ARM Architecture Reference Manual

Thumb-2 Supplement

ARM®

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ARM Architecture Reference Manual

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Release Information

The following changes have been made to this document.

Change History

Date	Issue	Change
December 2004	A	First release
April 2005	C	Updated to incorporate corrections to errata
December 2005	D	Updated for unified assembler syntax.

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Glossary

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Preface

This preface describes the contents of this manual, then lists the conventions and terminology it uses.

- *About this manual* on page viii
- *Unified Assembler Language* on page ix
- *Using this manual* on page x
- *Conventions* on page xi
- *Further reading* on page xii
- *Feedback* on page xiii.

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About this manual

The purpose of this manual is to describe Thumb®-2, its *Instruction Set Architecture* (ISA), and the changes to the programmers' model it introduces. This manual also describes the extensions to the ARM® ISA introduced at the same time. Thumb-2 is a superset of the ARMv6 Thumb ISA described in the *ARM Architecture Reference Manual* (ARM DDI 0100).

Thumb-2 extends the Thumb architecture by adding the following:

- A substantial number of new 32-bit Thumb instructions. These cover most of the functionality of the ARM instruction set. The main omission is the absence of a condition field in almost all Thumb instructions.
- Several new 16-bit Thumb instructions. One of these, the `IT` (If Then) instruction, provides an efficient alternative mechanism for conditional execution.

Thumb-2 also extends the ARM ISA by adding a small number of new ARM instructions, and some additional variants of the ARM `LDR` and `STR` instructions. The additions provide ARM equivalents of instructions supported in the Thumb instruction set.

The precise effects of each new instruction are described, including any restrictions on its use. This information is of primary importance to authors of compilers, assemblers, and other programs that generate Thumb and ARM machine code.

Assembler syntax is given for the instructions described in this manual, allowing instructions to be specified in textual form. This is of considerable use to assembly code writers, and also when debugging either assembler or high-level language code at the single instruction level.

However, this manual is not intended as tutorial material for ARM assembler language, nor does it describe ARM assembler language at anything other than a very basic level. To make effective use of ARM assembler language, consult the documentation supplied with the assembler being used. Different assemblers vary considerably with respect to many aspects of assembler language, such as which assembler directives are accepted and how they are coded.

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Unified Assembler Language

This version of the Thumb-2 supplement uses the new Unified Assembler Language (UAL). The new assembly language syntax provides a canonical form for all ARM and Thumb instructions. This replaces the earlier Thumb assembler language. For this reason, every Thumb instruction is included in this document.

The syntax of Thumb instructions is now the same as the syntax of ARM instructions. This requires some changes to the old Thumb syntax. See *Changes to Thumb assembly language syntax* on page 1-3 for details.

UAL describes the syntax for the mnemonic and the operands of each instruction. In addition, it assumes that instructions and data items can be given labels. It does not specify the syntax to be used for labels, nor what assembler directives and options are available. See your assembler documentation for these details.

UAL includes *instruction selection* rules that specify which instruction encoding is selected when more than one can provide the required functionality. For example, both 16-bit and 32-bit encodings exist for an `ADD R0,R1,R2` instruction.

The most common instruction selection rule is that when both a 16-bit encoding and a 32-bit encoding are available, the 16-bit encoding is selected, to optimize code density.

Syntax options exist to override the normal instruction selection rules and ensure that a particular encoding is selected. These are useful when disassembling code, to ensure that subsequent assembly produces the original code, and in some other situations.

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Using this manual

The information in this manual is organized into five chapters, as described below.

Chapter 1 ***Introduction to Thumb-2***

Gives a brief overview of the Thumb-2 extension to the ARM and Thumb instruction sets.

Chapter 2 ***Programmers' Model***

Describes the changes to the Programmers' Model introduced with Thumb-2.

Chapter 3 ***The Thumb Instruction Set***

Gives a description of the Thumb-2 extension to the ARM and Thumb instruction sets, organized by type of instruction.

Chapter 4 ***Thumb Instructions***

Contains detailed reference material on each Thumb instruction, arranged alphabetically by instruction mnemonic.

Chapter 5 ***New ARM instructions***

Contains detailed reference material on each new ARM instruction, arranged alphabetically by instruction mnemonic.

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Conventions

This manual employs typographic and other conventions intended to improve its ease of use.

General typographic conventions

`typewriter` Is used for assembler syntax descriptions, pseudo-code descriptions of instructions, and source code examples. For more details of the conventions used in assembler syntax descriptions see *Assembler syntax* on page 4-4. For more details of pseudo-code conventions see Appendix A *Pseudo-code definition*.

The `typewriter` font is also used in the main text for instruction mnemonics and for references to other items appearing in assembler syntax descriptions, pseudo-code descriptions of instructions and source code examples.

italic Highlights important notes, introduces special terminology, and denotes internal cross-references and citations.

bold Is used for emphasis in descriptive lists and elsewhere, where appropriate.

SMALL CAPITALS Are used for a few terms which have specific technical meanings. Their meanings can be found in the *Glossary*.

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Further reading

This section lists publications that provide additional information on the ARM family of processors.

ARM periodically provides updates and corrections to its documentation. See `http://www.arm.com` for current errata sheets and addenda, and the ARM Frequently Asked Questions.

ARM publications

This book is a supplement to, and must be read in conjunction with, the *ARM Architecture Reference Manual* (ARM DDI 0100), version F or later. This book also contains references to the *ARM Architecture Reference Manual, Security Extensions supplement* (ARM DDI 0309).

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Chapter 1
Introduction to Thumb-2

This chapter introduces Thumb®-2 and contains the following sections:

- *About Thumb-2* on page 1-2
- *Changes to Thumb assembly language syntax* on page 1-3
- *New 32-bit Thumb instructions* on page 1-4
- *New 16-bit Thumb instructions* on page 1-5
- *New 32-bit ARM instructions* on page 1-6
- *Hint instructions* on page 1-7
- *Thumb-2 architecture constraints* on page 1-9.

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1.1 About Thumb-2

Thumb-2 is a major enhancement to the Thumb *Instruction Set Architecture* (ISA). It introduces 32-bit instructions that can be intermixed freely with the older 16-bit Thumb instructions. These new 32-bit instructions cover almost all the functionality of the ARM® instruction set.

The most important difference between the Thumb ISA and the ARM ISA is that most 32-bit Thumb instructions are unconditional, whereas almost all ARM instructions can be conditional. However, Thumb-2 introduces a new *If-Then* (`IT`) instruction that delivers much of the functionality of the condition field in ARM instructions.

Thumb-2 delivers overall code density comparable with Thumb, together with the performance levels associated with the ARM ISA. Before Thumb-2, developers had to choose between Thumb for size, or ARM for performance.

In addition to the new 32-bit Thumb instructions, there are several new 16-bit Thumb instructions. Several new 32-bit ARM instructions are introduced at the same time.

1.1.1 Register 15

Most Thumb 32-bit instructions cannot use the PC as a source or destination register. Instead, if a register is specified as 0b1111 in an instruction encoding, the instruction is a special case instruction. If an instruction definition does not specify otherwise, the instruction is UNPREDICTABLE if a register is specified as 0b1111. See *Usage of 0b1111 as a register specifier in 32-bit encodings* on page 3-38 for more information.

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1.2 Changes to Thumb assembly language syntax

Table 1-1 lists changes to the assembly language syntax of pre-Thumb-2 instructions. These are required to avoid unreasonable complications in the syntax of Thumb-2 assembly language.

The resulting unified assembly language is syntactically the same for both ARM and Thumb-2.

Table 1-1 Assembly language syntax changes

Change	Example of syntax	
	Old Thumb	**Unified assembly language**
Where the first operand and the destination register are the same register, both are specified.	`ADD r0, r8`	`ADD r0, r0, r8`
Where the instruction sets the condition flags, you must specify this explicitly with the `S` suffix.	`ADD r0, r1, r2`	`ADDS r0, r1, r2`
The old `NEG` instruction becomes a reverse subtraction.	`NEG r0, r1`	`RSBS r0, r1, #0`
The old `MOV` (2) instruction becomes an addition.	`MOV r0, r1`	`ADDS r0, r1, #0`
The old `CPY` instruction becomes a move operation.	`CPY r0, r1`	`MOV r0, r1`
The old `SWI` instruction becomes `SVC`	`SWI #80`	`SVC #80`
The old `LSL #0` instruction becomes a move operation.	`LSL r0, r1, #0`	`MOVS r0, r1`
Increment After becomes the default addressing mode for Load Multiple.	`LDMIA r0!, {r1,r2}`	`LDM r0!, {r1,r2}`
Writeback is not specified in `LDM` if the base register is in the register list.	`LDMIA r0!, {r0,r1}`	`LDM r0, {r0,r1}`

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1.3 New 32-bit Thumb instructions

The new 32-bit Thumb instructions are designed for:

- the existing ARM/Thumb Programmers' Model, with as few modifications as possible. Certain changes are essential to introduce the 32-bit Thumb instructions, notably to the Prefetch abort and Undefined Instruction exceptions. There is no increase in the number of general purpose or special purpose registers, and no increase in register sizes.
- existing compiler code generation techniques, as far as possible. New concepts are supplementary rather than obligatory. For example, literals can still be loaded using PC-relative instructions, or use in-line immediate values embedded in the `MOV` 16-bit immediate and `MOVT` instructions.

The new 32-bit Thumb instructions are added in the space previously occupied by the Thumb `BL` and `BLX` instructions. This is made possible by treating the `BL` and `BLX` instructions as 32-bit instructions, instead of treating them as two 16-bit instructions.

This means that `BL` and `BLX`, and all the other 32-bit Thumb instructions, can only take exceptions on their start address. They cannot take exceptions at the boundary between halfword1 and halfword2 of the instruction. All implementations must ensure that both halfwords are fetched and consolidated before they are issued and executed to comply with this exception event restriction. This is a change from Thumb. Before Thumb-2, the two halfwords of `BL` and `BLX` instructions execute independently, and can take exceptions independently.

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1.4 New 16-bit Thumb instructions

There are seven new 16-bit Thumb instructions.

1.4.1 If-Then

`IT` allows one to four following Thumb instructions (the *IT block*) to be conditional. The conditions for the instructions in the IT block must either all be the same, or some of them can be the inverse condition of the others. See *IT* on page 4-92 for details.

1.4.2 Compare and branch on zero, or non-zero

`CBZ` and `CBNZ` improve code density by replacing a very common two instruction sequence with a single instruction.

In addition, they preserve the condition code flags. This means that a condition code flag setting generated before the instruction can be used after it. This is not possible with the two instruction sequence that `CBZ` and `CBNZ` replace.

See *CBZ* on page 4-60 and *CBNZ* on page 4-58 for details.

1.4.3 No operation

Use `NOP` for padding, for example to place the following instruction on a 64-bit boundary.

See *NOP-compatible hints* on page 1-8 and *NOP* on page 4-189 for details.

1.4.4 Send event

`SEV` (Send Event) is a hint instruction. See *SEV* on page 4-271 for details.

1.4.5 Wait for event

`WFE` (Wait For Event) is a hint instruction. See *WFE* on page 4-467 for details.

1.4.6 Wait for interrupt

`WFI` (Wait For Interrupt) is a hint instruction. See *WFI* on page 4-469 for details.

1.4.7 Yield

`YIELD` is a hint instruction. See *YIELD* on page 4-471 for details.

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1.5 New 32-bit ARM instructions

Some new functionality introduced for Thumb-2 is also available in the ARM ISA. This is described in:

- *New T variants of LDR and STR*
- *New variants of LDREX and STREX*
- *Miscellaneous instructions*.

1.5.1 New T variants of LDR and STR

The ARM `LDRH`, `LDRSB`, `LDRSH` and `STRH` instructions now have T variants.

Note

Like existing ARM T variants of `LDR` and `STR`, these instructions use a post-indexed addressing mode. This is different from Thumb variants of `LDR` and `STR`, which use pre-indexed addressing.

1.5.2 New variants of LDREX and STREX

The ARM `LDREX` and `STREX` instructions now have `B`, `H`, and `D` (Byte, Halfword, and Doubleword) variants. In addition, there is a `CLREX` instruction that clears the local record of a request for exclusive access without performing a store.

1.5.3 Miscellaneous instructions

The following instructions are introduced:

`BFC`	Bitfield Clear.
`BFI`	Bitfield Insert.
`MLS`	Multiply and Subtract. Subtracts the product from the accumulator register.
`MOV`	New Move Wide variant. Load a 16-bit immediate to bits[15:0] of a register.
`MOVT`	Move Top. Load a 16-bit immediate to bits[31:16] of a register, leaving bits[15:0] unaltered.
`RBIT`	Reverse bits in word.
`SBFX`	Signed Bitfield extract.
`UBFX`	Unsigned Bitfield extract.

For details, see Chapter 5 *New ARM instructions*.

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1.6 Hint instructions

There are two classes of hint instruction in the ARM architecture:

- memory hints, that interact with the memory system
- NOP-compatible hints, that have no associated register dependencies.

These are described in:

- *Memory hint instructions*
- *NOP-compatible hints* on page 1-8.

1.6.1 Memory hint instructions

In addition to the `PLD` and `PLI` instructions, additional 32-bit Thumb instruction set space has been reserved for memory hint instructions.

32-bit Thumb-2 memory hints decode as hw1[12:4] = 0b1100Ax0B1 where:

AB = 0b00 is assigned to `PLD`

AB = 0b10 is assigned to `PLI`

AB = 0bx1 is reserved and must behave as a `NOP` instruction.

An implementation is not obliged to implement memory hint instructions. If they are not implemented, they must behave as a `NOP` instruction.

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1.6.2 NOP-compatible hints

The following encodings have been added:

32-bit Thumb

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	15	14	13	12	11	10	9	8	7–0
1	1	1	1	0	0	1	1	1	0	1	0	(1)	(1)	(1)	(1)	1	0	(0)	0	(0)	0	0	0	hint

16-bit Thumb

15	14	13	12	11	10	9	8	7–4	3	2	1	0
1	0	1	1	1	1	1	1	hint	0	0	0	0

32-bit ARM

31–28	27–20	19–16	15–12	11–8	7–0
cond	0 0 1 1 0 0 1 0	0 0 0 0	(1) (1) (1) (1)	(0) (0) (0) (0)	hint

Table 1-2 lists the hint instructions that have been defined:

Table 1-2 NOP-compatible hint instructions

Instruction	Hint	Function	For Thumb see	For ARM see
`NOP`	`0x0`	No Operation	*NOP* on page 4-189	*NOP* on page 5-31
`YIELD`	`0x1`	Yield	*YIELD* on page 4-471	*YIELD* on page 5-58
`WFE`	`0x2`	Wait For Event	*WFE* on page 4-467	*WFE* on page 5-54
`WFI`	`0x3`	Wait For Interrupt	*WFI* on page 4-469	*WFI* on page 5-56
`SEV`	`0x4`	Send Event	*SEV* on page 4-271	*SEV* on page 5-40
`DBG`	`0xF0-0xFF`	Debug hints	*DBG* on page 4-80	*DBG* on page 5-7

The remainder of this space is RESERVED. The instructions must execute as NOPs, and must not be used.

The 32-bit ARM hints use an area of the instruction space that, until the introduction of these hints, was decoded as `MSR CPSR_<>, #immediate`, that is, an `MSR` with no field specifier.

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1.7 Thumb-2 architecture constraints

Almost all the functionality of the ARM ISA is covered by the Thumb ISA. Apart from the absence of a condition field, the main exceptions are covered in:

- *ARM instructions with no Thumb-2 equivalent*
- *New functionality introduced with Thumb-2*
- *32-bit Thumb instructions with less functionality than ARM instructions* on page 1-10.

1.7.1 ARM instructions with no Thumb-2 equivalent

The following ARM instructions have no Thumb-2 equivalents:

`RSC`	Reverse Subtract with Carry.
`SWP`	Swap. `SWP` is superseded by `LDREX` and `STREX`.
`SWPB`	Swap bytes. `SWPB` is superseded by `LDREXB` and `STREXB`.

The use of `SWP` and `SWPB` is deprecated in ARMv6.

1.7.2 New functionality introduced with Thumb-2

Some new 32-bit instructions are introduced in both Thumb and ARM. These are described in *New 32-bit Thumb instructions* on page 1-4 and *New 32-bit ARM instructions* on page 1-6.

In addition, there are two new 32-bit Thumb instructions with restricted availability:

`SDIV`	Signed Divide
`UDIV`	Unsigned Divide.

These two instructions are only available in ARMv7-R implementations, and are not available in ARM state.

Note

The ARM architecture defines architecture *profiles*, to target different market segments better. Two profiles are directly affected by this Thumb-2 supplement:

- ARMv7-A (the application profile) that supports the *Virtual Memory System Architecture* (VMSA)
- ARMv7-R (the real-time profile) that supports the *Protected Memory System Architecture* (PMSA).

These profiles share the existing ARM/Thumb Programmers' Model including the register file, exception handling, and the CPSR/SPSR.

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1.7.3 32-bit Thumb instructions with less functionality than ARM instructions

The following 32-bit Thumb instructions cannot update the condition code flags:

`MLA`	Multiply Accumulate
`MUL`	Multiply
`SMLAL`	Signed Multiply Accumulate Long
`SMULL`	Signed Multiply Long
`UMLAL`	Unsigned Multiply Accumulate Long
`UMULL`	Unsigned Multiply Long.

Data processing instructions cannot combine a register-controlled shift with other functions. Register-controlled shifts are only available as separate instructions. This affects the following instructions:

`AND`	Logical AND
`EOR`	Logical Exclusive OR
`SUB`	Subtract
`RSB`	Reverse Subtract
`ADD`	Add
`ADC`	Add with Carry
`SBC`	Subtract with Carry
`TST`	Test
`TEQ`	Test Equivalence
`CMP`	Compare
`CMN`	Compare negated
`ORR`	Logical (inclusive) OR
`MOV`	Move
`BIC`	Bit Clear
`MVN`	Move Not.

The Move to Status Register instruction, `MSR`, cannot load an immediate value.

Load Multiple and Store Multiple have some restrictions on their functionality. For details, see:

- *LDMDB / LDMEA* on page 4-96
- *LDMIA / LDMFD* on page 4-98
- *POP* on page 4-209
- *PUSH* on page 4-211
- *STMDB / STMFD* on page 4-333
- *STMIA / STMEA* on page 4-335.

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Chapter 2
Programmers' Model

This chapter describes the changes to the programmers' model introduced with Thumb®-2. It contains the following sections:

- *New program status register fields* on page 2-2
- *Changes to exception handling* on page 2-4
- *Non-maskable fast interrupt support* on page 2-7
- *Exception and reset handling in Thumb state* on page 2-9
- *Unaligned access support* on page 2-10
- *Endian support* on page 2-13
- *Memory stores and exclusive access* on page 2-14
- *Hardware divide support* on page 2-15.

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2.1 New program status register fields

Thumb-2 introduces eight new execution state bits in the CPSR and SPSRs, in addition to the J and T bits defined in previous versions of the ARM® architecture. These new bits are used by the *If-Then* (`IT`) instruction, to control the conditional execution of one to four instructions (the IT block) following the `IT` instruction.

