRUE;

    // Check for illegal return to EL1 when HCR.TGE is set and when either of
    // * SecureEL2 is enabled.
    // * SecureEL2 is not enabled and EL1 is in Non-secure state.
    if HaveEL(EL2) && target == EL1 && HCR_EL2.TGE == '1' then
        if (!IsSecureBelowEL3() || IsSecureEL2Enabled()) then return TRUE;
    return FALSE;

Library pseudocode for shared/functions/system/InstrSet

    enumeration InstrSet (InstrSet_A64, InstrSet_A32, InstrSet_T32);

Library pseudocode for shared/functions/system/InstructionSynchronizationBarrier

    InstructionSynchronizationBarrier();

Library pseudocode for shared/functions/system/InterruptPending

    // InterruptPending()  
    // ===============
    // Return TRUE if there are any pending physical or virtual interrupts, and FALSE otherwise
    boolean InterruptPending()
    return IsPhysicalSErrorPending() || IsVirtualSErrorPending();

Library pseudocode for shared/functions/system/IsEventRegisterSet

    // IsEventRegisterSet()  
    // ====================
    // Return TRUE if the Event Register of this PE is set, and FALSE otherwise
    boolean IsEventRegisterSet()
    return EventRegister == '1';
Library pseudocode for shared/functions/system/IsHighestEL

```java
// IsHighestEL()
// =============
// Returns TRUE if given exception level is the highest exception level implemented

boolean IsHighestEL(bits(2) el)
    return HighestEL() == el;
```

Library pseudocode for shared/functions/system/IsInHost

```java
// IsInHost()
// =========

boolean IsInHost()
    return ELIsInHost(PSTATE.EL);
```

Library pseudocode for shared/functions/system/IsPhysicalSErrorPending

```java
// Return TRUE if a physical SError interrupt is pending

boolean IsPhysicalSErrorPending();
```

Library pseudocode for shared/functions/system/IsSecure

```java
// IsSecure()
// ==========

boolean IsSecure()
// Return TRUE if current Exception level is in Secure state.

if HaveEL(EL3) && !UsingAArch32() && PSTATE.EL == EL3 then
    return TRUE;
elseif HaveEL(EL3) && UsingAArch32() && PSTATE.M == M32_Monitor then
    return TRUE;
else
    return IsSecureBelowEL3();
```

Library pseudocode for shared/functions/system/IsSecureBelowEL3

```java
// IsSecureBelowEL3()
// ==================
// Return TRUE if an Exception level below EL3 is in Secure state
// or would be following an exception return to that level.
// Differences from IsSecure in that it ignores the current EL or Mode
// in considering security state.
// That is, if at AArch64 EL3 or in AArch32 Monitor mode, whether an
// exception return would pass to Secure or Non-secure state.

boolean IsSecureBelowEL3()
    if HaveEL(EL3) then
        return SCR_GEN[].NS == '0';
    elif HaveEL(EL2) && (!HaveSecureEL2Ext() || HighestELUsingAArch32()) then
        // If Secure EL2 is not an architecture option then we must be Non-secure.
        return FALSE;
    else
        // TRUE if processor is Secure or FALSE if Non-secure.
        return boolean IMPLEMENTATION_DEFINED "Secure-only implementation";
```
// IsSecureEL2Enabled()
// Returns TRUE if Secure EL2 is enabled, FALSE otherwise

boolean IsSecureEL2Enabled()
    return (HaveSecureEL2Ext() && HaveEL(EL2) && !ELUsingAArch32(EL2) && (!HaveEL(EL2) && !ELUsingAArch32(EL3) && SCR_EL3.EEL2 == '1') || (!HaveEL(EL3) && IsSecure()));

// Return TRUE if a virtual SError interrupt is pending
boolean IsVirtualSErrorPending();

// PLOfEL()
// -------

PrivilegeLevel PLOfEL(bits(2) el)
    case el of
        when EL3 return if HighestELUsingAArch32() then PL1 else PL3;
        when EL2 return PL2;
        when EL1 return PL1;
        when EL0 return PL0;

// PSTATE

ProcState PSTATE;

// PrivilegeLevel

enumeration PrivilegeLevel {PL3, PL2, PL1, PL0};
**Library pseudocode for shared/functions/system/ProcState**

type ProcState is {
    bits (1) N, // Negative condition flag
    bits (1) Z, // Zero condition flag
    bits (1) C, // Carry condition flag
    bits (1) V, // Overflow condition flag
    bits (1) D, // Debug mask bit [AArch64 only]
    bits (1) A, // SError interrupt mask bit
    bits (1) I, // IRQ mask bit
    bits (1) F, // FIQ mask bit
    bits (1) PAN, // Privileged Access Never Bit [v8.1]
    bits (1) UAO, // User Access Override [v8.2]
    bits (1) DIT, // Data Independent Timing [v8.4]
    bits (1) TCO, // Tag Check Override [v8.5, AArch64 only]
    bits (2) BTYPE, // Branch Type [v8.5]
    bits (1) SS, // Software step bit
    bits (1) IL, // Illegal Execution state bit
    bits (2) EL, // Exception Level
    bits (1) nRW, // not Register Width: 0=64, 1=32
    bits (1) SP, // Stack pointer select: 0=SP0, 1=SPx [AArch64 only]
    bits (1) Q, // Cumulative saturation flag [AArch32 only]
    bits (4) GE, // Greater than or Equal flags [AArch32 only]
    bits (1) SSBS, // Speculative Store Bypass Safe
    bits (8) IT, // If-then bits, RES0 in CPSR [AArch32 only]
    bits (1) J, // J bit, RES0 [AArch32 only, RES0 in SPSR and CPSR]
    bits (1) T, // T32 bit, RES0 in CPSR [AArch32 only]
    bits (1) E, // Endianness bit [AArch32 only]
    bits (5) M // Mode field [AArch32 only]
}