The new execution state bits are bits[26:25,15:10] in the CPSR and SPSRs.

31	30	29	28	27	26–25	24	23–20	19–16	15–10	9	8	7	6	5	4–0
N	Z	C	V	Q	IT[1:0]	J	Reserved	GE[3:0]	IT[7:2]	E	A	I	F	T	M[4:0]

Execution state bits

In User mode, execution state bits cannot be written directly. They can be written indirectly by the execution of `IT`, `BX`, `BLX`, or `BXJ` instructions, or by a load to the PC that updates the CPSR. Any attempt to write directly to them from User mode is ignored.

In a privileged mode, you can write to the associated SPSR.

The execution state bits in the CPSR always read as zero when read by an `MRS` instruction, and writes to them by `MSR` instructions are ignored, unless the processor is in debug state, halting debug-mode. See the *ARM Architecture Reference Manual* for more details about debug state.

Reserved PSR bits

In Thumb-2, writes to reserved CPSR or SPSR bits are ignored in all modes.

Note

Thumb-2 provides access to the PSR with `MRS` and `MSR` instructions. Previously you had to change to ARM state for this.

2.1.1 The Application Program Status Register

The Application Program Status Register (APSR) is a name for the register containing those bits that deliver status information about the results of instructions.

For the purposes of this manual, the APSR is synonymous with the CPSR, but only the N, Z, C, V, Q and GE[3:0] bits of the CPSR are accessed using the APSR name.

2.1.2 The IT execution state bits

IT[7:5] encodes the *base condition* (that is, the top 3 bits of the condition specified by the IT instruction) for the current IT block, if any. It contains 0b000 when no IT block is active.

IT[4:0] encodes the number of instructions that are due to be conditionally executed, and whether the condition for each is the base condition code or the inverse of the base condition code. It contains 0b00000 when no IT block is active.

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When an IT instruction is executed, these bits are set according to the condition in the instruction, and the *Then* and *Else* (T and E) parameters in the instruction (see *IT* on page 4-92 for details).

During execution of an IT block, IT[4:0] is shifted:

- to reduce the number of instructions to be conditionally executed by one
- to move the next bit into position to form the least significant bit of the condition code.

See Table 2-1 for the way the shift operates.

Table 2-1 Shifting of IT execution state bits

	Old state						New state				
IT[7:5]	IT[4]	IT[3]	IT[2]	IT[1]	IT[0]	IT[7:5]	IT[4]	IT[3]	IT[2]	IT[1]	IT[0]
cond_base	P1	P2	P3	P4	1	cond_base	P2	P3	P4	1	0
cond_base	P1	P2	P3	1	0	cond_base	P2	P3	1	0	0
cond_base	P1	P2	1	0	0	cond_base	P2	1	0	0	0
cond_base	P1	1	0	0	0	0b000	0	0	0	0	0

See Table 2-2 for the effect of each state.

Table 2-2 Effect of IT execution state bits

Entry point for:	IT[7:5]	IT[4]	IT[3]	IT[2]	IT[1]	IT[0]	
4-instruction IT block	cond_base	P1	P2	P3	P4	1	Next instruction has condition cond_base, P1
3-instruction IT block	cond_base	P1	P2	P3	1	0	Next instruction has condition cond_base, P1
2-instruction IT block	cond_base	P1	P2	1	0	0	Next instruction has condition cond_base, P1
1-instruction IT block	cond_base	P1	1	0	0	0	Next instruction has condition cond_base, P1
	0b000	0	0	0	0	0	Normal execution (not in an IT block)
	non-zero	0	0	0	0	0	UNPREDICTABLE
	0bxxx	1	0	0	0	0	UNPREDICTABLE

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2.2 Changes to exception handling

Thumb-2 introduces some extra considerations in exception handling.

All Thumb-2 implementations must have:

- an IFAR
- a DFAR
- a memory read/write bit in the DFSRs.

For details, see the *ARM Architecture Reference Manual*.

This section describes the changes, in the following subsections:

- *IRQ and FIQ*
- *Prefetch abort*
- *Data abort*
- *SVC* on page 2-5
- *Undefined instruction* on page 2-5
- *Exception link register* on page 2-6.

2.2.1 IRQ and FIQ

Thumb-2 does not introduce any changes to the handling of IRQs or FIQs, except that exceptions cannot occur at the boundary between halfword1 and halfword2 of a 32-bit instruction. See *New 32-bit Thumb instructions* on page 1-4 for more information. No changes to code are required.

See also *Non-maskable fast interrupt support* on page 2-7.

2.2.2 Prefetch abort

Prefetch abort handlers must use the IFAR method to determine the aborting address.

This is because an instruction can span a page boundary. R14_abt indicates the address in the first page, but the abort might actually have occurred on the second page.

In Thumb-2, `BL` and `BLX` instructions are true 32-bit instructions. This means that even systems using only legacy code with none of the new Thumb instructions must use the IFAR method to determine the aborting address.

2.2.3 Data abort

Data abort handlers must use the DFAR register to determine the aborting address. This is because unaligned support introduced in ARMv6 can cause a data item to span a page boundary.

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2.2.4 SVC

All Thumb SVCs are 16-bit instructions. This means that no changes are required to existing SVC (formerly SWI) code written for Thumb.

2.2.5 Undefined instruction

An Undefined instruction can be 16-bit or 32-bit.

An Undefined Instruction handler might be designed to return:

- after the instruction, if the Undefined instruction is being emulated
- to the instruction that generated the exception, if resuming from a debug breakpoint for example.

The value placed in R14_undef is the address of the Undefined instruction + 2, regardless of whether a 16-bit or a 32-bit instruction is involved. The following pseudo-code shows how an Undefined Instruction handler might load the instruction that caused the exception:

```
addr = R14_undef - 2
instr = Memory[addr,2]
if (instr >> 11) > 28 then  /* 32-bit instruction */
    instr = (instr << 16) | Memory[addr+2,2]
    if (return after instruction wanted) then
        R14_undef += 2
```

After this, `instr` holds the instruction (in the range `0-0xE7FF` for a 16-bit instruction, `0xE8000000-0xFFFFFFFF` for a 32-bit instruction), and the exception can be returned from using:

```
SUBS PC,R14,#2
```

to return before the instruction or:

```
SUBS PC,R14,#0
```

to return after it.

Divide by zero

Thumb-2 adds signed and unsigned integer divide instructions `SDIV` and `UDIV`, in the ARMv7-R profile only. These instructions can have divide-by-zero trapping enabled. If it is not enabled, a division by zero produces a result of zero. If it is enabled, a division by zero causes an Undefined Instruction exception to occur on the `SDIV` or `UDIV` instruction.

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2.2.6 Exception link register

Thumb-2 introduces a new control bit to control whether exceptions are taken in ARM or Thumb state (see *Exception and reset handling in Thumb state* on page 2-9). The exception link register is set so that the normal return instruction performs correctly. See Table 2-3 for the link register values for exceptions generated during execution of Thumb code.

Table 2-3 Exception link register values

Exception	Exception link register value
Reset	UNPREDICTABLE
Undefined instruction	Address of Undefined instruction + 2
SVC	Address of SVC instruction + 2
Prefetch Abort	Address of aborted instruction fetch + 4
Data Abort	Address of the instruction that generated the abort + 8
IRQ	Address of the next instruction to be executed + 4
FIQ	Address of the next instruction to be executed + 4

2.2.7 Return from exceptions in Thumb-2

To return from an exception, an instruction must transfer the SPSR to the CPSR, and load the return address for execution to the PC. Either of the following instructions can be used for this:

`RFE` Return From Exception. See *RFE* on page 4-241 for details.

`SUBS PC, LR, #n`

Subtract *n* from the link register, place the result in the PC, and transfer the SPSR to the CPSR. See *SUBS PC, LR* on page 4-373 for details.

These instructions assume that the appropriate return address is the value saved in memory, with an offset of 0, +4, or +8.

There is one special case. When an Undefined Instruction exception occurs on a 32-bit Thumb instruction, the value stored in the LR is the address of the second halfword. The exception handling routine can increment this by 2 when it fetches the halfword as part of the emulation routine. It can then use `SUBS PC, LR, #0` as the return mechanism.

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2.3 Non-maskable fast interrupt support

Thumb-2 introduces support for Non-Maskable Fast Interrupts (NMFI):

- The behavior is controlled by a configuration input signal to the core, **CFGNMFI**. There is no software control.
- The value of **CFGNMFI** can be read from the NMFI bit, CP15 register 1 bit[27]:

  NMFI == 0 FIQ behavior as defined in the *ARM Architecture Reference Manual*

  NMFI == 1 FIQs behave as non-maskable fast interrupts.

When the NMFI bit is 1:

- An instruction writing 0 to the CPSR F-bit clears it, but an instruction attempting to write 1 to it leaves it unchanged.
- The CPSR F-bit can only be set by an FIQ exception.
- In Non-Secure world, Security Extension restrictions apply to writes to the CPSR F-bit.

2.3.1 Security extension implications

The ARM Architecture Security Extensions can affect the usage model using two control bits in the Secure Control Register (SCR):

- the FW bit (SCR[4]) determines whether FIQs can be masked by software in the Non-Secure state
- the FIQ bit (SCR[2]) determines whether FIQs are handled in FIQ or Monitor mode.

See the *ARM Architecture Reference Manual, Security Extensions supplement* for more details.

Only three of the four combinations are generally useful:

- SCR[2] == 0, SCR[4] == 0. This is the reset condition for legacy code. This code never changes from the Secure state.
- SCR[2] == 1, SCR[4] == 0. This condition provides secure FIQs, Non-Secure state is prevented from altering the F-bit.
- SCR[2] == 0, SCR[4] == 1. In this condition, FIQs are handled locally in either Secure or Non-Secure state.

The NMFI bit in CP15 register 1 is not banked because it is a read-only register reading the configuration signal on the core.

Table 2-4 on page 2-8 shows a summary of the associated software behavior.

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Table 2-4 NMFI behavior in Security Extensions systems

	NMFI == 0	NMFI == 1
NS-state == Secure	F-bit can be written to 0 or 1	F-bit can be written to 0 but not to 1
NS-state == Non-Secure, FW == 0	F-bit cannot be written	F-bit cannot be written
NS-state == Non-Secure, FW == 1	F-bit can be written to 0 or 1	F-bit can be written to 0 but not to 1

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2.4 Exception and reset handling in Thumb state

Thumb-2 introduces a new control bit, the *Thumb Exception enable* (TE) bit. The TE bit controls whether exceptions are taken in ARM or Thumb state. This bit is only available in architecture variants that support the Thumb-2 instruction set. In architectures that do not support the Thumb instruction set, this bit reads as 0 and ignores writes.

The TE bit is bit[30] in CP15 register 1:

TE == 0 Exceptions are handled in ARM state. That is, on exception entry, the CPSR T and J bits are T == 0, J == 0.

TE == 1 Exceptions are handled in Thumb state. That is, on exception entry, the CPSR T and J bits are T == 1, J == 0.

There is an optional configuration input signal, **CFGTE**, associated with the TE bit. **CFGTE** controls the value of CP15 register 1 TE, and the CPSR T-bit on Reset. If a processor does not have a **CFGTE** input and ARM state is supported, the reset value of TE is 0.

2.4.1 TE bit and the Security Extensions

If both Thumb-2 and the Security Extensions are implemented, the TE bit is a banked bit. This separates the usage model in each security state. (The Secure and Non-Secure states have separate vector base address registers.) The TE bit has the same read/write access policy as the other CP15 register 1 banked fields in the Security Extensions architecture.

CFGTE controls both versions of the TE bit.

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2.5 Unaligned access support

ARMv6 introduced unaligned support for word or halfword loads and stores. The unaligned and legacy (pre-ARMv6) behavior is supported by a new system control bit, the U-bit, in combination with the existing A-bit.

See *Load and store alignment checks* on page 2-11 for details of the behavior of all Thumb load and store instructions.

See *Unaligned exception returns* on page 2-12 for details of the behavior of exception return instructions.

Note

Use of U = 0 is deprecated in ARMv6T2, and obsolete from ARMv7.

From ARMv7, all accesses must comply with the U=1 alignment policy.

For more information about alignment, see the *ARM Architecture Reference Manual*.

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2.5.1 Load and store alignment checks

The checking of load and store alignment, for 16-bit and 32-bit instructions, is as follows:

- If U == 0 and A == 0:
  - Non halfword-aligned `LDR{S}H{T}` and `STRH{T}` are UNPREDICTABLE
  - Non halfword-aligned `LDREXH` and `STREXH` are UNPREDICTABLE
  - Non halfword-aligned `TBH` is UNPREDICTABLE
  - Non word-aligned `LDR{T}` and `STR{T}` are UNPREDICTABLE
  - Non word-aligned `LDREX` and `STREX` are UNPREDICTABLE
  - Non word-aligned `LDMIA`, `LDMDB`, `POP`, `LDC`, `RFE` ignore addr[1:0]
  - Non word-aligned `STMIA`, `STMDB`, `PUSH`, `STC`, `SRS` ignore addr[1:0]
  - Non doubleword-aligned `LDRD` and `STRD` are UNPREDICTABLE
  - Non doubleword-aligned `LDREXD` and `STREXD` are UNPREDICTABLE.
- If U == 1 and A == 0:
  - Non halfword-aligned `LDR{S}H{T}` and `STRH{T}` perform unaligned accesses
  - Non halfword-aligned `LDREXH` and `STREXH` produce Alignment faults
  - Non halfword-aligned `TBH` performs unaligned accesses
  - Non word-aligned `LDR{T}` and `STR{T}` perform unaligned accesses
  - Non word-aligned `LDREX` and `STREX` produce Alignment faults
  - Non word-aligned `LDMIA`, `LDMDB`, `POP`, `LDC`, `RFE` produce Alignment faults
  - Non word-aligned `STMIA`, `STMDB`, `PUSH`, `STC`, `SRS` produce Alignment faults
  - Non word-aligned `LDRD` and `STRD` produce Alignment faults
  - Non doubleword-aligned `LDREXD` and `STREXD` produce Alignment faults.
- If A == 1:
  - Non halfword-aligned `LDR{S}H{T}` and `STRH{T}` produce Alignment faults
  - Non halfword-aligned `LDREXH` and `STREXH` produce Alignment faults
  - Non halfword-aligned `TBH` produces Alignment faults
  - Non word-aligned `LDR{T}` and `STR{T}` produce Alignment faults
  - Non word-aligned `LDREX` and `STREX` produce Alignment faults
  - Non word-aligned `LDMIA`, `LDMDB`, `POP`, `LDC`, `RFE` produce Alignment faults
  - Non word-aligned `STMIA`, `STMDB`, `PUSH`, `STC`, `SRS` produce Alignment faults
  - If U == 0, non doubleword-aligned `LDRD` and `STRD` produce Alignment faults
  - If U == 1, non word-aligned `LDRD` and `STRD` produce Alignment faults
  - Non doubleword-aligned `LDREXD` and `STREXD` produce Alignment faults.

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2.5.2 Unaligned exception returns

An exception return instruction (`RFE` or `SUBS PC,LR,#imm8`) writes an address to the PC. The alignment of this address must be correct for the instruction set in use after the exception return. The instruction set is controlled by the (J,T) bits of the value written to the CPSR:

- For a return to ARM code ((J,T) == (0,0)), the address written to the PC must be word-aligned.
- For a return to Thumb-2 code ((J,T) == (0,1)), the address written to the PC must be halfword-aligned.
- For a return to Jazelle® opcodes ((J,T) == (1,0)), there are no alignment restrictions on the address written to the PC.

The results of breaking these rules are UNPREDICTABLE. However, no special precautions are needed in software if the instructions are used to return after a valid exception entry mechanism. A valid entry mechanism ensures that the T-bit in the SPSR and the link address bits[1:0] in R14, or the stacked equivalents for `RFE`, provide valid return addresses for Thumb or ARM state as appropriate.

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2.6 Endian support

All Thumb-2 instruction fetches are little-endian. Data accesses can be either little-endian or big-endian. For more information about endian support, see the *ARM Architecture Reference Manual*.

Note

Use of B = 1 is deprecated in ARMv6T2, and obsolete from ARMv7.

From ARMv7, all accesses must comply with the E-bit endian support policy.

2.6.1 Instruction alignment and byte ordering

In ARMv6 and above, all ARM and Thumb instructions are little-endian.

Thumb-2 enforces 16-bit alignment on all instructions. This means that 32-bit instructions are treated as two halfwords, hw1 and hw2, with hw1 at the lower address.

In instruction encoding diagrams, hw1 is shown to the left of hw2. This results in the encoding diagrams reading more naturally, and in a close correspondence between the ARM and Thumb encoding diagrams in some cases, particularly coprocessor instructions. However, it also makes the byte order of a 32-bit Thumb instruction differ from that of an ARM instruction. This is shown in Figure 2-1.

ARM 32-bit instruction order in memory

32-bit ARM instruction			
31 24	23 16	15 8	7 0
Byte at Address A+3	Byte at Address A+2	Byte at Address A+1	Byte at Address A

Thumb 32-bit instruction order in memory

32-bit Thumb instruction, hw1		32-bit Thumb instruction, hw2	
31 24	23 16	15 8	7 0
Byte at Address A+1	Byte at Address A	Byte at Address A+3	Byte at Address A+2

Figure 2-1 Instruction byte order in memory

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2.7 Memory stores and exclusive access

The Operation sections of instruction definitions, other than the exclusive stores, do not include pseudo-code describing exclusive access support in multiprocessor systems with shared memory. If your system has shared memory, all memory writes include the operations described by the following pseudo-code:

```
If (Shared(address)) then
    physical_address = TLB(address)
    ClearExclusiveByAddress(physical_address, <size>)
```

For more information about exclusive access support, see the *ARM Architecture Reference Manual*.

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2.8 Hardware divide support

ARMv7 introduces signed and unsigned hardware divide instructions for the R and M profiles only. See *SDIV* on page 4-265 and *UDIV* on page 4-409 for details.

In the R profile, the DZ bit in the System Control register (bit[19] of CP15 register 1) is used to support Divide-by-zero fault detection. When DZ == 1, `SDIV` and `UDIV` generate a fault on a divide-by-zero. When DZ == 0, divide-by-zero returns a zero result. DZ is cleared to zero on reset.

Note

`SDIV` and `UDIV` are UNDEFINED in ARMv7-A.

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Chapter 3
The Thumb Instruction Set

This chapter describes the Thumb® instruction set. It contains the following sections:

- *Instruction set encoding* on page 3-2
- *Instruction encoding for 32-bit Thumb instructions* on page 3-12
- *Conditional execution* on page 3-34
- *UNDEFINED and UNPREDICTABLE instruction set space* on page 3-36
- *Usage of 0b1111 as a register specifier in 32-bit encodings* on page 3-38
- *Usage of 0b1101 as a register specifier* on page 3-41
- *Thumb-2 and VFP support* on page 3-43.