**Library pseudocode for shared/functions/system/RandomTag**

```plaintext
// RandomTag()
// ===========
// Generate a random Allocation Tag.

bits(4) RandomTag()
    bits(4) tag;
    for i = 0 to 3
        tag<i> = NextRandomTagBit();
    return tag;
```

**Library pseudocode for shared/functions/system/RandomTagBit**

```plaintext
// RandomTagBit()
// ===============
// Generate a random bit suitable for generating a random Allocation Tag.

bit NextRandomTagBit()
    bits(16) lfsr = RGSR_EL1.SEED;
    bit top = lfsr<5> EOR lfsr<3> EOR lfsr<2> EOR lfsr<0>;
    RGSR_EL1.SEED = top:lfsr<15:1>;
    return top;
```
Library pseudocode for shared/functions/system/RestoredITBits

```c
// RestoredITBits()
// ===============
// Get the value of PSTATE.IT to be restored on this exception return.

bits(8) RestoredITBits(bits(32) spsr)
    it = spsr<15:10,26:25>;
    // When PSTATE.IL is set, it is CONSTRAINED UNPREDICTABLE whether the IT bits are each set to zero or copied from the SPSR.
    if PSTATE.IL == '1' then
        if ConstrainUnpredictableBool(Unpredictable_ILZEROIT) then return '00000000';
        else return it;
    // The IT bits are forced to zero when they are set to a reserved value.
    if !IsZero(it<7:4>) && !IsZero(it<3:0>) then return '00000000';
    // The IT bits are forced to zero when returning to A32 state, or when returning to an EL with the ITD bit set to 1, and the IT bits are describing a multi-instruction block.
    itd = if PSTATE.EL == EL2 then HSCTRL.ITD else SCTLR.ITD;
    if (spsr<5> == '0' && !IsZero(it)) || (itd == '1' && !IsZero(it<2:0>)) then return '00000000';
    else return it;
```

Library pseudocode for shared/functions/system/SCRType

```c
type SCRType;
```

Library pseudocode for shared/functions/system/SCR_GEN

```c
// SCR_GEN[]
// =========

SCRType SCR_GEN[]
    // AArch32 secure & AArch64 EL3 registers are not architecturally mapped
    assert HaveEL(EL3);
    bits(32) r;
    if HighestELUsingAArch32() then
        r = SCR;
    else
        r = SCR_EL3;
    return r;
```

Library pseudocode for shared/functions/system/SendEvent

```c
// Signal an event to all PEs in a multiprocessor system to set their Event Registers.
// When a PE executes the SEV instruction, it causes this function to be executed
SendEvent();
```

Library pseudocode for shared/functions/system/SendEventLocal

```c
// SendEventLocal()
// ================
// Set the local Event Register of this PE.
// When a PE executes the SEVL instruction, it causes this function to be executed
SendEventLocal()
    EventRegister = '1';
    return;
```
Library pseudocode for shared/functions/system/SetPSTATEFromPSR

```
// SetPSTATEFromPSR()
// ------------------
// Set PSTATE based on a PSR value

SetPSTATEFromPSR(bits(32) spsr)
    PSTATE.SS = DebugExceptionReturnSS(spsr);
    if IllegalExceptionReturn(spsr) then
        PSTATE.IL = '1';
    else
        // State that is reinstated only on a legal exception return
        PSTATE.IL = spsr<20>;
        if spsr<4> == '1' then // AArch32 state
            AArch32.WriteMode(spsr<4:0>); // Sets PSTATE.EL correctly
        else // AArch64 state
            PSTATE.nRW = '0';
            PSTATE.EL = spsr<3:2>;
            PSTATE.SP = spsr<0>;
        // If PSTATE.IL is set and returning to AArch32 state, it is CONSTRAINED UNPREDICTABLE whether
        // the T bit is set to zero or copied from SPSR.
        if PSTATE.IL == '1' && PSTATE.nRW == '1' then
            if ConstrainUnpredictableBool(Unpredictable_ILZEROT) then spsr<5> = '0';
        // State that is reinstated regardless of illegal exception return
        PSTATE.<N,Z,C,V> = spsr<31:28>;
        if PSTATE.nRW == '1' then // AArch32 state
            PSTATE.Q = RestoredITBits(spsr);
            ShouldAdvanceIT = FALSE;
            PSTATE.E = spsr<9>;
            PSTATE.T = spsr<5>; // PSTATE.J is RES0
            if HaveSSBSExt() then PSTATE.SSBS = spsr<23>;
            if HaveUAOExt() then PSTATE.UAO = spsr<23>;
            if HaveSSBSExt() then PSTATE.SSBS = spsr<12>;
            PSTATE.<D,A,I,F> = spsr<9:6>;
        else // AArch64 state
            PSTATE.<D,A,I,F> = spsr<9:6>;
            if HaveBTIExt() then PSTATE.BTYPE = spsr<11:10>;
            if HavePANExt() then PSTATE.PAN = spsr<22>;
            if HaveMTEExt() then
                if PSTATE.nRW != '1' then
                    PSTATE.TCO = spsr<25>;
            return;
```
SynchronizeContext();

// Implements the error synchronization event.
SynchronizeErrors();

// Take any pending unmasked physical SError interrupt or unmasked virtual SError interrupt.
TakeUnmaskedSErrorInterrupts();

// Take any pending unmasked physical SError interrupt
TakeUnmaskedPhysicalSErrorInterrupts(boolean iesb_req);

// Take any pending unmasked physical SError interrupt or unmasked virtual SError interrupt.
TakeUnmaskedSErrorInterrupts();

bits(32) ThisInstr();

integer ThisInstrLength();

Unreachable()
assert FALSE;

// UsingAArch32()
// ==============
// Return TRUE if the current Exception level is using AArch32, FALSE if using AArch64.

boolean UsingAArch32()
boolean aarch32 = (PSTATE.nRW == '1');
if !HaveAnyAArch32() then assert !aarch32;
if HighestELUsingAArch32() then assert aarch32;
return aarch32;

// WaitForEvent()
// ==============
// PE suspends its operation and enters a low-power state if the Event Register is clear when the WFE is executed

WaitForEvent()
if EventRegister == '0' then
    EnterLowPowerState();
return;
// WaitForInterrupt()
// ===============
// PE suspends its operation to enter a low-power state
// until a WFI wake-up event occurs or the PE is reset

WaitForInterrupt()
    EnterLowPowerState();
    return;
Library pseudocode for shared/functions/unpredictable/ConstrainUnpredictable
// ConstrainUnpredictable()
// ========================
// Return the appropriate Constraint result to control the caller's behavior. The return value
// is IMPLEMENTATION DEFINED within a permitted list for each UNPREDICTABLE case.
// (The permitted list is determined by an assert or case statement at the call site.)

// NOTE: This version of the function uses an Unpredictable argument to define the call site.
// This argument does not appear in the version used in the ARMv8 Architecture Reference Manual.
// The extra argument is used here to allow this example definition. This is an example only and
// does not imply a fixed implementation of these behaviors. Indeed the intention is that it should
// be defined by each implementation, according to its implementation choices.

Constraint ConstrainUnpredictable(Unpredictable which)
    case which of
        when Unpredictable_WBOVERLAPLD
            return Constraint_WBSUPPRESS; // return loaded value
        when Unpredictable_WBOVERLAPST
            return Constraint_NONE; // store pre-writeback value
        when Unpredictable_LPPOVERLAP
            return Constraint_UNDEF; // instruction is UNDEFINED
        when Unpredictable_BaseOVERTLAP
            return Constraint_NONE; // use original address
        when Unpredictable_DATAOVERLAP
            return Constraint_NONE; // store original value
        when Unpredictable_DEVPAGE2
            return Constraint_FAULT; // store original value
        when Unpredictable_INSTRDEVICE
            return Constraint_NONE; // Do not take a fault
        when Unpredictable_RESCPACR
            return Constraint_UNKNOWN; // Map to UNKNOWN value
        when Unpredictable_RESMAIR
            return Constraint_UNKNOWN; // Map to UNKNOWN value
        when Unpredictable_RESTEIXCB
            return Constraint_UNKNOWN; // Map to UNKNOWN value
        when Unpredictable_RESDACR
            return Constraint_NONE; // store original value
        when Unpredictable_RESFRR
            return Constraint_UNKNOWN; // Map to UNKNOWN value
        when Unpredictable_RESWPMASK
            return Constraint_DISABLED; // Watchpoint disabled
        when Unpredictable_WPMASKEDBITS
            return Constraint_FALSE; // Watchpoint disabled
        when Unpredictable_BPVECTORCATCHPRI
            return Constraint_TRUE; // Debug Vector Catch: match on 2nd halfword
        when Unpredictable_VCMATCHHALF
            return Constraint_FALSE; // No match
        when Unpredictable_VCMATCHDAPA
            return Constraint_FALSE; // No match on Data Abort or Prefetch abort
        when Unpredictable_WPMASKANDBAS
            return Constraint_FALSE; // Watchpoint disabled
        when Unpredictable_WPBASECONTIGUOUS
            return Constraint_FALSE; // Watchpoint disabled
        when Unpredictable_RESBPWPCTRL
            return Constraint_DISABLED; // Watchpoint disabled
        when Unpredictable_WPMASKEDBITS
            return Constraint_FALSE; // Watchpoint disabled
        when Unpredictable_SBNOTIMPL
            return Constraint_DISABLED; // Breakpoint/watchpoint disabled
        when Unpredictable_BPNOTIMPL
            return Constraint_DISABLED; // Breakpoint disabled
when Unpredictable_RESBPTYPE
    return Constraint_DISABLED; // Breakpoint disabled
when Unpredictable_BPNOTCTXCMP
    return Constraint_DISABLED; // Breakpoint disabled
when Unpredictable_BPMATCHHALF
    return Constraint_FALSE; // No match
when Unpredictable_BPMISMATCHHALF
    return Constraint_FALSE; // No match
when Unpredictable_RESTARTALIGNPC
    return Constraint_FALSE; // Do not force alignment
when Unpredictable_RESTARTZEROUPPERPC
    return Constraint_TRUE; // Force zero extension
when Unpredictable_ZEROUPPER
    return Constraint_TRUE; // zero top halves of X registers
when Unpredictable_ERETZEROUPPERPC
    return Constraint_TRUE; // zero top half of PC
when Unpredictable_A32FORCEALIGNPC
    return Constraint_FALSE; // Do not force alignment
when Unpredictable_SMD
    return Constraint_UNDEF; // disabled SMC is Unallocated
when Unpredictable_NONFAULT
    return Constraint_FALSE; // Speculation enabled
when Unpredictable_SVEZEROUPPER
    return Constraint_TRUE; // zero top bits of Z registers
when Unpredictable_SVELDNFDATA
    return Constraint_TRUE; // Load mem data in NF loads
when Unpredictable_SVELDNFZERO
    return Constraint_TRUE; // Write zeros in NF loads
when Unpredictable_AFUPDATE
    return Constraint_TRUE; // AF update for alignment or permission fault
when Unpredictable_IESBinDebug
    return Constraint_TRUE; // Use SCTLR[].IESB in Debug state
when Unpredictable ZEROBTYPE
    return Constraint_TRUE; // Save BTYPE in SPSR_ELx/DPSR_EL0 as '00'
when Unpredictable_CLEARERRITEZERO
    return Constraint_FALSE; // Clearing sticky errors when instruction in flight