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3.1 Instruction set encoding

Thumb instructions are either 16-bit or 32-bit. Bits[15:11] of the halfword that the PC points to determine whether it is a 16-bit instruction, or whether the following halfword is the second part of a 32-bit instruction.

Table 3-1 shows how the instruction set space is divided between 16-bit and 32-bit instructions. An x in the encoding indicates any bit, except that any combination of bits already defined is excluded.

Table 3-1 Determination of instruction length

hw1[15:11]	Function
0b11100	Thumb 16-bit unconditional branch instruction, defined in all Thumb architectures.
0b111xx	Thumb 32-bit instructions, defined in Thumb-2, see *Instruction encoding for 32-bit Thumb instructions* on page 3-12.
0bxxxxx	Thumb 16-bit instructions.

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3.2 Instruction encoding for 16-bit Thumb instructions

Figure 3-1 shows the main divisions of the Thumb 16-bit instruction set space. An entry in square brackets, for example [1], indicates a note below the table.

	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Shift by immediate, move register	0	0	0	opcode [1]		imm5					Rm			Rd		
Add/subtract register	0	0	0	1	1	0	opc	Rm			Rn			Rd		
Add/subtract immediate	0	0	0	1	1	1	opc	imm3			Rn			Rd		
Add/subtract/compare/move immediate	0	0	1	opcode		Rdn			imm8							
Data-processing register	0	1	0	0	0	0	opcode				Rm			Rdn		
Special data processing	0	1	0	0	0	1	opcode [1]		DN	Rm				Rdn		
Branch/exchange instruction set [3]	0	1	0	0	0	1	1	1	L	Rm				(0)	(0)	(0)
Load from literal pool	0	1	0	0	1	Rd			PC-relative imm8							
Load/store register offset	0	1	0	1	opcode			Rm			Rn			Rd		
Load/store word/byte immediate offset	0	1	1	B	L	imm5					Rn			Rd		
Load/store halfword immediate offset	1	0	0	0	L	imm5					Rn			Rd		
Load from or store to stack	1	0	0	1	L	Rd			SP-relative imm8							
Add to SP or PC	1	0	1	0	SP	Rd			imm8							
Miscellaneous: See Figure 6-2	1	0	1	1	x	x	x	x	x	x	x	x	x	x	x	x
Load/store multiple	1	1	0	0	L	Rn			register list							
Conditional branch	1	1	0	1	cond [2]				imm8							
Undefined instruction	1	1	0	1	1	1	1	0	x	x	x	x	x	x	x	x
Service (system) call	1	1	0	1	1	1	1	1	imm8							
Unconditional branch	1	1	1	0	0	imm11										
32-bit instruction	1	1	1	0	1	x	x	x	x	x	x	x	x	x	x	x
32-bit instruction	1	1	1	1	x	x	x	x	x	x	x	x	x	x	x	x

Figure 3-1 Thumb instruction set overview

1. opcode != 0b11.
2. cond != 0b111x.
3. The form with `L==1` is UNPREDICTABLE before ARMv5T.
4. This is an UNDEFINED instruction before ARMv5T.

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For further information about these instructions, see:

- Table 3-2 for shift (by immediate) and move (register) instructions
- Table 3-3 for add and subtract (register) instructions
- Table 3-4 on page 3-5 for add and subtract (3-bit immediate) instructions
- Table 3-5 on page 3-5 for add, subtract, compare and move (8-bit immediate) instructions
- Table 3-6 on page 3-6 for data processing (register) instructions
- Table 3-7 on page 3-6 for special data processing instructions
- Table 3-8 on page 3-7 for branch and exchange instruction set instructions
- *LDR (literal)* on page 4-102 for load from literal pool instructions
- Table 3-9 on page 3-7 for load and store (register offset) instructions
- Table 3-10 on page 3-7 for load and store, word or byte (immediate offset) instructions
- Table 3-11 on page 3-7 for load and store, halfword (immediate offset) instructions
- Table 3-12 on page 3-8 for load from or store to stack instructions
- Table 3-13 on page 3-8 for add 8-bit immediate to SP or PC instructions
- *Miscellaneous instructions* on page 3-9 for miscellaneous instructions
- Table 3-14 on page 3-8 for load and store multiple instructions
- *B* on page 4-38 for conditional branch instructions
- *SVC (formerly SWI)* on page 4-375 for service (system) call instructions
- *B* on page 4-38 for unconditional branch instructions.

Table 3-2 Shift by immediate and move (register) instructions

Function	Instruction	opcode	imm5
Move register (not in IT block)	*MOV (register)* on page 4-168	0b00	0b00000
Logical shift left	*LSL (immediate)* on page 4-150	0b00	!= 0b00000
Logical shift right	*LSR (immediate)* on page 4-154	0b01	any
Arithmetic shift right	*ASR (immediate)* on page 4-34	0b10	any

Table 3-3 Add and subtract (register) instructions

Function	Instruction	opc
Add register	*ADD (register)* on page 4-22	0b0
Subtract register	*SUB (register)* on page 4-367	0b1

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Table 3-4 Add and subtract (3-bit immediate) instructions

Function	Instruction	opc
Add immediate	*ADD (immediate)* on page 4-20	0b0
Subtract immediate	*SUB (immediate)* on page 4-365	0b1

Table 3-5 Add, subtract, compare, and move (8-bit immediate) instructions

Function	Instruction	opcode
Move immediate	*MOV (immediate)* on page 4-166	0b00
Compare immediate	*CMP (immediate)* on page 4-72	0b01
Add immediate	*ADD (immediate)* on page 4-20	0b10
Subtract immediate	*SUB (immediate)* on page 4-365	0b11

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Table 3-6 Data processing (register) instructions

Function	Instruction	opcode
Bitwise AND	*AND (register)* on page 4-32	0b0000
Bitwise Exclusive OR	*EOR (register)* on page 4-88	0b0001
Logical Shift Left	*LSL (register)* on page 4-152	0b0010
Logical Shift Right	*LSR (register)* on page 4-156	0b0011
Arithmetic shift right	*ASR (register)* on page 4-36	0b0100
Add with carry	*ADC (register)* on page 4-18	0b0101
Subtract with Carry	*SBC (register)* on page 4-261	0b0110
Rotate Right	*ROR (register)* on page 4-245	0b0111
Test	*TST (register)* on page 4-399	0b1000
Reverse subtract (from zero)	*RSB (immediate)* on page 4-249	0b1001
Compare	*CMP (register)* on page 4-74	0b1010
Compare Negative	*CMN (register)* on page 4-70	0b1011
Logical OR	*ORR (register)* on page 4-197	0b1100
Multiply	*MUL* on page 4-181	0b1101
Bit Clear	*BIC (register)* on page 4-46	0b1110
Move Negative	*MVN (register)* on page 4-185	0b1111

Table 3-7 Special data processing instructions

Function	Instruction	opcode
Add (register, including high registers)	*ADD (register)* on page 4-22	0b00
Compare (register, including high registers)	*CMP (register)* on page 4-74	0b01
Move (register, including high registers)	*MOV (register)* on page 4-168	0b10

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Table 3-8 Branch and exchange instruction set instructions

Function	Instruction	L
Branch and Exchange	*BX* on page 4-54	0b0
Branch with Link and Exchange	*BLX (register)* on page 4-52	0b1

Table 3-9 Load and store (register offset) instructions

Function	Instruction	opcode
Store word	*STR (register)* on page 4-339	0b000
Store halfword	*STRH (register)* on page 4-359	0b001
Store byte	*STRB (register)* on page 4-343	0b010
Load signed byte	*LDRSB (register)* on page 4-136	0b011
Load word	*LDR (register)* on page 4-104	0b100
Load unsigned halfword	*LDRH (register)* on page 4-128	0b101
Load unsigned byte	*LDRB (register)* on page 4-110	0b110
Load signed halfword	*LDRSH (register)* on page 4-144	0b111

Table 3-10 Load and store, word or byte (5-bit immediate offset) instructions

Function	Instruction	B	L
Store word	*STR (immediate)* on page 4-337	0b0	0b0
Load word	*LDR (immediate)* on page 4-100	0b0	0b1
Store byte	*STRB (immediate)* on page 4-341	0b1	0b0
Load byte	*LDRB (immediate)* on page 4-106	0b1	0b1

Table 3-11 Load and store halfword (5-bit immediate offset) instructions

Function	Instruction	L
Store halfword	*STRH (immediate)* on page 4-357	0b0
Load halfword	*LDRH (immediate)* on page 4-124	0b1

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Table 3-12 Load from stack and store to stack instructions

Function	Instruction	L
Store to stack	*STR (immediate)* on page 4-337	0b0
Load from stack	*LDR (immediate)* on page 4-100	0b1

Table 3-13 Add 8-bit immediate to SP or PC instructions

Function	Instruction	SP
Add (PC plus immediate)	*ADR* on page 4-28	0b0
Add (SP plus immediate)	*ADD (SP plus immediate)* on page 4-24	0b1

Table 3-14 Load and store multiple instructions

Function	Instruction	L
Store multiple	*STMIA / STMEA* on page 4-335	0b0
Load multiple	*LDMIA / LDMFD* on page 4-98	0b1

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3.2.1 Miscellaneous instructions

Figure 3-2 lists miscellaneous Thumb instructions. An entry in square brackets, for example [1], indicates a note below the figure.

	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Adjust stack pointer	1	0	1	1	0	0	0	0	opc	imm7						
Sign/zero extend [2]	1	0	1	1	0	0	1	0	opc		Rm			Rd		
Compare and Branch on (Non-)Zero [3]	1	0	1	1	N	0	i	1	imm5					Rn		
Push/pop register list	1	0	1	1	L	1	0	R	register list							
UNPREDICTABLE	1	0	1	1	0	1	1	0	0	1	0	0	x	x	x	x
Set Endianness [2]	1	0	1	1	0	1	1	0	0	1	0	1	E	(0)	(0)	(0)
Change Processor State [2]	1	0	1	1	0	1	1	0	0	1	1	im	0	A	I	F
UNPREDICTABLE	1	0	1	1	0	1	1	0	0	1	1	x	1	x	x	x
Reverse bytes [2]	1	0	1	1	1	0	1	0	opc		Rn			Rd		
Software breakpoint [1]	1	0	1	1	1	1	1	0	imm8							
If-Then instructions [3]	1	0	1	1	1	1	1	1	cond				mask (!= 0b0000)			
NOP-compatible hints [3]	1	0	1	1	1	1	1	1	hint				0	0	0	0

Figure 3-2 Miscellaneous Thumb instructions

1. This is an UNDEFINED instruction before ARMv5.
2. These are UNDEFINED instructions before ARMv6.
3. These are UNDEFINED instructions before Thumb-2.

Note

Any instruction with bits[15:12] = 1011, that is not shown in Figure 3-2, is an UNDEFINED instruction.

For further information about these instructions, see:

- Table 3-15 on page 3-10 for adjust stack pointer instructions
- Table 3-16 on page 3-10 for sign or zero extend instructions
- Table 3-17 on page 3-10 for compare (non-)zero and branch instructions
- Table 3-18 on page 3-10 for push and pop instructions
- *SETEND* on page 4-269 for the set endianness instruction
- *CPS* on page 4-76 for the change processor state instruction
- Table 3-19 on page 3-11 for reverse bytes instructions
- *BKPT* on page 4-48 for the software breakpoint instruction
- *IT* on page 4-92 for the If-Then instruction
- Table 3-20 on page 3-11 for NOP-compatible hint instructions.

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Table 3-15 Adjust stack pointer instructions

Function	Instruction	opc
Increment stack pointer	*ADD (SP plus immediate)* on page 4-24	0b0
Decrement stack pointer	*SUB (SP minus immediate)* on page 4-369	0b1

Table 3-16 Sign or zero extend instructions

Function	Instruction	opc
Signed Extend Halfword	*SXTH* on page 4-387	0b00
Signed Extend Byte	*SXTB* on page 4-383	0b01
Unsigned Extend Halfword	*UXTH* on page 4-465	0b10
Unsigned Extend Byte	*UXTB* on page 4-461	0b11

Table 3-17 Compare and branch on (non-)zero instructions

Function	Instruction	N
Compare and branch on zero	*CBZ* on page 4-60	0b0
Compare and branch on non-zero	*CBNZ* on page 4-58	0b1

Table 3-18 Push and pop instructions

Function	Instruction	L
Push registers	*PUSH* on page 4-211	0b0
Pop registers	*POP* on page 4-209	0b1

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Table 3-19 Reverse byte instructions

Function	Instruction	opc
Byte-Reverse Word	*REV* on page 4-235	0b00
Byte-Reverse Packed Halfword	*REV16* on page 4-237	0b01
UNDEFINED	-	0b10
Byte-Reverse Signed Halfword	*REVSH* on page 4-239	0b11

Table 3-20 NOP-compatible hint instructions

Function	Instruction	hint
No operation	*NOP* on page 4-189	0b0000
Yield	*YIELD* on page 4-471	0b0001
Wait For Event	*WFE* on page 4-467	0b0010
Wait For Interrupt	*WFI* on page 4-469	0b0011
Send event	*SEV* on page 4-271	0b0100

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3.3 Instruction encoding for 32-bit Thumb instructions

Figure 3-3 shows the main divisions of the Thumb 32-bit instruction set space.

The following sections give further details of each instruction type shown in Figure 3-3.

	hw1 15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	hw2 15	14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
Data processing: immediate, including bitfield, and saturate	1	1	1	1	0												0	
Data processing, no immediate operand	1	1	1		1	0	1											
Load and store single data item, memory hints	1	1	1	1	1	0	0											
Load and Store, Double and Exclusive, and Table Branch	1	1	1	0	1	0	0			1								
Load and Store Multiple, RFE and SRS	1	1	1	0	1	0	0			0								
Branches, miscellaneous control	1	1	1	1	0												1	
Coprocessor	1	1	1		1	1	1	1										

Figure 3-3 Thumb 32-bit instruction set summary

This section contains the following subsections:

- *Data processing instructions: immediate, including bitfield and saturate* on page 3-13
- *Data processing instructions, non-immediate* on page 3-17
- *Load and store single data item, and memory hints* on page 3-26
- *Load/store double and exclusive, and table branch* on page 3-28
- *Load and store multiple, RFE, and SRS* on page 3-30
- *Branches, miscellaneous control instructions* on page 3-31
- *Coprocessor instructions* on page 3-33.

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3.3.1 Data processing instructions: immediate, including bitfield and saturate

Figure 3-4 shows the encodings for:

- data processing instructions with an immediate operand
- data processing instructions with bitfield or saturating operations.

	hw1 15 14 13 12 11	10	9	8	7	6	5	4	3 2 1 0	hw2 15	14 13 12	11 10 9 8	7 6	5	4 3 2 1 0
General format	1 1 1 1 0									0					
Data processing, modified 12-bit immediate	1 1 1 1 0	i	0	OP				S	Rn	0	imm3	Rd	imm8		
Add, Subtract, plain 12-bit immediate	1 1 1 1 0	i	1	0	OP	0	OP2		Rn	0	imm3	Rd	imm8		
Move, plain 16-bit immediate	1 1 1 1 0	i	1	0	OP	1	OP2		imm4	0	imm3	Rd	imm8		
Bit field operations, Saturation with shift	1 1 1 1 0	SBZ	1	1	OP			0	Rn	0	imm3	Rd	imm2	SBZ	imm5
Reserved	1 1 1 1 0		1	1				1		0					

Figure 3-4 Data processing instructions: immediate, bitfield, and saturating

This section contains the following subsections:

- *Data processing instructions with modified 12-bit immediate* on page 3-14
- *Data processing instructions with plain 12-bit immediate* on page 3-15
- *Data processing instructions with plain 16-bit immediate* on page 3-15
- *Data processing instructions, bitfield and saturate* on page 3-16.

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Data processing instructions with modified 12-bit immediate

Table 3-21 gives the opcodes and locations of further information about the data processing instructions with modified 12-bit immediate data. For information about modified 12-bit immediate data, see *Immediate constants* on page 4-8.

In these instructions, if the S bit is set, the instruction updates the condition code flags according to the results of the instruction, see *Conditional execution* on page 3-34.

Table 3-21 Data processing instructions with modified 12-bit immediate

Function	Instruction	OP	Notes
Add with carry	*ADC (immediate)* on page 4-16	0b1010	
Add	*ADD (immediate)* on page 4-20	0b1000	
Logical AND	*AND (immediate)* on page 4-30	0b0000	
Bit clear	*BIC (immediate)* on page 4-44	0b0001	
Compare negative	*CMN (immediate)* on page 4-68	0b1000	`ADD` with `Rd` == 0b1111, `S` == 1
Compare	*CMP (immediate)* on page 4-72	0b1101	`SUB` with `Rd` == 0b1111, `S` == 1
Exclusive OR	*EOR (immediate)* on page 4-86	0b0100	
Move	*MOV (immediate)* on page 4-166	0b0010	`ORR` with `Rn` == 0b1111
Move negative	*MVN (immediate)* on page 4-183	0b0011	`ORN` with `Rn` == 0b1111
Logical OR NOT	*ORN (immediate)* on page 4-191	0b0011	
Logical OR	*ORR (immediate)* on page 4-195	0b0010	
Reverse subtract	*RSB (immediate)* on page 4-249	0b1110	
Subtract with carry	*SBC (immediate)* on page 4-259	0b1011	
Subtract	*SUB (immediate)* on page 4-365	0b1101	
Test equal	*TEQ (immediate)* on page 4-393	0b0100	`EOR` with `Rd` == 0b1111, `S` == 1
Test	*TST (immediate)* on page 4-397	0b0000	`AND` with `Rd` == 0b1111, `S` == 1

Instructions of this format using any other combination of the OP bits are UNDEFINED.

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Data processing instructions with plain 12-bit immediate

Table 3-22 gives the opcodes and locations of further information about the data processing instructions with plain 12-bit immediate data.

In these instructions, the immediate value is in `i:imm3:imm8`.

Table 3-22 Data processing instructions with plain 12-bit immediate

Function	Instruction	OP	OP2
Add wide	*ADD (immediate)* on page 4-20, encoding T4	0	0b00
Subtract wide	*SUB (immediate)* on page 4-365, encoding T4	1	0b10
Address (before current instruction)	*ADR* on page 4-28, encoding T2	0	0b10
Address (after current instruction)	*ADR* on page 4-28, encoding T3	1	0b00

Instructions of this format using any other combination of the OP and OP2 bits are UNDEFINED.

Data processing instructions with plain 16-bit immediate

Table 3-23 gives the opcodes and locations of further information about the data processing instructions with plain 16-bit immediate data.

In these instructions, the immediate value is in `imm4:i:imm3:imm8`.

Table 3-23 Data processing instructions with plain 16-bit immediate

Function	Instruction	OP	OP2
Move top	*MOVT* on page 4-171	1	0b00
Move wide	*MOV (immediate)* on page 4-166, encoding T3	0	0b00

Instructions of this format using any other combination of the OP and OP2 bits are UNDEFINED.

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Data processing instructions, bitfield and saturate

Table 3-24 gives the opcodes and locations of further information about saturation, bitfield extract, clear, and insert instructions.