Library pseudocode for shared/functions/unpredictable/ConstrainUnpredictableBits

// ConstrainUnpredictableBits()
// ----------------------------------------

// This is a variant of ConstrainUnpredictable for when the result can be Constraint_UNKNOWN.
// If the result is Constraint_UNKNOWN then the function also returns UNKNOWN value, but that
// value is always an allocated value; that is, one for which the behavior is not itself
// CONSTRAINED.

// NOTE: This version of the function uses an Unpredictable argument to define the call site.
// This argument does not appear in the version used in the ARMv8 Architecture Reference Manual.
// See the NOTE on ConstrainUnpredictable() for more information.

// This is an example placeholder only and does not imply a fixed implementation of the bits part
// of the result, and may not be applicable in all cases.

(Constraint,bits(width)) ConstrainUnpredictableBits(Unpredictable which)

    c = ConstrainUnpredictable(which);
    if c == Constraint_UNKNOWN then
        return (c, Zeros(width)); // See notes; this is an example implementation only
    else
        return (c, bits(width) UNKNOWN); // bits result not used
// ConstrainUnpredictableBool()
// -------------------------------------

// This is a simple wrapper function for cases where the constrained result is either TRUE or FALSE.

// NOTE: This version of the function uses an Unpredictable argument to define the call site.
// This argument does not appear in the version used in the ARMv8 Architecture Reference Manual.
// See the NOTE on ConstrainUnpredictable() for more information.

boolean ConstrainUnpredictableBool(Unpredictable which)
{
    c = ConstrainUnpredictable(which);
    assert c IN {Constraint_TRUE, Constraint_FALSE};
    return (c == Constraint_TRUE);
}

// ConstrainUnpredictableInteger()
// ----------------------------------

// This is a variant of ConstrainUnpredictable for when the result can be Constraint_UNKNOWN. If
// the result is Constraint_UNKNOWN then the function also returns an UNKNOWN value in the range
// low to high, inclusive.

// NOTE: This version of the function uses an Unpredictable argument to define the call site.
// This argument does not appear in the version used in the ARMv8 Architecture Reference Manual.
// See the NOTE on ConstrainUnpredictable() for more information.
// This is an example placeholder only and does not imply a fixed implementation of the integer part
// of the result.

(Constraint, integer) ConstrainUnpredictableInteger(integer low, integer high, Unpredictable which)
{
    c = ConstrainUnpredictable(which);
    if c == Constraint_UNSUPPORTED then
        return (c, low);                // See notes; this is an example implementation only
    else
        return (c, integer UNKNOWN);    // integer result not used
}