Table 3-24 Miscellaneous data processing instructions

Function	Instruction	OP	Notes
Bit Field Clear	*BFC* on page 4-40	0b011	Rn == 0b1111, meaning #0
Bit Field Insert	*BFI* on page 4-42	0b011	
Signed Bit Field extract	*SBFX* on page 4-263	0b010	
Signed saturate, LSL	*SSAT* on page 4-321	0b000	
Signed saturate, ASR	*SSAT* on page 4-321	0b001	
Signed saturate 16-bit	*SSAT16* on page 4-323	0b001	shift_imm == 0
Unsigned Bit Field extract	*UBFX* on page 4-407	0b110	
Unsigned saturate, LSL	*USAT* on page 4-445	0b100	
Unsigned saturate, ASR	*USAT* on page 4-445	0b101	
Unsigned saturate 16-bit	*USAT16* on page 4-447	0b101	shift_imm == 0

Instructions of this format using any other combination of the OP bits are UNDEFINED.

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3.3.2 Data processing instructions, non-immediate

Figure 3-5 shows the encodings for data processing instructions without an immediate operand.

In these instructions, if the S bit is set, the instruction updates the condition code flags according to the results of the instruction, see *Conditional execution* on page 3-34.

	hw1 (bits 15–0)	hw2 (bits 15–0)
General format	1 1 1 1 0 1	
Data processing: constant shift	1 1 1 0 1 0 1 · OP · S · Rn	SBZ · imm3 · Rd · imm2 · type · Rm
Register-controlled shift	1 1 1 1 1 0 1 0 0 · 0 · OP · S · Rn	1 1 1 1 · Rd · 0 · OP2 · Rm
Sign or zero extension, with optional addition	1 1 1 1 1 0 1 0 0 · 0 · OP · Rn	1 1 1 1 · Rd · 1 · SBZ · rot · Rm
SIMD add or subtract	1 1 1 1 1 0 1 0 · 1 · OP · Rn	1 1 1 1 · Rd · 0 · prefix · Rm
Other three register data processing	1 1 1 1 1 0 1 0 · 1 · OP · Rn	1 1 1 1 · Rd · 1 · OP2 · Rm
Reserved	1 1 1 1 1 0 1 0	Not 1111
32-bit multiplies and Sum of absolute differences, with or without accumulate	1 1 1 1 1 0 1 1 0 · OP · Rn	Racc · Rd · OP2 · Rm
64-bit multiplies and multiply-accumulates. Divides.	1 1 1 1 1 0 1 1 1 · OP · Rn	RdLo · RdHi · OP2 · Rm

Figure 3-5 Data processing instructions, non-immediate

This section contains the following subsections:

- *Data processing instructions with constant shift* on page 3-18
- *Register-controlled shift instructions* on page 3-19
- *Signed and unsigned extend instructions with optional addition* on page 3-20
- *SIMD add and subtract* on page 3-21
- *Other three-register data processing instructions* on page 3-23
- *32-bit multiplies and sum of absolute differences, with or without accumulate* on page 3-24
- *64-bit multiply, multiply-accumulate, and divide instructions* on page 3-25.

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Data processing instructions with constant shift

Table 3-25 gives the opcodes and locations of further information about the data processing instructions with a constant shift applied to the second operand register. For information about constant shifts, see *Constant shifts applied to a register* on page 4-10.

In these instructions, if the S bit is set, the instruction updates the condition code flags according to the results of the instruction, see *Conditional execution* on page 3-34.

The shift type is encoded in hw2[5:4]. The shift value is encoded in hw2[14:12,7:6].

Table 3-25 Data processing instructions with constant shift

Function	Instruction	OP	Notes
Add with carry	*ADC (register)* on page 4-18	0b1010	
Add	*ADD (register)* on page 4-22	0b1000	
Logical AND	*AND (register)* on page 4-32	0b0000	
Bit clear	*BIC (register)* on page 4-46	0b0001	
Compare negative	*CMN (register)* on page 4-70	0b1000	`ADD` with `Rd` == 0b1111, `S` == 1
Compare	*CMP (register)* on page 4-74	0b1101	`SUB` with `Rd` == 0b1111, `S` == 1
Exclusive OR	*EOR (register)* on page 4-88	0b0100	
Move, and immediate shift	*Move, and immediate shift instructions* on page 3-19	0b0010	`ORR` with `Rn` == 0b1111
Move negative	*MVN (register)* on page 4-185	0b0011	`ORN` with `Rn` == 0b1111
Logical OR NOT	*ORN (register)* on page 4-193	0b0011	
Logical OR	*ORR (register)* on page 4-197	0b0010	
Pack halfword, BT	*PKH* on page 4-199	0b0110	shift_type == 0b00 (`LSL`), `S` == 0
Pack halfword, TB	*PKH* on page 4-199	0b0110	shift_type == 0b10 (`ASR`), `S` == 0
Reverse subtract	*RSB (register)* on page 4-251	0b1110	
Subtract with carry	*SBC (register)* on page 4-261	0b1011	
Subtract	*SUB (register)* on page 4-367	0b1101	
Test equal	*TEQ (register)* on page 4-395	0b0100	`EOR` with `Rd` == 0b1111, `S` == 1
Test	*TST (register)* on page 4-399	0b0000	`AND` with `Rd` == 0b1111, `S` == 1

Instructions of this format using any other combination of the OP bits are UNDEFINED.

Instructions of this format with OP == 0b0110 are UNDEFINED if S == 1 or shift_type == 0b01 or shift_type == 0b11.

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Move, and immediate shift instructions

Table 3-26 gives the locations of further information about the move, and immediate shift instructions.

In these instructions, if the S bit is set, the instruction updates the condition code flags according to the results of the instruction, see *Conditional execution* on page 3-34.

Table 3-26 Move, and immediate shift instructions

Function	Instruction	type	imm5
Move	*MOV (register)* on page 4-168	0b00	0b00000
Logical Shift Left	*LSL (immediate)* on page 4-150	0b00	not 0b00000
Logical Shift Right	*LSR (immediate)* on page 4-154	0b01	any
Arithmetic Shift Right	*ASR (immediate)* on page 4-34	0b10	any
Rotate Right	*ROR (immediate)* on page 4-243	0b11	not 0b00000
Rotate Right with Extend	*RRX* on page 4-247	0b11	0b00000

Register-controlled shift instructions

Table 3-27 gives the opcodes and locations of further information about the register-controlled shift instructions.

In these instructions, if the S bit is set, the instruction updates the condition code flags according to the results of the instruction, see *Conditional execution* on page 3-34.

Table 3-27 Register-controlled shift instructions

Function	Instruction	type	OP
Logical Shift Left	*LSL (register)* on page 4-152	0b00	0b000
Logical Shift Right	*LSR (register)* on page 4-156	0b01	0b000
Arithmetic Shift Right	*ASR (register)* on page 4-36	0b10	0b000
Rotate Right	*ROR (register)* on page 4-245	0b11	0b000

Instructions of this format using any other combination of the OP and OP2 bits are UNDEFINED.

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Signed and unsigned extend instructions with optional addition

Table 3-28 gives the opcodes and locations of further information about the signed and unsigned (zero) extend instructions with optional addition.

Table 3-28 Signed and unsigned extend instructions with optional addition

Function	Instruction	OP	Rn
Signed extend byte and add	*SXTAB* on page 4-377	0b100	Not R15
Signed extend two bytes to halfwords, and add	*SXTAB16* on page 4-379	0b010	Not R15
Signed extend halfword and add	*SXTAH* on page 4-381	0b000	Not R15
Signed extend byte	*SXTB* on page 4-383	0b100	0b1111
Signed extend two bytes to halfwords	*SXTB16* on page 4-385	0b010	0b1111
Signed extend halfword	*SXTH* on page 4-387	0b000	0b1111
Unsigned extend byte and add	*UXTAB* on page 4-455	0b101	Not R15
Unsigned extend two bytes to halfwords, and add	*UXTAB16* on page 4-457	0b011	Not R15
Unsigned extend halfword and add	*UXTAH* on page 4-459	0b001	Not R15
Unsigned extend byte	*UXTB* on page 4-461	0b101	0b1111
Unsigned extend two bytes to halfwords	*UXTB16* on page 4-463	0b011	0b1111
Unsigned extend halfword	*UXTH* on page 4-465	0b001	0b1111

Instructions of this format using any other combination of the OP bits are UNDEFINED.

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SIMD add and subtract

Table 3-29 gives the opcodes and locations of further information about *Single Instruction, Multiple Data* (SIMD) instructions.

The meanings of the prefix letters and the instruction mnemonics are explained in Table 3-30 on page 3-22.

Table 3-29 SIMD instructions

Instruction	OP	Prefix	Instruction	OP	Prefix
QADD16 on page 4-215	0b001	0b001	*UADD16* on page 4-401	0b001	0b100
QADD8 on page 4-217	0b000	0b001	*UADD8* on page 4-403	0b000	0b100
QASX on page 4-219	0b010	0b001	*UASX* on page 4-405	0b010	0b100
QSUB16 on page 4-229	0b101	0b001	*UHADD16* on page 4-411	0b001	0b110
QSUB8 on page 4-231	0b100	0b001	*UHADD8* on page 4-413	0b000	0b110
QSAX on page 4-225	0b110	0b001	*UHASX* on page 4-415	0b010	0b110
SADD16 on page 4-253	0b001	0b000	*UHSUB16* on page 4-419	0b101	0b110
SADD8 on page 4-255	0b000	0b000	*UHSUB8* on page 4-421	0b100	0b110
SASX on page 4-257	0b010	0b000	*UHSAX* on page 4-417	0b110	0b110
SHADD16 on page 4-273	0b001	0b010	*UQADD16* on page 4-429	0b001	0b101
SHADD8 on page 4-275	0b000	0b010	*UQADD8* on page 4-431	0b000	0b101
SHASX on page 4-277	0b010	0b010	*UQASX* on page 4-433	0b010	0b101
SHSUB16 on page 4-281	0b101	0b010	*UQSUB16* on page 4-437	0b101	0b101
SHSUB8 on page 4-283	0b100	0b010	*UQSUB8* on page 4-439	0b100	0b101
SHSAX on page 4-279	0b110	0b010	*UQSAX* on page 4-435	0b110	0b101
SSUB16 on page 4-327	0b101	0b000	*USUB16* on page 4-451	0b101	0b100
SSUB8 on page 4-329	0b100	0b000	*USUB8* on page 4-453	0b100	0b100
SSAX on page 4-325	0b110	0b000	*USAX* on page 4-449	0b110	0b100

Instructions of this format using any other combination of the OP and Prefix bits are UNDEFINED.

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Table 3-30 SIMD mnemonic elements

Mnemonic element	Meaning
Q prefix	Signed saturating arithmetic.
S prefix	Signed arithmetic, modulo 2^8 or 2^{16}.
SH prefix	Signed halving arithmetic. The result of the calculation is halved.
U prefix	Unsigned arithmetic, modulo 2^8 or 2^{16}.
UH prefix	Unsigned halving arithmetic. The result of the calculation is halved.
UQ prefix	Unsigned saturating arithmetic.
16 suffix	The instruction performs two 16-bit calculations.
8 suffix	The instruction performs four 8-bit calculations.
ASX mnemonic	The instruction performs one 16-bit addition and one 16-bit subtraction. The X indicates that the halfwords of the second operand are exchanged before the operation.
SAX mnemonic	The instruction performs one 16-bit subtraction and one 16-bit addition. The X indicates that the halfwords of the second operand are exchanged before the operation.

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Other three-register data processing instructions

Table 3-31 gives the opcodes and locations of further information about other three-register data processing instructions.

Table 3-31 Other three-register data processing instructions

Function	Instruction	OP	OP2
Count Leading Zeros	*CLZ* on page 4-66	0b011	0b000
Saturating Add	*QADD* on page 4-213	0b000	0b000
Saturating Double and Add	*QDADD* on page 4-221	0b000	0b001
Saturating Double and Subtract	*QDSUB* on page 4-223	0b000	0b011
Saturating Subtract	*QSUB* on page 4-227	0b000	0b010
Reverse Bits	*RBIT* on page 4-233	0b001	0b010
Byte-Reverse Word	*REV* on page 4-235	0b001	0b000
Byte-Reverse Packed Halfword	*REV16* on page 4-237	0b001	0b001
Byte-Reverse Signed Halfword	*REVSH* on page 4-239	0b001	0b011
Select bytes	*SEL* on page 4-267	0b010	0b000

Instructions of this format using any other combination of the OP and OP2 bits are UNDEFINED.

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32-bit multiplies and sum of absolute differences, with or without accumulate

Table 3-32 gives the opcodes and locations of further information about multiply and multiply-accumulate instructions with 32-bit results, and absolute difference and accumulate absolute difference instructions.

Table 3-32 Other two-register data processing instructions

Function	Instruction	OP	OP2	Ra
32 + 32 x 32-bit, least significant word	*MLA* on page 4-162	0b000	0b0000	not R15
32 – 32 x 32-bit, least significant word	*MLS* on page 4-164	0b000	0b0001	not R15
32 x 32-bit, least significant 32-bit word	*MUL* on page 4-181	0b000	0b0000	0b1111
32 + 16 x 16-bit, 32-bit result	*SMLABB, SMLABT, SMLATB, SMLATT* on page 4-287	0b001	0b00xx	not R15
Signed Dual Multiply-Accumulate Add	*SMLAD* on page 4-289	0b010	0b000x	not R15
Signed 32 + 16 x 32-bit, most significant word	*SMLAWB, SMLAWT* on page 4-297	0b011	0b000x	not R15
Signed Dual Multiply Subtract and Accumulate	*SMLSD* on page 4-299	0b100	0b000x	not R15
Signed 32 + 32 x 32-bit, most significant word	*SMMLA* on page 4-303	0b101	0b000x	not R15
Signed 32 – 32 x 32-bit, most significant word	*SMMLS* on page 4-305	0b110	0b000x	not R15
Signed 32 x 32-bit, most significant 32-bit word	*SMMUL* on page 4-307	0b101	0b000x	0b1111
Signed Dual Multiply Add	*SMUAD* on page 4-309	0b010	0b000x	0b1111
16 x 16-bit, 32-bit result	*SMULBB, SMULBT, SMULTB, SMULTT* on page 4-311	0b001	0b00xx	0b1111
Signed 16 x 32-bit, most significant 32-bit word	*SMULWB, SMULWT* on page 4-315	0b011	0b000x	0b1111
Signed Dual Multiply Subtract	*SMUSD* on page 4-317	0b100	0b000x	0b1111
Unsigned Sum of Absolute Differences	*USAD8* on page 4-441	0b111	0b0000	0b1111
Unsigned Accumulate Absolute Differences	*USADA8* on page 4-443	0b111	0b0000	not R15

Instructions of this format using any other combination of the OP and OP2 bits are UNDEFINED.

An instruction that matches the OP and OP2 fields, but not the Ra column, is UNPREDICTABLE under the usage rules for R15.

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64-bit multiply, multiply-accumulate, and divide instructions

Table 3-33 gives the opcodes and locations of further information about multiply and multiply accumulate instructions with 64-bit results, and divide instructions.

Table 3-33 Other two-register data processing instructions

Function	Instruction	OP	OP2
Signed 32 x 32	*SMULL* on page 4-313	0b000	0b0000
Signed divide	*SDIV* on page 4-265	0b001	0b1111
Unsigned 32 x 32	*UMULL* on page 4-427	0b010	0b0000
Unsigned divide	*UDIV* on page 4-409	0b011	0b1111
Signed 64 + 32 x 32	*SMLAL* on page 4-291	0b100	0b0000
Signed 64 + 16 x 16	*SMLALBB, SMLALBT, SMLALTB, SMLALTT* on page 4-293	0b100	0b10xy
Signed Multiply Accumulate Long Dual	*SMLALD* on page 4-295	0b100	0b110x
Signed Multiply Subtract accumulate Long Dual	*SMLSLD* on page 4-301	0b101	0b110x
Unsigned 64 + 32 x 32	*UMLAL* on page 4-425	0b110	0b0000
Unsigned 32 + 32 + 32 x 32	*UMAAL* on page 4-423	0b110	0b0110

Instructions of this format using any other combination of the OP and OP2 bits are UNDEFINED.

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3.3.3 Load and store single data item, and memory hints

Figure 3-6 shows the encodings for loads and stores with single data items.

	hw1 15 14 13 12 11	10 9	8	7	6 5	4	3 2 1 0	hw2 15 14 13 12	11	10	9	8	7 6	5 4	3 2 1 0
General format	1 1 1 1 1	0 0													
PC +/– imm12 (1)	1 1 1 1 1	0 0	S	U	size	1	1 1 1 1	Rt	imm12						
Rn + imm12 (2)	1 1 1 1 1	0 0	S	1	size	L	Rn	Rt	imm12						
Rn – imm8 (3)	1 1 1 1 1	0 0	S	0	size	L	Rn	Rt	1	1	0	0	imm8		
Rn + imm8, User privilege (4)	1 1 1 1 1	0 0	S	0	size	L	Rn	Rt	1	1	1	0	imm8		
Rn post-indexed by +/– imm8 (5)	1 1 1 1 1	0 0	S	0	size	L	Rn	Rt	1	0		1	imm8		
Rn pre-indexed by +/– imm8 (6)	1 1 1 1 1	0 0	S	0	size	L	Rn	Rt	1	1		1	imm8		
Rn + shifted register (7)	1 1 1 1 1	0 0	S	0	size	L	Rn	Rt	0	0	0	0	0 0	shift	Rm
Reserved	1 1 1 1 1	0 0		0			Not 1111		1	0		0			
Reserved	1 1 1 1 1	0 0		0			Not 1111		0	Not 00000					
Reserved	1 1 1 1 1	0 0				0	1 1 1 1								

Figure 3-6 Load and store instructions, single data item

In these instructions:

`L` specifies whether the instruction is a load (L == 1) or a store (L == 0)

`S` specifies whether a load is sign extended (S == 1) or zero extended (S == 0)

`U` specifies whether the indexing is upwards (U == 1) or downwards (U == 0)

`Rn` cannot be r15 (if it is, the instruction is `PC +/- imm12`)

`Rm` cannot be r13 or r15 (if it is, the instruction is UNPREDICTABLE).

Table 3-34 gives the encoding and locations of further information about load and store single data item instructions, and memory hints.

Table 3-34 Load and store single data item, and memory hints

Instruction	Format	S	size	L	Rt
`LDR`, `LDRB`, `LDRSB`, `LDRH`, `LDRSH` (immediate offset)	2	X	0b0X	1	Not R15
		0	0b10	1	Any, including R15
`LDR`, `LDRB`, `LDRSB`, `LDRH`, `LDRSH` (negative immediate offset)	3	X	0b0X	1	Not R15
		0	0b10	1	Any, including R15
`LDR`, `LDRB`, `LDRSB`, `LDRH`, `LDRSH` (post-indexed)	5	X	0b0X	1	Not R15
		0	0b10	1	Any, including R15

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Table 3-34 Load and store single data item, and memory hints (continued)

Instruction	Format	S	size	L	Rt
LDR, LDRB, LDRSB, LDRH, LDRSH (pre-indexed)	6	X	0b0X	1	Not R15
		0	0b10	1	Any, including R15
LDR, LDRB, LDRSB, LDRH, LDRSH (register offset)	7	X	0b0X	1	Not R15
		0	0b10	1	Any, including R15
LDR, LDRB, LDRSB, LDRH, LDRSH (PC-relative)	1	X	0b0X	1	Not R15
		0	0b10	1	Any, including R15
LDRT, LDRBT, LDRSBT, LDRHT, LDRSHT	4	X	0b0X	1	Not R15
		0	0b10	1	Not R15
PLD	1, 2, 3, 7	0	0b00	1	R15
PLI	1, 2, 3, 7	1	0b00	1	R15
Unallocated memory hints (execute as NOP)	1, 2, 3, 7	X	0b01	1	R15
UNPREDICTABLE	4, 5, 6	X	0b0X	1	R15
STR, STRB, STRH (immediate offset) on page 4-245	2	0	Not 0b11	0	Not R15
STR, STRB, STRH (negative immediate offset) on page 4-247	3	0	Not 0b11	0	Not R15
STR, STRB, STRH (post-indexed) on page 4-249	5	0	Not 0b11	0	Not R15
STR, STRB, STRH (pre-indexed) on page 4-251	6	0	Not 0b11	0	Not R15
STR, STRB, STRH (register offset) on page 4-253	7	0	Not 0b11	0	Not R15
STRT, STRBT, STRHT on page 4-268	4	0	Not 0b11	0	Not R15

Instruction encodings using any combination of Format, S, size, and L bits that is not covered by Table 3-34 on page 3-26 are UNDEFINED.

An instruction that matches the Format, S, and L fields, but not the Rt column, is UNPREDICTABLE under the usage rules for R15.

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3.3.4 Load/store double and exclusive, and table branch

Figure 3-7 shows the encodings for load and store double, load and store exclusive, and table branch instructions.

	hw1								hw2			
	15 14 13 12 11	10 9	8	7	6	5	4	3 2 1 0	15 14 13 12	11 10 9 8	7 6 5 4	3 2 1 0
General format	1 1 1 0 1	0 0			1							
Load and Store Double (only if PW != 0b00)	1 1 1 0 1	0 0	P	U	1	W	L	Rn	Rt	Rt2	imm8	
Load and Store Exclusive	1 1 1 0 1	0 0	0	0	1	0	L	Rn	Rt	Rd	imm8	
Load and Store Exclusive Byte, Halfword, Doubleword, and Table Branch.	1 1 1 0 1	0 0	0	1	1	0	L	Rn	Rt	Rt2	OP	Rm

Figure 3-7 Load and store double, load and store exclusive, and table branch

In these instructions:

`L` specifies whether the instruction is a load (L == 1) or a store (L == 0)

`P` specifies pre-indexed addressing (P == 1) or post-indexed addressing (P == 0)

`U` specifies whether the indexing is upwards (U == 1) or downwards (U == 0)

`W` specifies whether the address is written back to the base register (W == 1) or not (W == 0).

For further details about the load and store double instructions, see:

- *LDRD (immediate)* on page 4-114
- *STRD (immediate)* on page 4-347.

For further details about the load and store exclusive word instructions, see:

- *LDREX* on page 4-116
- *STREX* on page 4-349.

Table 3-35 on page 3-29 gives details of the encoding of load and store exclusive byte, halfword, and doubleword, and the table branch instructions.

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Table 3-35 Load and store exclusive byte, halfword, and doubleword, and table branch instructions

Instruction	L	OP	Rn	Rt	Rt2	Rm
LDREXB on page 4-118	1	0b0100	Not R15	Not R15	SBO	SBO
LDREXH on page 4-122	1	0b0101	Not R15	Not R15	SBO	SBO
LDREXD on page 4-120	1	0b0111	Not R15	Not R15	Not R15	SBO
STREXB on page 4-351	0	0b0100	Not R15	Not R15	SBO	Not R15
STREXH on page 4-355	0	0b0101	Not R15	Not R15	SBO	Not R15
STREXD on page 4-353	0	0b0111	Not R15	Not R15	Not R15	Not R15
TBB on page 4-389	1	0b0000	Any including R15	SBO	SBZ	Not R15
TBH on page 4-391	1	0b0001	Any including R15	SBO	SBZ	Not R15

Instructions of this format using any other combination of the L and OP bits are UNDEFINED.

An instruction that matches the OP and L fields, but not the Rn, Rm, Rt, or Rt2 columns, is UNPREDICTABLE under the usage rules for R15.

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3.3.5 Load and store multiple, RFE, and SRS

Figure 3-8 shows encodings for the load and store multiple instructions, together with the `RFE` and `SRS` instructions.

	hw1 15–11	10–9	8	7	6	5	4	3–0	hw2 15	14	13	12–5	4–0
General format	1 1 1 0 1	0 0			0								
Load and Store Multiple	1 1 1 0 1	0 0	V	U	0	W	L	Rn	P	M	SBZ	mask	
Return from exception (without using stack)	1 1 1 0 1	0 0	U	U	0	W	1	Rn	SBO		SBZ		
Save return state	1 1 1 0 1	0 0	U	U	0	W	0	Rn	SBO		SBZ		mode

Figure 3-8 Load and store multiple, RFE, and SRS

In these instructions:

`L`	specifies whether the instruction is a load (L == 1) or a store (L == 0)
`mask`	specifies which registers, in the range R0-R12, must be loaded or stored
`M`	specifies whether R14 is to be loaded or stored
`P`	specifies whether the PC is to be loaded (the PC cannot be stored)
`U`	specifies whether the indexing is upwards (U == 1) or downwards (U == 0)
`V`	is NOT U
`W`	specifies whether the address is written back to the base register (W == 1) or not (W == 0).

For further details about these instructions, see:

- *LDMDB / LDMEA* on page 4-96 (Load Multiple Decrement Before / Empty Ascending)
- *LDMIA / LDMFD* on page 4-98 (Load Multiple Increment After / Full Descending)
- *POP* on page 4-209
- *PUSH* on page 4-211
- *RFE* on page 4-241 (Return From Exception)
- *SRS* on page 4-319 (Store Return State)
- *STMDB / STMFD* on page 4-333 (Store Multiple Decrement Before / Full Descending)
- *STMIA / STMEA* on page 4-335 (Store Multiple Increment After / Empty Ascending).

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3.3.6 Branches, miscellaneous control instructions

Figure 3-9 shows the encodings for branches and various control instructions.

	hw1																hw2															
	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
General format	1	1	1	1	0												1															
Branch	1	1	1	1	0	S	offset[21:12]										1	0	J1	1	J2	offset[11:1]										
Branch with link	1	1	1	1	0	S	offset[21:12]										1	1	J1	1	J2	offset[11:1]										
Branch with link, change to ARM	1	1	1	1	0	S	offset[21:12]										1	1	J1	0	J2	offset[11:2]										0
Reserved	1	1	1	1	0												1	1		0												1
Conditional branch	1	1	1	1	0	S	cond				offset[17:12]						1	0	J1	0	J2	offset[11:1]										
Secure Monitor Interrupt	1	1	1	1	0	1	1	1	1	1	1	1	imm[3:0]				1	0	0	0	imm[11:4]								imm[15:12]			
Move to status from register	1	1	1	1	0	0	1	1	1	0	0	R	Rn				1	0	SBZ	0	field_mask				SBZ							
Change processor state (imod, M != 00,0)	1	1	1	1	0	0	1	1	1	0	1	0	SBO				1	0	SBZ	0	SBZ	imod		M	A	I	F	mode				
No operation, hints	1	1	1	1	0	0	1	1	1	0	1	0	SBO				1	0	SBZ	0	SBZ	0	0	0	hint							
Special control operations	1	1	1	1	0	0	1	1	1	0	1	1	SBO				1	0	SBZ	0	SBO				OP				option			
Branch, Change to Java	1	1	1	1	0	0	1	1	1	1	0	0	Rn				1	0	SBZ	0	SBO				SBZ							
Exception return	1	1	1	1	0	0	1	1	1	1	0	1	(1)	(1)	(1)	(0)	1	0	SBZ	0	SBO				imm8							
Move to register from status	1	1	1	1	0	0	1	1	1	1	1	R	SBO				1	0	SBZ	0	Rd				SBZ							
RESERVED	1	1	1	1	0	1	1	1	1	1	1	1					1	0	1	0												
Permanently **UNDEFINED**	1	1	1	1	0	1	1	1	1	1	1	1					1	0	1	0					1	1	1	1				

Figure 3-9 Branches and miscellaneous control instructions

In these instructions:

`A`, `I`, `F` specifies which interrupt disable flags a CPS instruction must alter

`I1`,`I2` contain bits[23:22] of the offset, exclusive ORed with the S bit

`J1`,`J2` contain bits[19:18] of the offset

`M` specifies whether a `CPS` instruction modifies the mode (M == 1) or not (M == 0)

`R` specifies whether an `MRS` instruction accesses the SPSR (R== 1) or the CPSR (R == 0)

`S` contains the sign bit, duplicated to bits[31:24] of the offset, or to bits[31:20] of the offset for conditional branches.

For further details about the No operation and hint instructions, see Table 3-36 on page 3-32.

For further details about the Special control operation instructions, see Table 3-37 on page 3-32.

For further details about Exception Return, see *SUBS PC, LR* on page 4-373.

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For further details about the other branch and miscellaneous control instructions, see:

- *B* on page 4-38 (Branch)
- *BL, BLX (immediate)* on page 4-50 (Branch with Link, Branch with Link and change to ARM® instruction set)
- *BLX (register)* on page 4-52 (Branch with Link and change to ARM® instruction set)
- *BX* on page 4-54 (Branch and change to ARM® instruction set)
- *BXJ* on page 4-56 (Branch and change to Jazelle® state)
- *CPS* on page 4-76 (Change Processor State)
- *MRS* on page 4-177 (Move from Status register to ARM Register)
- *MSR (register)* on page 4-179 (Move from ARM register to Status register)
- *SUBS PC, LR* on page 4-373 on page 4-274 (Return From Exception).

Table 3-36 NOP-compatible hint instructions

Function	Hint number	For details see
No operation	0b00000000	*NOP* on page 4-189
Yield	0b00000001	*YIELD* on page 4-471
Wait for event	0b00000010	*WFE* on page 4-467
Wait for interrupt	0b00000011	*WFI* on page 4-469
Send event	0b00000100	*SEV* on page 4-271
Debug hint	0b1111xxxx	*DBG* on page 4-80

The remainder of this space is RESERVED. The instructions must execute as No Operations, and must not be used.

Table 3-37 Special control operations

Function	OP	For details see
Clear Exclusive	0b0010	*CLREX* on page 4-64
Data Synchronization Barrier	0b0100	*DSB* on page 4-84
Data Memory Barrier	0b0101	*DMB* on page 4-82
Instruction Synchronization Barrier	0b0110	*ISB* on page 4-90

Instructions of this format using any other combination of the OP bits are UNDEFINED.

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3.3.7 Coprocessor instructions

Figure 3-10 shows the encodings for coprocessor instructions.

These are exactly equivalent to the ARM coprocessor instructions. See the *ARM Architecture Reference Manual* for details, except that:

- R15 reads as the address of the instruction plus four, rather than the address of the instruction plus eight.
- Like all other 32-bit Thumb instructions, the instructions are stored in memory in a different byte order from ARM instructions. See *Instruction alignment and byte ordering* on page 2-13 for details.

	hw1 15	14	13	12	11	10	9	8	7	6	5	4	3–0	hw2 15–12	11–8	7–5	4	3–0
General format	1	1	1		1	1												
MRRC and MCRR coprocessor register transfers	1	1	1	C	1	1	0	0	0	1	0	L	Rt2	Rt	coproc	opcode		CRm
Load and store coprocessor	1	1	1	C	1	1	0	P	U	N	W	L	Rn	CRd	coproc	imm8		
Coprocessor data processing	1	1	1	C	1	1	1	0	opc1				CRn	CRd	coproc	opc2	0	CRm
MRC and MCR coprocessor register transfers	1	1	1	C	1	1	1	0	opc1			L	CRn	Rxf	coproc	opc2	1	CRm
Reserved for AdvSIMD	1	1	1		1	1	1	1										

Figure 3-10 Coprocessor instructions

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3.4 Conditional execution

Unlike ARM instructions, most Thumb instructions are unconditional. Before Thumb-2, the only conditional Thumb instruction was a 16-bit conditional branch instruction, `B<cond>`, with a branch range of –256 to +254 bytes.

Thumb-2 adds the following instructions:

- A 32-bit conditional branch, with a branch range of approximately ± 1MB, see *B* on page 4-38.
- A 16-bit If-Then instruction, `IT`. `IT` makes up to four following instructions conditional, see *IT* on page 4-92. The instructions that are made conditional by an `IT` instruction are called its *IT block*.
- A 16-bit Compare and Branch on Zero instruction, with a branch range of +4 to +130 bytes, see *CBZ* on page 4-60.
- A 16-bit Compare and Branch on Non-Zero instruction, with a branch range of +4 to +130 bytes, see *CBNZ* on page 4-58.

The condition codes that the conditional branch and `IT` instructions use are shown in Table 3-38 on page 3-35. They are the same as ARM condition codes.

The conditions of the instructions in an IT block are either all the same, or some of them are the inverse of the first condition.

3.4.1 Assembly language syntax

Although Thumb instructions are unconditional, all instructions that are made conditional by an `IT` instruction must be written with a condition. These conditions must match the conditions imposed by the `IT` instruction. For example, an `ITTEE EQ` instruction imposes the `EQ` condition on the first two following instructions, and the `NE` condition on the next two. Those four instructions must be written with `EQ`, `EQ`, `NE` and `NE` conditions respectively.

Some instructions are not allowed to be made conditional by an `IT` instruction, or are only allowed to be if they are the last instruction in the IT block.

The branch instruction encodings that include a condition field are not allowed to be made conditional by an `IT` instruction. If the assembler syntax indicates a conditional branch that correctly matches a preceding `IT` instruction, it must be assembled using a branch instruction encoding that does not include a condition field.

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Table 3-38 Condition codes

Opcode	Mnemonic extension	Meaning	Condition flag state
0000	EQ	Equal	Z set
0001	NE	Not equal	Z clear
0010	CS [a]	Carry set	C set
0011	CC [b]	Carry clear	C clear
0100	MI	Minus/negative	N set
0101	PL	Plus/positive or zero	N clear
0110	VS	Overflow	V set
0111	VC	No overflow	V clear
1000	HI	Unsigned higher	C set and Z clear
1001	LS	Unsigned lower or same	C clear or Z set
1010	GE	Signed greater than or equal	N set and V set, or N clear and V clear (N == V)
1011	LT	Signed less than	N set and V clear, or N clear and V set (N != V)
1100	GT	Signed greater than	Z clear, and either N set and V set, or N clear and V clear (Z == 0,N == V)
1101	LE	Signed less than or equal	Z set, or N set and V clear, or N clear and V set (Z == 1 or N != V)
1110	AL	Always (unconditional). AL can only be used with IT instructions.	-
1111	-	Alternative instruction, always (unconditional).	-

a. HS (unsigned Higher or Same) is a synonym for CS.
b. LO (unsigned Lower) is a synonym for CC.

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3.5 UNDEFINED and UNPREDICTABLE instruction set space

An attempt to execute an unallocated instruction results in either:

- Unpredictable behavior. The instruction is described as UNPREDICTABLE.
- An Undefined Instruction exception. The instruction is described as UNDEFINED.

This section describes the general rules that determine whether an unallocated instruction in the Thumb instruction set space is UNDEFINED or UNPREDICTABLE.

Note

See *Usage of 0b1111 as a register specifier in 32-bit encodings* on page 3-38 and *Usage of 0b1101 as a register specifier* on page 3-41 for additional information on UNPREDICTABLE behavior associated with the usage models of R13 and R15.

3.5.1 16-bit instruction set space

Instruction bits[15:6] are used for decode.

Instructions where bits[15:10] == 0b010001 are *special data processing* operations. Unallocated instructions in this space are UNPREDICTABLE. In ARMv6 this is where bits[9:6] == 0b0000 or 0b0100. In ARMv7 this is where bits[9:6] == 0b0100.

All other unallocated instructions are UNDEFINED.

Permanently undefined space

The part of the instruction set space where bits[15:8] == 0b11011110 is architecturally undefined. This space is available for instruction emulation, or for other purposes where software wants to force an Undefined Instruction exception to occur.

3.5.2 32-bit instruction set space

The following general rules apply to all 32-bit Thumb instructions:

- The hw1[15:11] bit-field is always in the range 0b11101 to 0b11111 inclusive.
- Instruction classes are determined by hw1[15:8,6] and hw2[15]. For details see Figure 3-3 on page 3-12.
- Instructions are made up of three types of bit field:
  - opcode fields
  - register specifiers
  - immediate fields specifying shifts or immediate values.
- Opcode fields are defined in Figure 3-4 on page 3-13 to Figure 3-10 on page 3-33 inclusive.

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An instruction is UNDEFINED if:

- it corresponds to any Undefined or Reserved encoding in Figure 3-4 on page 3-13 to Figure 3-10 on page 3-33 inclusive
- it corresponds to an opcode bit pattern that is missing from the tables associated with the figures (that is, Table 3-21 on page 3-14 to Table 3-37 on page 3-32 inclusive), or noted in the subsection text
- it is declared as UNDEFINED within an instruction description.

An instruction is UNPREDICTABLE if:

- a register specifier is 0b1111 or 0b1101 and the instruction does not specifically describe this case
- an SBZ bit or multi-bit field is not zero or all zeros
- an SBO bit or multi-bit field is not one or all ones
- it is declared as UNPREDICTABLE within an instruction description.

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3.6 Usage of 0b1111 as a register specifier in 32-bit encodings

In ARM instructions, a value of 0b1111 in a register specification normally specifies the PC. This usage is not normally permitted in Thumb-2.

When a value of 0b1111 is permitted, a variety of meanings is possible. For register reads, these meanings are:

- Read the PC value, that is, the address of the current instruction + 4. The base register of the table branch instructions TBB and TBH is allowed to be the PC. This allows branch tables to be placed in memory immediately after the instruction. (Some instructions read the PC value implicitly, without the use of a register specifier, for example the conditional branch instruction B<cond>.)

  Note

  Use of the PC as the base register in the STC instruction is deprecated in ARMv7.

- Read the word-aligned PC value, that is, the address of the current instruction + 4, with bits[1:0] forced to zero. The base register of LDC, STC, LDR, LDRB, LDRD (pre-indexed, no writeback), LDRH, LDRSB, and LDRSH instructions are allowed to be the word-aligned PC. This allows PC-relative data addressing. In addition, the ADDW and SUBW instructions allow their source registers to be 0b1111 for the same purpose.