// General

enum Constraint
{
    Constraint_NONE,            // Instruction executes with
    Constraint_UNKNOWN,         // no change or side-effect to its described
    Constraint_UNDEF,           // Destination register has UNKNOWN value
    Constraint_UNDEFEL0,        // Instruction is UNDEFINED
    Constraint_NOP,             // Instruction is UNDEFINED at EL0 only
    Constraint_TRUE,            // Instruction executes as NOP
    Constraint_FALSE,
    Constraint_DISABLED,
    Constraint_UNCOND,          // Instruction executes unconditionally
    Constraint_COND,            // Instruction executes conditionally
    Constraint_ADDITIONAL_DECODE, // Instruction executes with additional decode
    Constraint_WBSUPPRESS,      // Load-store
    Constraint_FAULT,           // IPA too large
    Constraint_FORCE,
    Constraint_FORCENOSLCHECK
};
enumeration Unpredictable {// Writeback/transfer register overlap (load)
  Unpredictable_WBOVERLAPLD,
  // Writeback/transfer register overlap (store)
  Unpredictable_WBOVERLAPST,
  // Load Pair transfer register overlap
  Unpredictable_LDPOVERLAP,
  // Store-exclusive base/status register overlap
  Unpredictable_BASEOVERLAP,
  // Store-exclusive data/status register overlap
  Unpredictable_DATAOVERLAP,
  // Load-store alignment checks
  Unpredictable_DEVPAGE2,
  // Instruction fetch from Device memory
  Unpredictable_INSTRDEVICE,
  // Reserved CPACR value
  Unpredictable_RESCPACR,
  // Reserved MAIR value
  Unpredictable_RESCAIR,
  // Reserved TEX:C:B value
  Unpredictable_RESTEXCB,
  // Reserved PRRR value
  Unpredictable_RESPPRRR,
  // Reserved DACR field
  Unpredictable_RESDACR,
  // Reserved VTCR.S value
  Unpredictable_RESVTCRS,
  // Reserved TCR.TnSZ value
  Unpredictable_RESTnSZ,
  // Out-of-range TCR.TnSZ value
  Unpredictable_OORTnSZ,
  // IPA size exceeds PA size
  Unpredictable_LARGЕIPA,
  // Syndrome for a known-passing conditional A32 instruction
  Unpredictable_ESRCONDPASS,
  // Illegal State exception: zero PSTATE.IT
  Unpredictable_ILZEROIT,
  // Illegal State exception: zero PSTATE.T
  Unpredictable_ILZEROIT,
  // Debug: prioritization of Vector Catch
  Unpredictable_BPVECTORCATCHPRI,
  // Debug Vector Catch: match on 2nd halfword
  Unpredictable_VCMATCHHALF,
  // Debug Vector Catch: match on Data Abort or Prefetch abort
  Unpredictable_VCMATCHDAPA,
  // Debug watchpoints: non-zero MASK and non-ones BAS
  Unpredictable_WPMASKANDBAS,
  // Debug watchpoints: non-contiguous BAS
  Unpredictable_WPBASCONTIGUOUS,
  // Debug watchpoints: reserved MASK
  Unpredictable_RESWPMASK,
  // Debug watchpoints: non-zero MASKed bits of address
  Unpredictable_WPMASKEDBITS,
  // Debug breakpoints and watchpoints: reserved control bits
  Unpredictable_RESBFWPCTRL,
  // Debug breakpoints: not implemented
  Unpredictable_BPNOTIMPL,
  // Debug breakpoints: reserved type
  Unpredictable_RESBTYPE,
  // Debug breakpoints: not-context-aware breakpoint
  Unpredictable_BPNOTCTXCMP,
  // Debug breakpoints: match on 2nd halfword of instruction
  Unpredictable_BPMATCHHALF,
  // Debug breakpoints: mismatch on 2nd halfword of instruction
  Unpredictable_BPMISMATCHHALF,
  // Debug: restart to a misaligned AArch32 PC value
  Unpredictable_RESTARTALIGNPC,
  // Debug: restart to a not-zero-extended AArch32 PC value
  Unpredictable_RESTARTZEROUPPERPC,
  // Zero top 32 bits of X registers in AArch32 state
  UnpredictableZEROUPPER,
// Zero top 32 bits of PC on illegal return to AArch32 state
Unpredictable_ERETZEROUPPERPC,
// Force address to be aligned when interworking branch to A32 state
Unpredictable_A32FORCEALIGNPC,
// SMC disabled
Unpredictable_SMD,
// FF speculation
Unpredictable_NONFAULT,
// Zero top bits of Z registers in EL change
Unpredictable_SVEZEROUPPER,
// Load mem data in NF loads
Unpredictable_SVELDNFDATA,
// Write zeros in NF loads
Unpredictable_SVELDNFZERO,
// Access Flag Update by HW
Unpredictable_AFUPDATE,
// Consider SCTLR[].IESB in Debug state
Unpredictable_IESBinDebug,
// No events selected in PMSEVFR_EL1
Unpredictable_ZEROPMSEVFR,
// No operation type selected in PMSFCR_EL1
Unpredictable_NOOPTYPES,
// Zero latency in PMSLATFR_EL1
Unpredictable_ZEROMINLATENCY,
// Zero saved BType value in SPSR_ELx/DPSR_EL0
Unpredictable_ZEROBTYPE,
// Clearing DCC/ITR sticky flags when instruction is in flight
Unpredictable_CLEARERRITEZERO);}
// Library pseudocode for shared/functions/vector/AdvSIMDExpandImm

// AdvSIMDExpandImm()
// -----------------

bits(64) AdvSIMDExpandImm(bit op, bits(4) cmode, bits(8) imm8)

  case cmode<3:1> of
    when '000'  
      imm64 = Replicate(Zeros(24):imm8, 2);
    when '001'
      imm64 = Replicate(Zeros(16):imm8:Zeros(8), 2);
    when '010'
      imm64 = Replicate(Zeros(8):imm8:Zeros(16), 2);
    when '011'
      imm64 = Replicate(imm8:Zeros(24), 2);
    when '100'
      imm64 = Replicate(Zeros(8):imm8, 4);
    when '101'
      imm64 = Replicate(Zeros(8):Zeros(8), 4);
    when '110' 
      if cmode<0> == '0' then
        imm64 = Replicate(Zeros(16):imm8:Ones(8), 2);
      else
        imm64 = Replicate(imm8:Ones(16), 2);
    when '111' 
      if cmode<0> == '0' && op == '0' then
        imm64 = Replicate(imm8, 8);
      if cmode<0> == '0' && op == '1' then
        imm8a = Replicate(imm8<7>, 8); imm8b = Replicate(imm8<6>, 8);
        imm8c = Replicate(imm8<5>, 8); imm8d = Replicate(imm8<4>, 8);
        imm8e = Replicate(imm8<3>, 8); imm8f = Replicate(imm8<2>, 8);
        imm8g = Replicate(imm8<1>, 8); imm8h = Replicate(imm8<0>, 8);
      if cmode<0> == '1' && op == '0' then
        imm32 = imm8<7>:NOT(imm8<6>):Replicate(imm8<6>, 5):imm8<5:0>:Zeros(19);
        imm64 = Replicate(imm32, 2);
      if cmode<0> == '1' && op == '1' then
        if UsingAArch32() then ReservedEncoding();
        imm64 = imm8<7>:NOT(imm8<6>):Replicate(imm8<6>, 8):imm8<5:0>:Zeros(48);

  return imm64;