- Read zero. This is done when one instruction is a special case of another, more general instruction, but with one operand zero. In these cases, the instructions are listed on separate pages, with Encoding notes for each instruction cross-referencing the other. This is the case for the following instructions:

BFC	special case of BFI
MOV	special case of ORR
MUL	special case of MLA
MVN	special case of ORN
SMMUL	special case of SMMLA
SMUAD	special case of SMLAD
SMUL<x><y>	special case of SMLA<x><y>
SMULW<y>	special case of SMLAW<y>
SMUSD	special case of SMLSD
SXTB	special case of SXTAB
SXTB16	special case of SXTAB16
SXTH	special case of SXTAH
USAD8	special case of USADA8
UXTB	special case of UXTAB
UXTB16	special case of UXTAB16
UXTH	special case of UXTAH.

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For register writes, these meanings are:

- The PC can be specified as the destination register of an LDR instruction. This is done by encoding Rt as 0b1111. The loaded value is treated as an address, and the effect of execution is a branch to that address. Bit[0] of the loaded value selects whether to execute ARM or Thumb instructions after the branch.

  Some other instructions write the PC in similar ways, either implicitly (for example, B<cond>) or by using a register mask rather than a register specifier (LDM). The address to branch to can be a loaded value (for example, RFE), a register value (for example, BX), or the result of a calculation (for example, TBB or TBH). The ARM or Thumb instruction set selection can be similar to the LDR case (LDM or BX), unconditional (for example, the revised 32-bit form of BLX), unchanged (for example, B<cond>), or set from the (J,T) bits of the SPSR (RFE and SUBS PC,LR,#imm8).

- Discard the result of a calculation. This is done when one instruction is a special case of another, more general instruction, but with the result discarded. In these cases, the instructions are listed on separate pages, with Encoding notes for each instruction cross-referencing the other.

  This is the case for the following instructions:

  CMN special case of ADDS

  CMP special case of SUBS

  TEQ special case of EORS

  TST special case of ANDS.

- If the destination register specifier of an LDRB, LDRH, LDRSB, or LDRSH instruction is 0b1111, the instruction is a memory hint instead of a load operation.

  This is the case for the following instructions:

  PLD uses LDRB encoding

  PLI uses LDRSB encoding.

  The unallocated memory hint instruction encodings (LDRH and LDRSH encodings) execute as NOP, instead of being UNDEFINED or UNPREDICTABLE like most other unallocated instruction encodings. See *Memory hints* on page 4-14 for further details.

- If the destination register specifier of an MRC instruction is 0b1111, bits[31:28] of the value transferred from the coprocessor are written to the (N,Z,C,V) flags in the CPSR, and bits[27:0] are discarded.

3.6.1 ARM-Thumb interworking

Thumb interworking uses bit[0] on a write to the PC to determine the CPSR T bit. For 16-bit instructions, interworking behavior is as follows:

- ADD (4) and MOV (3) branch within Thumb state ignoring bit[0].
- B (unconditional) and B (conditional) branch without interworking
- BKPT and SVC (SWI) cause an exception, the exception mechanism responsible for any state transition, and are not considered as interworking instructions.

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- `BLX`(2) and `BX` interwork on the value in Rm

For 32-bit instructions, interworking behavior is as follows:

- `B` (unconditional) and `B` (conditional) branch without interworking
- `BL` and `BLX` branch to Thumb and ARM state respectively based on the instruction encoding, not due to bit[0] of the value written to the PC. They are therefore related to interworking instructions, rather than being interworking instructions themselves.
- `LDM` and `LDR` support interworking using the value written to the PC.
- `TBB` and `TBH` branch without interworking.

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3.7 Usage of 0b1101 as a register specifier

R13 is redefined in Thumb-2 so that its usage model is strongly linked to that of a stack pointer. This change aligns R13 with the ARM *Procedure Call Standard* (PCS), the architecture usage model defined by the `SRS` and `RFE` 32-bit instructions, and the `PUSH` and `POP` instructions in the 16-bit instruction set.

In the 32-bit Thumb instruction set, if you use R13 as a general purpose register beyond the architecturally defined constraints described in this section, the results are UNPREDICTABLE. For the ARM ISA, support of R13, other than that described for Thumb-2, is deprecated.

The changes to R13 are described in:

- *R13[1:0] definition*
- *Thumb-2 ISA support for R13*.

See also *Thumb-2 16-bit ISA support for R13* on page 3-42.

3.7.1 R13[1:0] definition

Bits[1:0] of R13 adopt a *SBZP* (Should Be Zero or Preserved) write policy, that is, it is permitted to write zeros or values read from them. Writing anything else to bits[1:0] results in UNPREDICTABLE values. Reading bits[1:0] returns the value written earlier, unless the value read is UNPREDICTABLE.

This definition means that R13 can be set to a word-aligned address. This supports `ADD/SUB R13,R13,#4` without either a requirement that R13[1:0] must always read as zero or a need to use `ADD/SUB Rt,R13,#4; BIC R13,Rt,#3` to force word-alignment of the write to R13.

3.7.2 Thumb-2 ISA support for R13

R13 instruction support is restricted to the following:

- R13 as the source or destination register of a `MOV` instruction. Only register <=> register (no shift) transfers are supported, with no flag setting:

```
MOV     SP,Rm
MOV     Rn,SP
```

- Adjusting R13 up or down by a multiple of its alignment:

```
ADD{W}  SP,SP,#N             ; For N a multiple of 4
SUB{W}  SP,SP,#N             ; For N a multiple of 4
ADD     SP,SP,Rm,LSL #shft   ; For shft=0,1,2,3
SUB     SP,SP,Rm,LSL #shft   ; For shft=0,1,2,3
```

- R13 as a base register (Rn) of any load or store instruction. This supports SP-based addressing for load, store, or memory hint instructions, with positive or negative offsets, with and without writeback.

- R13 as the first operand (Rn) in any `ADD{S}`, `ADDW`, `CMN`, `CMP`, `SUB{S}`, or `SUBW` instruction. The add/subtract instructions support SP-based address generation, with the address going into a general-purpose register. `CMN` and `CMP` are useful for stack checking in some circumstances.

- R13 as the transferred register (Rt) in any `LDR` or `STR` instruction.

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3.7.3 Thumb-2 16-bit ISA support for R13

For 16-bit data processing instructions that affect high registers, R13 can only be used as described in *Thumb-2 ISA support for R13* on page 3-41. Any other use is deprecated. This affects the high register forms of `CMP` and `ADD`, where the use of R13 as Rm is deprecated. For more information about high registers, see the *ARM Architecture Reference Manual*.

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3.8 Thumb-2 and VFP support

VFP instructions are coprocessor instructions, where the coprocessor number is either 10 or 11.

VFP instructions are supported in Thumb-2 as unconditional versions of their ARM encodings. hw1[15:0] corresponds to the ARM instruction bits[31:16] and hw2[15:0] corresponds to the ARM instruction bits[15:0].

All VFP instructions can be made conditional in Thumb-2 using the `IT` instruction (see *IT* on page 4-92).

VFP instructions that follow the `MCR`, `MRC`, `MRRC`, `MCRR`, `LDC`, `STC` and `CDP` formats are identical to the unconditional form of the ARM instructions, that is hw1[15:12] == 0b1110.

VFP instructions that follow the `MCR2`, `MRC2`, `MRRC2`, `MCRR2`, `LDC2`, `STC2` and `CDP2` formats are identical to the ARM instructions, that is, hw1[15:12] == 0b1111.

The VFP load and store multiple instructions, `LDC` (2) and `STC` (2), are UNPREDICTABLE when the base register is R15.

Note

This is different from their equivalent ARM instruction. This is because the PC value used (CurrentInstructionAddress + 4) does not allow for a branch around a literal pool.

For more information about VFP, see the *ARM Architecture Reference Manual*.

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Chapter 4
Thumb Instructions

This chapter describes each Thumb®-2 32-bit instruction. It contains the following sections:

- *Format of instruction descriptions* on page 4-2
- *Immediate constants* on page 4-8
- *Constant shifts applied to a register* on page 4-10
- *Memory accesses* on page 4-13
- *Memory hints* on page 4-14
- *Alphabetical list of Thumb instructions* on page 4-15.

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4.1 Format of instruction descriptions

The instruction descriptions in the alphabetical lists of instructions in *Alphabetical list of Thumb instructions* on page 4-15 and *Alphabetical list of new ARM instructions* on page 5-2 normally use the following format:

- instruction section title
- introduction to the instruction
- instruction encoding(s)
- architecture version information
- assembler syntax
- pseudo-code describing how the instruction operates
- exception information
- notes (where applicable).

Each of these items is described in more detail in the following subsections.

A few instruction descriptions describe alternative mnemonics for other instructions and use an abbreviated and modified version of this format.

4.1.1 Instruction section title

The instruction section title gives the base mnemonic for the instructions described in the section. When one mnemonic has multiple forms described in separate instruction sections, this is followed by a short description of the form in parentheses. The most common use of this is to distinguish between forms of an instruction in which one of the operands is an immediate value and forms in which it is a register.

Parenthesized text is also used to document the former mnemonic in some cases where a mnemonic has been replaced entirely by another mnemonic in the new assembler syntax.

4.1.2 Introduction to the instruction

The instruction section title is followed by text that briefly describes the main features of the instruction. This description is not necessarily complete and is not definitive. If there is any conflict between it and the more detailed information that follows, the latter takes priority.

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4.1.3 Instruction encodings

The *Encodings* subsection contains a list of one or more instruction encodings. For reference purposes, each instruction encoding is labelled, T1, T2, T3... (for Thumb instructions) or A1, A2, A3... (for ARM instructions).

Each instruction encoding description consists of:

- An assembly syntax that ensures that the assembler selects the encoding in preference to any other encoding. In some cases, multiple syntaxes are given. The correct one to use is sometimes indicated by annotations to the syntax, such as *Inside IT block* and *Outside IT block*. In other cases, the correct one to use can be determined by looking at the assembler syntax description and using it to determine which syntax corresponds to the instruction being disassembled.

  There is usually more than one syntax that ensures re-assembly to any particular encoding, and the exact set of syntaxes that do so usually depends on the register numbers, immediate constants and other operands to the instruction. For example, when assembling to the Thumb instruction set, the syntax `AND R0,R0,R8` ensures selection of a 32-bit encoding but `AND R0,R0,R1` selects a 16-bit encoding.

  The assembly syntax documented for the encoding is chosen to be the simplest one that ensures selection of that encoding for all operand combinations supported by that encoding. This often means that it includes elements that are only necessary for a small subset of operand combinations. For example, the assembler syntax documented for the 32-bit Thumb `AND` (register) encoding includes the `.W` qualifier to ensure that the 32-bit encoding is selected even for the small proportion of operand combinations for which the 16-bit encoding is also available.

  The assembly syntax given for an encoding is therefore a suitable one for a disassembler to disassemble that encoding to. However, disassemblers may wish to use simpler syntaxes when they are suitable for the operand combination, in order to produce more readable disassembled code.

- An encoding diagram. This is half-width for 16-bit Thumb encodings and full-width for 32-bit Thumb and ARM encodings. The 32-bit Thumb encodings use a double vertical line between the two halfwords of the instruction to distinguish them from ARM encodings and to act as a reminder that 32-bit Thumb encodings use the byte order of a sequence of two halfwords rather than of a word, as described in *Instruction alignment and byte ordering* on page 2-13.

- Encoding-specific pseudo-code. This is pseudo-code that translates the encoding-specific instruction fields into inputs to the encoding-independent pseudo-code in the later *Operation* subsection, and that picks out any special cases in the encoding. For a detailed description of the pseudo-code used and of the relationship between the encoding diagram, the encoding-specific pseudo-code and the encoding-independent pseudo-code, see Appendix A *Pseudo-code definition*.

4.1.4 Architecture version information

The *Architecture versions* subsection contains information about which architecture versions include the instruction. This often differs between encodings.

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4.1.5 Assembler syntax

The Assembly syntax subsection describes the standard UAL syntax for the instruction.

Each syntax description consists of the following elements:

- One or more syntax prototype lines written in a typewriter font, using the conventions described in *Assembler syntax prototype line conventions* on page 4-5. Each prototype line documents the mnemonic and (where appropriate) operand parts of a full line of assembler code. When there is more than one such line, each prototype line is annotated to indicate required results of the encoding-specific pseudo-code. For each instruction encoding, this information can be used to determine whether any instructions matching that encoding are available when assembling that syntax, and if so, which ones.

- The line *where:* followed by descriptions of all of the variable or optional fields of the prototype syntax line.

  Some syntax fields are standardized across all or most instructions. These fields are described in *Standard assembler syntax fields* on page 4-6.

  By default, syntax fields that specify registers (such as `<Rd>`, `<Rn>`, or `<Rt>`) are permitted to be any of R0-R12 or LR in Thumb instructions, and any of R0-R12, SP or LR in ARM instructions. These require that the encoding-specific pseudo-code should set the corresponding integer variable (such as `d`, `n`, or `t`) to the corresponding register number (0-12 for R0-R12, 13 for SP, 14 for LR). This can normally be done by setting the corresponding bitfield in the instruction (named Rd, Rn, Rt...) to the binary encoding of that number. In the case of 16-bit Thumb encodings, this bitfield is normally of length 3 and so the encoding is only available when one of R0-R7 was specified in the assembler syntax. It is also common for such encodings to use a bitfield name such as Rdn. This indicates that the encoding is only available if `<Rd>` and `<Rn>` specify the same register, and that the register number of that register is encoded in the bitfield if they do.

  The description of a syntax field that specifies a register sometimes extends or restricts the permitted range of registers or document other differences from the default rules for such fields. Typical extensions are to allow the use of the SP in Thumb instructions and to allow the use of the PC (using register number 15).

- Where appropriate, text that briefly describes changes from the pre-UAL ARM assembler syntax. Where this is present, it usually consists of an alternative pre-UAL form of the assembler mnemonic. The pre-UAL ARM assembler syntax does not conflict with UAL, and support for it is a recommended optional extension to UAL, to allow the assembly of pre-UAL ARM assembler source files.

Note

The pre-UAL Thumb assembler syntax is incompatible with UAL and is not documented in the instruction sections.

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Assembler syntax prototype line conventions

The following conventions are used in assembler syntax prototype lines and their subfields:

`< >` Any item bracketed by < and > is a short description of a type of value to be supplied by the user in that position. A longer description of the item is normally supplied by subsequent text. Such items often correspond to a similarly named field in an encoding diagram for an instruction. When the correspondence simply requires the binary encoding of an integer value or register number to be substituted into the instruction encoding, it is not described explicitly. For example, if the assembler syntax for an ARM instruction contains an item `<Rn>` and the instruction encoding diagram contains a 4-bit field named Rn, the number of the register specified in the assembler syntax is encoded in binary in the instruction field.

If the correspondence between the assembler syntax item and the instruction encoding is more complex than simple binary encoding of an integer or register number, the item description indicates how it is encoded.

`{ }` Any item bracketed by `{` and `}` is optional. A description of the item and of how its presence or absence is encoded in the instruction is normally supplied by subsequent text.

`|` This indicates an alternative character string. For example, `LDM|STM` is either `LDM` or `STM`.

spaces Single spaces are used for clarity, to separate items. When a space is obligatory in the assembler syntax, two or more consecutive spaces are used.

`+/-` This indicates an optional + or − sign. If neither is coded, + is assumed.

`*` When used in a combination like `<immed_8> * 4`, this describes an immediate value which must be a specified multiple of a value taken from a numeric range. In this instance, the numeric range is 0 to 255 (the set of values that can be represented as an 8-bit immediate) and the specified multiple is 4, so the value described must be a multiple of 4 in the range 4*0 = 0 to 4*255 = 1020.

All other characters must be encoded precisely as they appear in the assembler syntax. Apart from `{` and `}`, the special characters described above do not appear in the basic forms of assembler instructions documented in this manual. The `{` and `}` characters need to be encoded in a few places as part of a variable item. When this happens, the long description of the variable item indicates how they must be used.

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Standard assembler syntax fields

The following assembler syntax fields are standard across all or most instructions:

`<c>` Is an optional field. It specifies the condition under which the instruction is executed. If `<c>` is omitted, it defaults to *always* (`AL`). For details see *Conditional execution* on page 3-34.

`<q>` Specifies optional assembler qualifiers on the instruction. The following qualifiers are defined:

`.N` Meaning narrow, specifies that the assembler must select a 16-bit encoding for the instruction. If this is not possible, an assembler error is produced.

`.W` Meaning wide, specifies that the assembler must select a 32-bit encoding for the instruction. If this is not possible, an assembler error is produced.

If neither `.W` nor `.N` is specified, the assembler can select either 16-bit or 32-bit encodings. If both are available, it must select a 16-bit encoding. In a few cases, more than one encoding of the same length can be available for an instruction. The rules for selecting between such encodings are instruction-specific and are part of the instruction description.

Note

When assembling to ARM, the .N qualifier will produce an assembler error and the .W qualifier has no effect, because all ARM instructions have length 32 bits.

4.1.6 Pseudo-code describing how the instruction operates

The *Operation* subsection contains encoding-independent pseudo-code that describes the main operation of the instruction. For a detailed description of the pseudo-code used and of the relationship between the encoding diagram, the encoding-specific pseudo-code and the encoding-independent pseudo-code, see Appendix A *Pseudo-code definition*.

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4.1.7 Exception information

The *Exceptions* subsection contains a list of the exceptional conditions that can be caused by execution of the instruction.

Processor exceptions are listed as follows:

- Resets and interrupts (both IRQs and FIQs) are not listed. They can occur before or after the execution of any instruction, and in some cases during the execution of an instruction, but they are not in general caused by the instruction concerned.
- Prefetch Abort exceptions are normally caused by a memory abort when an instruction is fetched, followed by an attempt to execute that instruction. This can happen for any instruction, but is caused by the aborted attempt to fetch the instruction rather than by the instruction itself, and so is not listed. A special case is the `BKPT` instruction, which is defined as causing a Prefetch Abort exception in some circumstances.
- Data Abort exceptions are listed for all instructions that perform data memory accesses.
- Undefined Instruction exceptions are listed when they are part of the effects of a defined instruction. For example, all coprocessor instructions are defined to produce the Undefined Instruction exception if not accepted by their coprocessor. Undefined Instruction exceptions caused by the execution of an UNDEFINED instruction are not listed, even when the UNDEFINED instruction is a special case of one or more of the encodings of the instruction. Such special cases are instead indicated in the encoding-specific pseudo-code for the encoding.
- Supervisor Call and Secure Monitor Call exceptions are listed for the `SVC` and `SMC` instructions respectively. Supervisor Call exceptions and the `SVC` instruction were formerly called Software Interrupt exceptions and the `SWI` instruction. Secure Monitor Call exceptions and the `SMC` instruction were formerly called Secure Monitor interrupts and the `SMI` instruction.

4.1.8 Notes

Where appropriate, additional notes about the instruction appear under further subheadings.

Note

Information that was documented in notes in previous versions of the ARM Architecture Reference Manual and its supplements has often been moved elsewhere in this supplement. For example, operand restrictions on the values of bitfields in an instruction encoding are now normally documented in the encoding-specific pseudo-code for that encoding.

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4.2 Immediate constants

Thumb data-processing instructions have a different range of immediate constants from ARM®
data-processing instructions.

The following classes of constant are available in Thumb-2:

- Any constant that can be produced by shifting an 8-bit value left by any number of bits. See *Shifted 8-bit values* for details of the encoding.
- Any replicated halfword constant of the form `0x00XY00XY`. See *Constants of the form 0x00XY00XY* for details of the encoding.
- Any replicated halfword constant of the form `0xXY00XY00`. See *Constants of the form 0xXY00XY00* for details of the encoding.
- Any replicated byte constant of the form `0xXYXYXYXY`. See *Constants of the form 0xXYXYXYXY* on page 4-9 for details of the encoding.

Constants produced by rotating an 8-bit value right by 2, 4, or 6 bits are available in ARM data-processing instructions, but not in Thumb-2.

4.2.1 Encoding

The assembler encodes the constant in an instruction into `imm12`, as described below. `imm12` is mapped into the instruction encoding in hw1[10] and hw2[14:12,7:0], in the same order.

Shifted 8-bit values

If the constant lies in the range 0-255, then `imm12` is the unmodified constant.

Otherwise, the 32-bit constant is rotated left until the most significant bit is bit[7]. The size of the left rotation is encoded in bits[11:7], overwriting bit[7]. `imm12` is bits[11:0] of the result.

For example, the constant 0x01100000 has its most significant bit at bit position 24. To rotate this bit to bit[7], a left rotation by 15 bits is required. The result of the rotation is 0b10001000. The 12-bit encoding of the constant consists of the 5-bit encoding of the rotation amount 15 followed by the bottom 7 bits of this result, and so is 0b011110001000.

Constants of the form 0x00XY00XY

Bits[11:8] of `imm12` are set to 0b0001, and bits[7:0] are set to 0xXY.

This form is UNPREDICTABLE if `bits[7:0] == 0x00`.

Constants of the form 0xXY00XY00

Bits[11:8] of `imm12` are set to 0b0010, and bits[7:0] are set to 0xXY.

This form is UNPREDICTABLE if `bits[7:0] == 0x00`.

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Constants of the form 0xXYXYXYXY

Bits[11:8] of `imm12` are set to 0b0011, and bits[7:0] are set to 0xXY.

This form is UNPREDICTABLE if `bits[7:0] == 0x00`.

4.2.2 Operation

```
// ThumbExpandImm()
// ----------------

bits(32) ThumbExpandImm(bits(12) imm12)
(imm32, -) = ThumbExpandImmWithC(imm12);
return imm12;

// ThumbExpandImmWithC()
// ---------------------

(bits(32), bit) ThumbExpandImmWithC(bits(12) imm12)

if imm12<11:10> == '00' then

    case imm12<9:8> of
        when '00'
            imm32 = ZeroExtend(imm12<7:0>, 32);
        when '01'
            if imm12<7:0> == '00000000' then UNPREDICTABLE;
            imm32 = '00000000' : imm12<7:0> : '00000000' : imm12<7:0>;
        when '10'
            if imm12<7:0> == '00000000' then UNPREDICTABLE;
            imm32 = imm12<7:0> : '00000000' : imm12<7:0> : '00000000';
        when '11'
            if imm12<7:0> == '00000000' then UNPREDICTABLE;
            imm32 = imm12<7:0> : imm12<7:0> : imm12<7:0> : imm12<7:0>;

    carry_out = APSR.C;

else

    unrotated_value = ZeroExtend('1':imm12<6:0>, 32);
    (imm32, carry_out) = ROR_C(unrotated_value, UInt(imm12<11:7>));

return (imm32, carry_out);
```


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4.3 Constant shifts applied to a register

Thumb-2 constant-shifted register operands are the same as in the ARM instruction set, except that the input bits come from different positions.

`<shift>` is an optional shift to be applied to `<Rm>`. It can be any one of:

(omitted) Equivalent to `LSL #0`.

`LSL #n` logical shift left n bits. $0 \leq n \leq 31$.

`LSR #n` logical shift right n bits. $1 \leq n \leq 32$.

`ASR #n` arithmetic shift right n bits. $1 \leq n \leq 32$.

`ROR #n` rotate right n bits. $1 \leq n \leq 31$.

`RRX` rotate right one bit, with extend. Bit[0] is written to `shifter_carry_out`, bits[31:1] are shifted right one bit, and the Carry Flag is shifted into bit[31].

4.3.1 Encoding

The assembler encodes `<shift>` into two type bits and five immediate bits, as follows:

(omitted) type = 0b00, immediate = 0.

`LSL #n` type = 0b00, immediate = n.

`LSR #n` type = 0b01.
If $n < 32$, immediate = n.
If $n == 32$, immediate = 0.

`ASR #n` type = 0b10.
If $n < 32$, immediate = n.
If $n == 32$, immediate = 0.

`ROR #n` type = 0b11, immediate = n.

`RRX` type = 0b11, immediate = 0.

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4.3.2 Shift operations

```
enumeration SRType (SRType_None, SRType_LSL, SRType_LSR,
                    SRType_ASR, SRType_ROR, SRType_RRX);

// 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);

// 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;

// Shift()
// -------
```


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```
bits(N) Shift(bits(N) value, SRType type, integer amount, bit carry_in)
(result, -) = Shift_C(value, type, amount, carry_in);
return result;

// Shift_C()
// ---------

(bits(N), bit) Shift_C(bits(N) value, SRType type, integer amount, bit
carry_in)

case type of

    when SRType_None  // Identical to SRType_LSL with amount == 0
        (result, carry_out) = (value, carry_in);

    when SRType_LSL
        if amount == 0 then
            (result, carry_out) = (value, carry_in);
        else
            (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);
```

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4.4 Memory accesses

Memory access instructions can use any of three addressing modes:

Offset addressing

The offset value is added to or subtracted from an address obtained from the base register. The result is used as the address for the memory access. The base register is unaltered.

The assembly language syntax for this mode is:

```
[<Rn>,<offset>]
```

Pre-indexed addressing

The offset value is added to or subtracted from an address obtained from the base register. The result is used as the address for the memory access, and written back into the base register.

The assembly language syntax for this mode is:

```
[<Rn>,<offset>]!
```

Post-indexed addressing

The address obtained from the base register is used, unaltered, as the address for the memory access. The offset value is added to or subtracted from the address, and written back into the base register

The assembly language syntax for this mode is:

```
[<Rn>],<offset>
```

In each case, `<Rn>` is the base register. `<offset>` can be:

- an immediate constant, such as `<imm8>` or `<imm12>`
- an index register, `<Rm>`
- a shifted index register, such as `<Rm>, LSL #<shift>`.

For information about unaligned access, endianness, and exclusive access, see:

- *Unaligned access support* on page 2-10
- *Endian support* on page 2-13
- *Memory stores and exclusive access* on page 2-14.

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4.5 Memory hints

Some load instructions with Rt == 0b1111, are memory *hints*. Memory hints allow you to provide advance information to memory systems about future memory accesses, without actually loading or storing any data.

`PLD` and `PLI` are the only memory hint instructions currently provided. For details, see:

- *PLD (immediate)* on page 4-201
- *PLD (register)* on page 4-203
- *PLI (immediate)* on page 4-205
- *PLI (register)* on page 4-207.

Other memory hints are currently unallocated. Unallocated memory hints must be implemented as `NOP`, and software must not use them.

See also *Load and store single data item, and memory hints* on page 3-26 and *Usage of 0b1111 as a register specifier in 32-bit encodings* on page 3-38.

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4.6 Alphabetical list of Thumb instructions

Every Thumb instruction is listed in this section. See *Format of instruction descriptions* on page 4-2 for details of the format used.

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4.6.1 ADC (immediate)

Add with Carry (immediate) adds an immediate value and the carry flag value to a register value, and writes the result to the destination register. It can optionally update the condition flags based on the result.

Encodings

T1

```
ADC{S}<c> <Rd>,<Rn>,#<const>
```

15 14 13 12 11	10	9	8 7 6 5	4	3 2 1 0	15	14 13 12	11 10 9 8	7 6 5 4 3 2 1 0
1 1 1 1 0	i	0	1 0 1 0	S	Rn	0	imm3	Rd	imm8

```
d = UInt(Rd);  n = UInt(Rn);  setflags = (S == '1');
imm32 = ThumbExpandImm(i:imm3:imm8);
if BadReg(d) || BadReg(n) then UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

```
ADC{S}<c><q>  {<Rd>,} <Rn>, #<const>
```

where:

`S` If present, specifies that the instruction updates the flags. Otherwise, the instruction does not update the flags.

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<Rd>` Specifies the destination register. If `<Rd>` is omitted, this register is the same as `<Rn>`.

`<Rn>` Specifies the register that contains the first operand.

`<const>` Specifies the immediate value to be added to the value obtained from `<Rn>`. See *Immediate constants* on page 4-8 for the range of allowed values.

The pre-UAL syntax `ADC<c>S` is equivalent to `ADCS<c>`.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    (result, carry, overflow) = AddWithCarry(R[n], imm32, APSR.C);
    R[d] = result;
    if setflags then
        APSR.N = result<31>;
        APSR.Z = IsZeroBit(result);
        APSR.C = carry;
        APSR.V = overflow;
```

Exceptions

None.

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4.6.2 ADC (register)

Add with Carry (register) adds a register value, the carry flag value, and an optionally-shifted register value, and writes the result to the destination register. It can optionally update the condition flags based on the result.

Encodings

T1 `ADCS <Rdn>,<Rm>` Outside IT block.

`ADC<c> <Rdn>,<Rm>` Inside IT block.

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0	1	0	0	0	0	0	1	0	1	Rm			Rdn		

```
d = UInt(Rdn);  n = UInt(Rdn);  m = UInt(Rm);  setflags = !InITBlock();
(shift_t, shift_n) = (SRType_None, 0);
```

T2 `ADC{S}<c>.W <Rd>,<Rn>,<Rm>{,<shift>}`

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	0	1	0	1	1	0	1	0	S	Rn			

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
(0)	imm3			Rd				imm2		type		Rm			

```
d = UInt(Rd);  n = UInt(Rn);  m = UInt(Rm);  setflags = (S == '1');
(shift_t, shift_n) = DecodeImmShift(type, imm3:imm2);
if BadReg(d) || BadReg(n) || BadReg(m) THEN UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set

Encoding T2 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

```
ADC{S}<c><q>  {<Rd>,} <Rn>, <Rm> {,<shift>}
```

where:

S — If present, specifies that the instruction updates the flags. Otherwise, the instruction does not update the flags.

<c><q> — See *Standard assembler syntax fields* on page 4-6.

<Rd> — Specifies the destination register. If <Rd> is omitted, this register is the same as <Rn>.

<Rn> — Specifies the register that contains the first operand.

<Rm> — Specifies the register that is optionally shifted and used as the second operand.

<shift> — Specifies the shift to apply to the value read from <Rm>. If <shift> is omitted, no shift is applied and both encodings are permitted. If <shift> is specified, only encoding T2 is permitted. The possible shifts and how they are encoded are described in *Constant shifts applied to a register* on page 4-10.

A special case is that if ADC<c> <Rd>,<Rn>,<Rd> is written with <Rd> and <Rn> both in the range R0-R7, it will be assembled using encoding T2 as though ADC<c> <Rd>,<Rn> had been written. To prevent this happening, use the .W qualifier.

The pre-UAL syntax ADC<c>S is equivalent to ADCS<c>.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    shifted = Shift(R[m], shift_t, shift_n, APSR.C);
    (result, carry, overflow) = AddWithCarry(R[n], shifted, APSR.C);
    R[d] = result;
    if setflags then
        APSR.N = result<31>;
        APSR.Z = IsZeroBit(result);
        APSR.C = carry;
        APSR.V = overflow;
```

Exceptions

None.

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4.6.3 ADD (immediate)

This instruction adds an immediate value to a register value, and writes the result to the destination register. It can optionally update the condition flags based on the result.

Encodings

T1 `ADDS <Rd>,<Rn>,#<imm3>` Outside IT block.

`ADD<c> <Rd>,<Rn>,#<imm3>` Inside IT block.

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0	0	0	1	1	1	0	imm3			Rn			Rd		

```
d = UInt(Rd);  n = UInt(Rn);  setflags = !InITBlock();
imm32 = ZeroExtend(imm3, 32);
```

T2 `ADDS <Rdn>,#<imm8>` Outside IT block.

`ADD<c> <Rdn>,#<imm8>` Inside IT block.

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0	0	1	1	0	Rdn			imm8							

```
d = UInt(Rdn);  n = UInt(Rdn);  setflags = !InITBlock();
imm32 = ZeroExtend(imm8, 32);
```

T3 `ADD{S}<c>.W <Rd>,<Rn>,#<const>`

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	1	0	i	0	1	0	0	0	S	Rn				0	imm3			Rd				imm8							

```
d = UInt(Rd);  n = UInt(Rn);  setflags = (S == '1');
imm32 = ThumbExpandImm(i:imm3:imm8);
if d == 15 && setflags then SEE CMN (immediate) on page 4-68;
if n == 13 then SEE ADD (SP plus immediate) on page 4-24;
if BadReg(d) || n == 15 then UNPREDICTABLE;
```

T4 `ADDW<c> <Rd>,<Rn>,#<imm12>`

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	1	0	i	1	0	0	0	0	0	Rn				0	imm3			Rd				imm8							

```
d = UInt(Rd);  n = UInt(Rn);  setflags = FALSE;
imm32 = ZeroExtend(i:imm3:imm8, 32);
if n == 15 then SEE ADR on page 4-28;
if n == 13 then SEE ADD (SP plus immediate) on page 4-24;
if BadReg(d) then UNPREDICTABLE;
```

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Architecture versions

Encodings T1, T2 All versions of the Thumb instruction set.

Encodings T3, T4 All versions of the Thumb instruction set from Thumb-2 onwards.

Assembler syntax

`ADD{S}<c><q> {<Rd>,} <Rn>, #<const>`	All encodings permitted
`ADDW<c><q> {<Rd>,} <Rn>, #<const>`	Only encoding T4 permitted

where:

`S` If present, specifies that the instruction updates the flags. Otherwise, the instruction does not update the flags.

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<Rd>` Specifies the destination register. If `<Rd>` is omitted, this register is the same as `<Rn>`.

`<Rn>` Specifies the register that contains the first operand. If the SP is specified for `<Rn>`, see *ADD (SP plus immediate)* on page 4-24. If the PC is specified for `<Rn>`, see *ADR* on page 4-28.

`<const>` Specifies the immediate value to be added to the value obtained from `<Rn>`. The range of allowed values is 0-7 for encoding T1, 0-255 for encoding T2 and 0-4095 for encoding T4. See *Immediate constants* on page 4-8 for the range of allowed values for encoding T3.

When multiple encodings of the same length are available for an instruction, encoding T3 is preferred to encoding T4 (if encoding T4 is required, use the `ADDW` syntax). Encoding T1 is preferred to encoding T2 if `<Rd>` is specified and encoding T2 is preferred to encoding T1 if `<Rd>` is omitted.

The pre-UAL syntax `ADD<c>S` is equivalent to `ADDS<c>`.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    (result, carry, overflow) = AddWithCarry(R[n], imm32, '0');
    R[d] = result;
    if setflags then
        APSR.N = result<31>;
        APSR.Z = IsZeroBit(result);
        APSR.C = carry;
        APSR.V = overflow;
```

Exceptions

None.

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4.6.4 ADD (register)

This instruction adds a register value and an optionally-shifted register value, and writes the result to the destination register. It can optionally update the condition flags based on the result.

Encodings

T1

ADDS <Rd>,<Rn>,<Rm>	Outside IT block.
ADD<c> <Rd>,<Rn>,<Rm>	Inside IT block.

15 14 13	12 11	10	9	8 7 6	5 4 3	2 1 0
0 0 0	1 1	0	0	Rm	Rn	Rd

```
d = UInt(Rd);  n = UInt(Rn);  m = UInt(Rm);  setflags = !InITBlock();
(shift_t, shift_n) = (SRType_None, 0);
```

T2 ADD<c> <Rdn>,<Rm>

15 14 13 12 11 10	9 8	7	6 5 4 3	2 1 0
0 1 0 0 0 1	0 0	DN	Rm	Rdn

```
d = UInt(DN:Rdn);  n = UInt(DN:Rdn);  m = UInt(Rm);  setflags = FALSE;
(shift_t, shift_n) = (SRType_None, 0);
if d == 13 || m == 13 then SEE ADD (SP plus register) on page 4-26;
```

T3 ADD{S}<c>.W <Rd>,<Rn>,<Rm>{,<shift>}

15 14 13 12 11	10 9	8 7 6 5	4	3 2 1 0	15	14 13 12	11 10 9 8	7 6	5 4	3 2 1 0
1 1 1 0 1	0 1	1 0 0 0	S	Rn	(0)	imm3	Rd	imm2	type	Rm

```
d = UInt(Rd);  n = UInt(Rn);  m = UInt(Rm);  setflags = (S == '1');
(shift_t, shift_n) = DecodeImmShift(type, imm3:imm2);
if d == 15 && setflags then SEE CMN (register) on page 4-70;
if n == 13 then SEE ADD (SP plus register) on page 4-26;
if BadReg(d) || n == 15 || BadReg(m) then UNPREDICTABLE;
```

Architecture versions

Encodings T1, T2 All versions of the Thumb instruction set. Before Thumb-2, encoding T2 required that either <Rdn>, or <Rm>, or both, had to be from {R8-R12, LR, PC}.

Encoding T3 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

```
ADD{S}<c><q>  {<Rd>,} <Rn>, <Rm> {,<shift>}
```

where:

`S` If present, specifies that the instruction updates the flags. Otherwise, the instruction does not update the flags.

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<Rd>` Specifies the destination register. If `<Rd>` is omitted, this register is the same as `<Rn>` and encoding T2 is preferred to encoding T1 if both are available (this can only happen inside an IT block). If `<Rd>` is specified, encoding T1 is preferred to encoding T2.

`<Rn>` Specifies the register that contains the first operand. If the SP is specified for `<Rn>`, see *ADD (SP plus register)* on page 4-26.

`<Rm>` Specifies the register that is optionally shifted and used as the second operand.

`<shift>` Specifies the shift to apply to the value read from `<Rm>`. If `<shift>` is omitted, no shift is applied and all encodings are permitted. If `<shift>` is specified, only encoding T3 is permitted. The possible shifts and how they are encoded are described in *Constant shifts applied to a register* on page 4-10.

A special case is that if `ADD<c> <Rd>,<Rn>,<Rd>` is written and cannot be encoded using encoding T1, it is assembled using encoding T2 as though `ADD<c> <Rd>,<Rn>` had been written. To prevent this happening, use the `.W` qualifier.