// Library pseudocode for shared/functions/vector/PolynomialMult

// PolynomialMult()
// ---------------

bits(M+N) PolynomialMult(bits(M) op1, bits(N) op2)

  result = Zeros(M+N);
  extended_op2 = ZeroExtend(op2, M+N);
  for i=0 to M-1 
    if op1<i> == '1' then
      result = result EOR LSL(extended_op2, i);
  return result;

// Library pseudocode for shared/functions/vector/SatQ

// SatQ()
// ------

(bits(N), boolean) SatQ(integer i, integer N, boolean unsigned)

  (result, sat) = if unsigned then UnsignedSatQ(i, N) else SignedSatQ(i, N);
  return (result, sat);
// SignedSatQ()
// ============

(bits(N), boolean) SignedSatQ(integer i, integer N)
if i > 2^(N-1) - 1 then
  result = 2^(N-1) - 1;  saturated = TRUE;
elsif i < -(2^(N-1)) then
  result = -(2^(N-1));  saturated = TRUE;
else
  result = i;  saturated = FALSE;
return (result<N-1:0>, saturated);

// UnsignedRSqrtEstimate()
// =======================

bits(N) UnsignedRSqrtEstimate(bits(N) operand)
assert N IN {16,32};
if operand<N-1:N-2> == '00' then  // Operands <= 0x3FFFFFFF produce 0xFFFFFFFF
  result = Ones(N);
else
  // input is in the range 0x40000000 .. 0xffffffff representing [0.25 .. 1.0)
  // estimate is in the range 256 .. 511 representing [1.0 .. 2.0)
  case N of
    when 16 estimate = RecipSqrtEstimate(UInt(operand<15:7>));
    when 32 estimate = RecipSqrtEstimate(UInt(operand<31:23>));
  // result is in the range 0x80000000 .. 0xff800000 representing [1.0 .. 2.0)
  result = estimate<8:0> : Zeros(N-9);
return result;

// UnsignedRecipEstimate()
// =======================

bits(N) UnsignedRecipEstimate(bits(N) operand)
assert N IN {16,32};
if operand<N-1> == '0' then  // Operands <= 0x7FFFFFFF produce 0xFFFFFFFF
  result = Ones(N);
else
  // input is in the range 0x80000000 .. 0xffffffff representing [0.5 .. 1.0)
  // estimate is in the range 256 to 511 representing [1.0 .. 2.0)
  case N of
    when 16 estimate = RecipEstimate(UInt(operand<15:7>));
    when 32 estimate = RecipEstimate(UInt(operand<31:23>));
  // result is in the range 0x80000000 .. 0xff800000 representing [1.0 .. 2.0)
  result = estimate<8:0> : Zeros(N-9);
return result;
Library pseudocode for shared/functions/vector/UnsignedSatQ

// UnsignedSatQ()
// ==============
<bits(N), boolean) UnsignedSatQ(integer i, integer N)
    if i > 2^N - 1 then
        result = 2^N - 1;  saturated = TRUE;
    elseif i < 0 then
        result = 0;  saturated = TRUE;
    else
        result = i;  saturated = FALSE;
    return (result<N-1:0>, saturated);

Library pseudocode for shared/translation/attrs/CombineS1S2AttrHints

// CombineS1S2AttrHints()
// ======================
MemAttrHints CombineS1S2AttrHints(MemAttrHints s1desc, MemAttrHints s2desc)
    MemAttrHints result;
    if s2desc.attrs == '01' || s1desc.attrs == '01' then
        result.attrs = bits(2) UNKNOWN;   // Reserved
    elseif s2desc.attrs == HaveStage2MemAttrControl() && HCR_EL2.FWB == '1' then
        if s2desc.attrs == MemAttr_WB then
            result.attrs = s1desc.attrs;
        elseif s2desc.attrs == MemAttr_WT then
            result.attrs = MemAttr_WB;
        else
            result.attrs = MemAttr_NC;
    else
        if s2desc.attrs == '01' || s1desc.attrs == '01' then
            result.attrs = bits(2) UNKNOWN;   // Reserved
        elseif s2desc.attrs == MemAttr_NC || s1desc.attrs == MemAttr_NC then
            result.attrs = MemAttr_NC;  // Non-cacheable
        elseif s2desc.attrs == MemAttr_WT || s1desc.attrs == MemAttr_WT then
            result.attrs = MemAttr_WT;  // Write-through
        else
            result.attrs = MemAttr_WB;  // Write-back
    result.hints = s1desc.hints;
    result.transient = s1desc.transient;
    return result;
// CombineS1S2Desc()
// ------------------
// Combines the address descriptors from stage 1 and stage 2

AddressDescriptor CombineS1S2Desc(AddressDescriptor s1desc, AddressDescriptor s2desc)
{
    AddressDescriptor result;

    result.paddress = s2desc.paddress;

    if IsFault(s1desc) || IsFault(s2desc) then
        result = if IsFault(s1desc) then s1desc else s2desc;
    elsif s2desc.memattrs.type == MemType_Device || s1desc.memattrs.type == MemType_Device then
        result.memattrs.type = MemType_Device;
        if s1desc.memattrs.type == MemType_Normal then
            result.memattrs.device = s2desc.memattrs.device;
        elsif s2desc.memattrs.type == MemType_Normal then
            result.memattrs.device = s1desc.memattrs.device;
        else
            result.memattrs.device = CombineS1S2Device(s1desc.memattrs.device, s2desc.memattrs.device);
        end
    end

    result.memattrs.tagged = FALSE;

    if s2device == DeviceType_nGnRnE || s1device == DeviceType_nGnRnE then
        result = DeviceType_nGnRnE;
    elsif s2device == DeviceType_nGnRE || s1device == DeviceType_nGnRE then
        result = DeviceType_nGnRE;
    elsif s2device == DeviceType_nGRE || s1device == DeviceType_nGRE then
        result = DeviceType_nGRE;
    else
        result = DeviceType_GRE;
    end

    return result;
}

// CombineS1S2Device()
// -------------------
// Combines device types from stage 1 and stage 2

DeviceType CombineS1S2Device(DeviceType s1device, DeviceType s2device)
{
    if s2device == DeviceType_nGnRnE || s1device == DeviceType_nGnRnE then
        result = DeviceType_nGnRnE;
    elsif s2device == DeviceType_nGnRE || s1device == DeviceType_nGnRE then
        result = DeviceType_nGnRE;
    elsif s2device == DeviceType_nGRE || s1device == DeviceType_nGRE then
        result = DeviceType_nGRE;
    else
        result = DeviceType_GRE;
    end

    return result;
}
Library pseudocode for shared/translation/attrs/LongConvertAttrsHints

```
// LongConvertAttrsHints()
// =======================
// Convert the long attribute fields for Normal memory as used in the MAIR fields
// to orthogonal attributes and hints

MemAttrHints LongConvertAttrsHints(bits(4) attrfield, AccType acctype)
assert !IsZero(attrfield);
MemAttrHints result;
if S1CacheDisabled(acctype) then             // Force Non-cacheable
  result.attrs = MemAttr_NC;
  result.hints = MemHint_No;
else
  if attrfield<3:2> == '00' then          // Write-through transient
    result.attrs = MemAttr_WT;
    result.hints = attrfield<1:0>;
    result.transient = TRUE;
  elseif attrfield<3:0> == '0100' then     // Non-cacheable (no allocate)
    result.attrs = MemAttr_NC;
    result.hints = MemHint_No;
    result.transient = FALSE;
  elseif attrfield<3:2> == '01' then       // Write-back transient
    result.attrs = MemAttr_WB;
    result.hints = attrfield<1:0>;
    result.transient = TRUE;
  else                                    // Write-through/Write-back non-transient
    result.attrs = attrfield<3:2>;
    result.hints = attrfield<1:0>;
    result.transient = FALSE;
return result;
```

Library pseudocode for shared/translation/attrs/MemAttrDefaults

```
// MemAttrDefaults()
// ===============
// Supply default values for memory attributes, including overriding the shareability attributes
// for Device and Non-cacheable memory types.

MemoryAttributes MemAttrDefaults(MemoryAttributes memattrs)
if memattrs.type == MemType_Device then
  memattrs.inner = MemAttrHints UNKNOWN;
  memattrs.outer = MemAttrHints UNKNOWN;
  memattrs.shareable = TRUE;
  memattrs.outershareable = TRUE;
else
  memattrs.device = DeviceType UNKNOWN;
  if memattrs.inner.attrs == MemAttr_NC & memattrs.outer.attrs == MemAttr_NC then
    memattrs.shareable = TRUE;
    memattrs.outershareable = TRUE;
return memattrs;
```
Library pseudocode for shared/translation/attrs/S1CacheDisabled

```plaintext
// S1CacheDisabled()
// ===============

boolean S1CacheDisabled(AccType acctype)
if ELUsingAArch32(S1TranslationRegime()) then
    if PSTATE.EL == EL2 then
        enable = if acctype == AccType_IFETCH then HSCTLR.I else HSCTLR.C;
    else
        enable = if acctype == AccType_IFETCH then SCTLR.I else SCTLR.C;
    else
        enable = if acctype == AccType_IFETCH then SCTLR[].I else SCTLR[].C;
return enable == '0';
```

Library pseudocode for shared/translation/attrs/S2AttrDecode

```plaintext
// S2AttrDecode()
// ==============

MemoryAttributes S2AttrDecode(bits(2) SH, bits(4) attr, AccType acctype)

    MemoryAttributes memattrs;

    apply_force_writeback = if attr<3:2> == '00' then                    // Device
        memattrs.type == HaveStage2MemAttrControl() && HCR_EL2.FWB == '1';
    // Device memory
    if (apply_force_writeback && attr<2> == '0') || attr<3:2> == '00' then
        memattrs.type = MemType_Device;
        case attr<1:0> of
            when '00'  memattrs.device = DeviceType_nGnRnE;
            when '01'  memattrs.device = DeviceType_nGnRE;
            when '10'  memattrs.device = DeviceType_nGRE;
            when '11'  memattrs.device = DeviceType_GRE;
    // Normal memory
    elsif attr<1:0> != '00' then
        if apply_force_writeback then
            memattrs.outer = S2ConvertAttrsHints(attr<1:0>, acctype);
        else
            memattrs.outer = S2ConvertAttrsHints(attr<3:2>, acctype);
        memattrs.inner = S2ConvertAttrsHints(attr<1:0>, acctype);
        memattrs.shareable = SH<1> == '1';
        memattrs.outershareable = SH == '10';
        elsif memattrs = MemoryAttributes UNKNOWN; // Reserved
return MemAttrDefaults(memattrs);
```

Library pseudocode for shared/translation/attrs/S2CacheDisabled

```plaintext
// S2CacheDisabled()
// ==============

boolean S2CacheDisabled(AccType acctype)
if ELUsingAArch32(EL2) then
    disable = if acctype == AccType_IFETCH then HCR2.ID else HCR2.CD;
else
    disable = if acctype == AccType_IFETCH then HCR_EL2.ID else HCR_EL2.CD;
return disable == '1';
```
// S2ConvertAttrsHints()
// ---------------------
// Converts the attribute fields for Normal memory as used in stage 2
// descriptors to orthogonal attributes and hints

MemAttrHints S2ConvertAttrsHints(bits(2) attr, AccType acctype)
assert !IsZero(attr);

MemAttrHints result;

if S2CacheDisabled(acctype) then // Force Non-cacheable
    result.attrs = MemAttr_NC;
    result.hints = MemHint_No;
else
    case attr of
        when '01'                               // Non-cacheable (no allocate)
            result.attrs = MemAttr_NC;
            result.hints = MemHint_No;
        when '10'                               // Write-through
            result.attrs = MemAttr_WT;
            result.hints = MemHint_RWA;
        when '11'                               // Write-back
            result.attrs = MemAttrWB;
            result.hints = MemHint_RWA;
    endcase attr of

result.transient = FALSE;
return result;

// ShortConvertAttrsHints()
// -------------------------
// Converts the short attribute fields for Normal memory as used in the TTBR and
// TEX fields to orthogonal attributes and hints

MemAttrHints ShortConvertAttrsHints(bits(2) RGN, AccType acctype, boolean secondstage)

MemAttrHints result;

if (!secondstage && S1CacheDisabled(acctype)) || (secondstage && S2CacheDisabled(acctype)) then // Force Non-cacheable
    result.attrs = MemAttr_NC;
    result.hints = MemHint_No;
else
    case RGN of
        when '00'                   // Non-cacheable (no allocate)
            result.attrs = MemAttr_NC;
            result.hints = MemHint_No;
        when '01'                   // Write-back, Read and Write allocate
            result.attrs = MemAttr WB;
            result.hints = MemHint RWA;
        when '10'                   // Write-through, Read allocate
            result.attrs = MemAttr WT;
            result.hints = MemHint RA;
        when '11'                   // Write-back, Read allocate
            result.attrs = MemAttr WB;
            result.hints = MemHint RA;
    endcase RGN of

result.transient = FALSE;
return result;
Library pseudocode for shared/translation/attrs/WalkAttrDecode

```c
// WalkAttrDecode()
// ================
MemoryAttributes WalkAttrDecode(bits(2) SH, bits(2) ORGN, bits(2) IRGN, boolean secondstage)
{
    MemoryAttributes memattrs;
    AccType acctype = AccType_NORMAL;
    memattrs.type = MemType_Normal;
    memattrs.inner = ShortConvertAttrsHints(IRGN, acctype, secondstage);
    memattrs.outer = ShortConvertAttrsHints(ORGN, acctype, secondstage);
    memattrs.shareable = SH<1> == '1';
    memattrsoutershareable = SH == '10';
    memattrs.tagged = FALSE;
    return MemAttrDefaults(memattrs);
}
```

Library pseudocode for shared/translation/translation/HasS2Translation

```c
// HasS2Translation()
// ==================
// Returns TRUE if stage 2 translation is present for the current translation regime
return (EL2Enabled() && !IsInHost() && PSTATE.EL IN {EL0,EL1});
```

Library pseudocode for shared/translation/translation/Have16bitVMID

```c
// Have16bitVMID()
// ===============
// Returns TRUE if EL2 and support for a 16-bit VMID are implemented.
return HaveEL(EL2) && boolean IMPLEMENTATION_DEFINED;
```

Library pseudocode for shared/translation/translation/PAMax

```c
// PAMax()
// =======
// Returns the IMPLEMENTATION DEFINED upper limit on the physical address size for this processor, as log2().
return integer IMPLEMENTATION_DEFINED "Maximum Physical Address Size";
```
Library pseudocode for shared/translation/translation/S1TranslationRegime

// S1TranslationRegime()
// ---------------------
// Stage 1 translation regime for the given Exception level

bits(2) S1TranslationRegime(bits(2) el)
    if el != EL0 then
        return el;
    elsif HaveEL(EL3) & ELUsingAArch32(EL3) & SCR.NS == '0' then
        return EL3;
    elsif HaveVirtHostExt() & ELIsInHost(el) then
        return EL2;
    else
        return EL1;

// S1TranslationRegime()
// ---------------------
// Returns the Exception level controlling the current Stage 1 translation regime. For the most
// part this is unused in code because the system register accessors (SCTLR[], etc.) implicitly
// return the correct value.

bits(2) S1TranslationRegime()
    return S1TranslationRegime(PSTATE.EL);

Library pseudocode for shared/translation/translation/VAMax

// VAMax()
// -------
// Returns the IMPLEMENTATION DEFINED upper limit on the virtual address
// size for this processor, as log2().

integer VAMax()
    return integer IMPLEMENTATION_DEFINED "Maximum Virtual Address Size";

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