The pre-UAL syntax `ADD<c>S` is equivalent to `ADDS<c>`.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    shifted = Shift(R[m], shift_t, shift_n, APSR.C);
    (result, carry, overflow) = AddWithCarry(R[n], shifted, '0');
    if d == 15 then
        ALUWritePC(result);  // setflags is always FALSE here
    else
        R[d] = result;
        if setflags then
            APSR.N = result<31>;
            APSR.Z = IsZeroBit(result);
            APSR.C = carry;
            APSR.V = overflow;
```

Exceptions

None.

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4.6.5 ADD (SP plus immediate)

This instruction adds an immediate value to the SP value, and writes the result to the destination register.

Encodings

T1 ADD<c> <Rd>,SP,#<imm>

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	0	1	0	1	Rd			imm8							

```
d = UInt(Rd);  setflags = FALSE;  imm32 = ZeroExtend(imm8:'00', 32);
```

T2 ADD<c> SP,SP,#<imm>

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	0	1	1	0	0	0	0	0	imm7						

```
d = 13;  setflags = FALSE;  imm32 = ZeroExtend(imm7:'00', 32);
```

T3 ADD{S}<c>.W <Rd>,SP,#<const>

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	1	0	i	0	1	0	0	0	S	1	1	0	1	0	imm3			Rd				imm8							

```
d = UInt(Rd);  setflags = (S == '1');
imm32 = ThumbExpandImm(i:imm3:imm8);
if d == 15 && setflags then SEE CMN (immediate) on page 4-68;
if d == 15 then UNPREDICTABLE;
```

T4 ADDW<c> <Rd>,SP,#<imm>

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	1	0	i	1	0	0	0	0	0	1	1	0	1	0	imm3			Rd				imm8							

```
d = UInt(Rd);  setflags = FALSE;  imm32 = ZeroExtend(i:imm3:imm8, 32);
if d == 15 then UNPREDICTABLE;
```

Architecture versions

Encodings T1, T2 All versions of the Thumb instruction set.

Encodings T3, T4 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

`ADD{S}<c><q> {<Rd>,} SP, #<const>`	All encodings permitted
`ADDW<c><q> {<Rd>,} SP, #<const>`	Only encoding T4 is permitted

where:

`S` If present, specifies that the instruction updates the flags. Otherwise, the instruction does not update the flags.

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<Rd>` Specifies the destination register. If `<Rd>` is omitted, this register is SP.

`<const>` Specifies the immediate value to be added to the value obtained from `<Rn>`. Allowed values are multiples of 4 in the range 0-1020 for encoding T1, multiples of 4 in the range 0-508 for encoding T2 and any value in the range 0-4095 for encoding T4. See *Immediate constants* on page 4-8 for the range of allowed values for encoding T3.

When both 32-bit encodings are available for an instruction, encoding T3 is preferred to encoding T4 (if encoding T4 is required, use the `ADDW` syntax).

The pre-UAL syntax `ADD<c>S` is equivalent to `ADDS<c>`.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    (result, carry, overflow) = AddWithCarry(SP, imm32, '0');
    R[d] = result;
    if setflags then
        APSR.N = result<31>;
        APSR.Z = IsZeroBit(result);
        APSR.C = carry;
        APSR.V = overflow;
```

Exceptions

None.

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4.6.6 ADD (SP plus register)

This instruction adds an optionally-shifted register value to the SP value, and writes the result to the destination register.

Encodings

T1 `ADD<c> <Rdm>, SP, <Rdm>`

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0	1	0	0	0	1	0	0	DM	1	1	0	1	Rdm		

```
d = UInt(DM:Rdm);  m = UInt(DM:Rdm);  setflags = FALSE;
(shift_t, shift_n) = (SRType_None, 0);
```

T2 `ADD<c> SP,<Rm>`

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0	1	0	0	0	1	0	0	1	Rm				1	0	1

```
d = 13;  m = UInt(Rm);  setflags = FALSE;
(shift_t, shift_n) = (SRType_None, 0);
if m == 13 then SEE encoding T1
```

T3 `ADD{S}<c>.W <Rd>,SP,<Rm>{,<shift>}`

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	0	1	0	1	1	0	0	0	S	1	1	0	1	0	imm3			Rd				imm2		type		Rm			

```
d = UInt(Rd);  m = UInt(Rm);  setflags = (S == '1');
(shift_t, shift_n) = DecodeImmShift(type, imm3:imm2);
if d == 15 || BadReg(m) then UNPREDICTABLE;
```

Architecture versions

Encodings T1, T2 All versions of the Thumb instruction set.

Encoding T3 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

```
ADD{S}<c><q>  {<Rd>,} SP, <Rm>{, <shift>}
```

where:

`S`	If present, specifies that the instruction updates the flags. Otherwise, the instruction does not update the flags.
`<c><q>`	See *Standard assembler syntax fields* on page 4-6.
`<Rd>`	Specifies the destination register. If `<Rd>` is omitted, this register is SP.
`<Rm>`	Specifies the register that is optionally shifted and used as the second operand.
`<shift>`	Specifies the shift to apply to the value read from `<Rm>`. If `<shift>` is omitted, no shift is applied and all encodings are permitted. If `<shift>` is specified, only encoding T3 is permitted. The possible shifts and how they are encoded are described in *Constant shifts applied to a register* on page 4-10.

The pre-UAL syntax `ADD<c>S` is equivalent to `ADDS<c>`.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    shifted = Shift(R[m], shift_t, shift_n, APSR.C);
    (result, carry, overflow) = AddWithCarry(SP, shifted, '0');
    R[d] = result;
    if setflags then
        APSR.N = result<31>;
        APSR.Z = IsZeroBit(result);
        APSR.C = carry;
        APSR.V = overflow;
```

Exceptions

None.

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4.6.7 ADR

Address to Register adds an immediate value to the PC value, and writes the result to the destination register.

Encodings

T1 `ADR<c> <Rd>,<label>`

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	0	1	0	0	Rd			imm8							

```
d = UInt(Rd);  imm32 = ZeroExtend(imm8:'00', 32);  add = TRUE;
```

T2 `ADR<c>.W <Rd>,<label>` <label> before current instruction

`SUB <Rd>,PC,#0` Special case for zero offset

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	1	0	i	1	0	1	0	1	0	1	1	1	1	0	imm3			Rd				imm8							

```
d = UInt(Rd);  imm32 = ZeroExtend(i:imm3:imm8, 32);  add = FALSE;
if BadReg(d) then UNPREDICTABLE;
```

T3 `ADR<c>.W <Rd>,<label>` <label> after current instruction

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	1	0	i	1	0	0	0	0	0	1	1	1	1	0	imm3			Rd				imm8							

```
d = UInt(Rd);  imm32 = ZeroExtend(i:imm3:imm8, 32);  add = TRUE;
if BadReg(d) then UNPREDICTABLE;
```

Architecture versions

Encodings T1 All versions of the Thumb instruction set.

Encodings T2, T3 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

`ADR<c><q> <Rd>, <label>`	Normal syntax
`ADD<c><q> <Rd>, PC, #<const>`	Alternative for encodings T1, T3
`SUB<c><q> <Rd>, PC, #<const>`	Alternative for encoding T2

where:

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<Rd>` Specifies the destination register.

`<label>` Specifies the label of an instruction or literal data item whose address is to be loaded into `<Rd>`. The assembler calculates the required value of the offset from the `Align(PC,4)` value of the `ADR` instruction to this label.

If the offset is positive, encodings T1 and T3 are permitted with `imm32` equal to the offset. Allowed values of the offset are multiples of four in the range 0 to 1020 for encoding T1 and any value in the range 0 to 4095 for encoding T3.

If the offset is negative, encoding T2 is permitted with `imm32` equal to minus the offset. Allowed values of the offset are -4095 to -1.

In the alternative syntax forms:

`<const>` Specifies the offset value for the `ADD` form and minus the offset value for the `SUB` form. Allowed values are multiples of four in the range 0 to 1020 for encoding T1 and any value in the range 0 to 4095 for encodings T2 and T3.

Note

It is recommended that the alternative syntax forms are avoided where possible. However, the only possible syntax for encoding T2 with all immediate bits zero is `SUB<c><q> <Rd>,PC,#0`.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    base = Align(PC, 4);      // Word-aligned PC
    R[d] = if add then (base + imm32) else (base - imm32);
```

Exceptions

None.

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4.6.8 AND (immediate)

This instruction performs a bitwise AND of a register value and an immediate value, and writes the result to the destination register.

Encodings

T1

```
AND{S}<c> <Rd>,<Rn>,#<const>
```

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	1	0	i	0	0	0	0	0	S	Rn				0	imm3			Rd				imm8							

```
d = UInt(Rd);  n = UInt(Rn);  setflags = (S == '1');
(imm32, carry) = ThumbExpandImmWithC(i:imm3:imm8, APSR.C);
if d == 15 && setflags then SEE TST (immediate) on page 4-397;
if BadReg(d) || BadReg(n) then UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

`AND{S}<c><q>  {<Rd>,} <Rn>, #<const>`

where:

`S`	If present, specifies that the instruction updates the flags. Otherwise, the instruction does not update the flags.
`<c><q>`	See *Standard assembler syntax fields* on page 4-6.
`<Rd>`	Specifies the destination register. If `<Rd>` is omitted, this register is the same as `<Rn>`.
`<Rn>`	Specifies the register that contains the first operand.
`<const>`	Specifies the immediate value to be added to the value obtained from `<Rn>`. See *Immediate constants* on page 4-8 for the range of allowed values.

The pre-UAL syntax `AND<c>S` is equivalent to `ANDS<c>`.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    result = R[n] AND imm32;
    R[d] = result;
    if setflags then
        APSR.N = result<31>;
        APSR.Z = IsZeroBit(result);
        APSR.C = carry;
        // APSR.V unchanged
```

Exceptions

None.

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4.6.9 AND (register)

This instruction performs a bitwise AND of a register value and an optionally-shifted register value, and writes the result to the destination register. It can optionally update the condition flags based on the result.

Encodings

T1 `ANDS <Rdn>,<Rm>` Outside IT block.

`AND<c> <Rdn>,<Rm>` Inside IT block.

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0	1	0	0	0	0	0	0	0	0	Rm			Rdn		

```
d = UInt(Rdn);  n = UInt(Rdn);  m = UInt(Rm);  setflags = !InITBlock();
(shift_t, shift_n) = (SRType_None, 0);
```

T2 `AND{S}<c>.W <Rd>,<Rn>,<Rm>{,<shift>}`

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	0	1	0	1	0	0	0	0	S	Rn				(0)	imm3			Rd				imm2		type		Rm			

```
d = UInt(Rd);  n = UInt(Rn);  m = UInt(Rm);  setflags = (S == '1');
(shift_t, shift_n) = DecodeImmShift(type, imm3:imm2);
if d == 15 && setflags then SEE TST (register) on page 4-399;
if BadReg(d) || BadReg(n) || BadReg(m) THEN UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set

Encoding T2 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

```
AND{S}<c><q>  {<Rd>,} <Rn>, <Rm> {,<shift>}
```

where:

S — If present, specifies that the instruction updates the flags. Otherwise, the instruction does not update the flags.

<c><q> — See *Standard assembler syntax fields* on page 4-6.

<Rd> — Specifies the destination register. If <Rd> is omitted, this register is the same as <Rn>.

<Rn> — Specifies the register that contains the first operand.

<Rm> — Specifies the register that is optionally shifted and used as the second operand.

<shift> — Specifies the shift to apply to the value read from <Rm>. If <shift> is omitted, no shift is applied and both encodings are permitted. If <shift> is specified, only encoding T2 is permitted. The possible shifts and how they are encoded are described in *Constant shifts applied to a register* on page 4-10.

A special case is that if AND<c> <Rd>,<Rn>,<Rd> is written with <Rd> and <Rn> both in the range R0-R7, it will be assembled using encoding T2 as though AND<c> <Rd>,<Rn> had been written. To prevent this happening, use the .W qualifier.

The pre-UAL syntax AND<c>S is equivalent to ANDS<c>.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    (shifted, carry) = Shift_C(R[m], shift_t, shift_n, APSR.C);
    result = R[n] AND shifted;
    R[d] = result;
    if setflags then
        APSR.N = result<31>;
        APSR.Z = IsZeroBit(result);
        APSR.C = carry;
        // APSR.V unchanged
```

Exceptions

None.

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4.6.10 ASR (immediate)

Arithmetic Shift Right (immediate) shifts a register value right by an immediate number of bits, shifting in copies of its sign bit, and writes the result to the destination register. It can optionally update the condition flags based on the result.

Encodings

T1 `ASRS <Rd>,<Rm>,#<imm5>` Outside IT block.

`ASR<c> <Rd>,<Rm>,#<imm5>` Inside IT block.

15	14	13	12	11	10 9 8 7 6	5 4 3	2 1 0
0	0	0	1	0	imm5	Rm	Rd

```
d = UInt(Rd);  m = UInt(Rm);  setflags = !InITBlock();
(-, shift_n) = DecodeImmShift('10', imm5);
```

T2 `ASR{S}<c>.W <Rd>,<Rm>,#<imm5>`

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	15	14 13 12	11 10 9 8	7 6	5	4	3 2 1 0
1	1	1	0	1	0	1	0	0	1	0	S	1	1	1	1	(0)	imm3	Rd	imm2	1	0	Rm

```
d = UInt(Rd);  m = UInt(Rm);  setflags = (S == '1');
(-, shift_n) = DecodeImmShift('10', imm3:imm2);
if BadReg(d) || BadReg(m) THEN UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set.

Encoding T2 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

`ASR{S}<c><q>  <Rd>, <Rm>, #<imm5>`

where:

`S` If present, specifies that the instruction updates the flags. Otherwise, the instruction does not update the flags.

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<Rd>` Specifies the destination register.

`<Rm>` Specifies the register that contains the first operand.

`<imm5>` Specifies the shift amount, in the range 1 to 32. See *Constant shifts applied to a register* on page 4-10.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    (result, carry) = Shift_C(R[m], SRType_ASR, shift_n, APSR.C);
    R[d] = result;
    if setflags then
        APSR.N = result<31>;
        APSR.Z = IsZeroBit(result);
        APSR.C = carry;
        // APSR.V unchanged
```

Exceptions

None.

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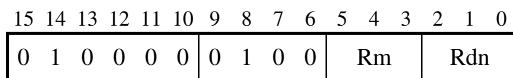
4.6.11 ASR (register)

Arithmetic Shift Right (register) shifts a register value right by a variable number of bits, shifting in copies of its sign bit, and writes the result to the destination register. The variable number of bits is read from the bottom byte of a register. It can optionally update the condition flags based on the result.

Encodings

T1 ASRS <Rdn>,<Rm> Outside IT block.

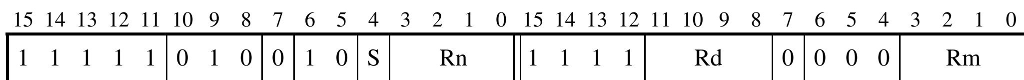
ASR<c> <Rdn>,<Rm> Inside IT block.



15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0	1	0	0	0	0	0	1	0	0	Rm			Rdn		

```
d = UInt(Rdn);  n = UInt(Rdn);  m = UInt(Rm);  setflags = !InITBlock();
```

T2 ASR{S}<c>.W <Rd>,<Rn>,<Rm>



15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	1	1	0	1	0	0	1	0	S	Rn				1	1	1	1	Rd				0	0	0	0	Rm			

```
d = UInt(Rd);  n = UInt(Rn);  m = UInt(Rm);  setflags = (S == '1');
if BadReg(d) || BadReg(n) || BadReg(m) then UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set

Encoding T2 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

`ASR{S}<c><q>  <Rd>, <Rn>, <Rm>`

where:

`S` If present, specifies that the instruction updates the flags. Otherwise, the instruction does not update the flags.

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<Rd>` Specifies the destination register.

`<Rn>` Specifies the register that contains the first operand.

`<Rm>` Specifies the register whose bottom byte contains the amount to shift by.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    shift_n = UInt(R[m]<7:0>);
    (result, carry) = Shift_C(R[n], SRType_ASR, shift_n, APSR.C);
    R[d] = result;
    if setflags then
        APSR.N = result<31>;
        APSR.Z = IsZeroBit(result);
        APSR.C = carry;
        // APSR.V unchanged
```

Exceptions

None.

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4.6.12 B

Branch causes a branch to a target address.

Encodings

T1 B<c> <label> Not allowed in IT block.

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	0	1	cond				imm8							

```
imm32 = SignExtend(imm8:'0', 32);
if cond == '1110' then SEE Permanently undefined space on page 3-36;
if cond == '1111' then SEE SVC (formerly SWI) on page 4-375;
if InITBlock() then UNPREDICTABLE;
```

T2 B<c> <label> Outside or last in IT block

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	0	0	imm11										

```
imm32 = SignExtend(imm11:'0', 32);
if InITBlock() && !LastInITBlock() then UNPREDICTABLE;
```

T3 B<c>.W <label> Not allowed in IT block.

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	1	0	S	cond				imm6						1	0	J1	0	J2	imm11										

```
imm32 = SignExtend(S:J2:J1:imm6:imm11:'0', 32);
if cond<3:1> == '111' then
    SEE Branches, miscellaneous control instructions on page 3-31;
if InITBlock() then UNPREDICTABLE;
```

T4 B<c>.W <label> Outside or last in IT block

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	1	0	S	imm10										1	0	J1	1	J2	imm11										

```
I1 = NOT(J1 EOR S);  I2 = NOT(J2 EOR S);
imm32 = SignExtend(S:I1:I2:imm10:imm11:'0', 32);
if InITBlock() && !LastInITBlock() then UNPREDICTABLE;
```

Architecture versions

Encodings T1, T2 All versions of the Thumb instruction set

Encodings T3, T4 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

```
B<c><q>  <label>
```

where:

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

Note

Encodings T1 and T3 are conditional in their own right, and do not require an `IT` instruction to make them conditional.

For encodings T1 and T3, `<c>` is not allowed to be `AL` or omitted. The 4-bit encoding of the condition is placed in the instruction and not in a preceding `IT` instruction, and the instruction is not allowed to be in an IT block. As a result, encodings T1 and T2 are never both available to the assembler, nor are encodings T3 and T4.

`<label>` Specifies the label of the instruction that is to be branched to. The assembler calculates the required value of the offset from the PC value of the `B` instruction to this label, then selects an encoding that will set `imm32` to that offset.

Allowed offsets are even numbers in the range -256 to 254 for encoding T1, -2048 to 2046 for encoding T2, -1048576 to 1048574 for encoding T3, and -16777216 to 16777214 for encoding T4.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    BranchWritePC(PC + imm32);
```

Exceptions

None.

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4.6.13 BFC

Bit Field Clear clears any number of adjacent bits at any position in a register, without affecting the other bits in the register.

Encodings

T1 BFC<c> <Rd>,#<lsb>,#<width>

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	1	0	(0)	1	1	0	1	1	0	1	1	1	1	0	imm3			Rd				imm2		(0)	msb				

```
d = UInt(Rd);  msbit = UInt(msb);  lsbit = UInt(imm3:imm2);
if BadReg(d) then UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

```
BFC<c><q>  <Rd>, #<lsb>, #<width>
```

where:

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<Rd>` Specifies the destination register.

`<lsb>` Specifies the least significant bit that is to be cleared, in the range 0 to 31. This determines the required value of `lsbit`.

`<width>` Specifies the number of bits to be cleared, in the range 1 to 32-`<lsb>`. The required value of `msbit` is `<lsb>+<width>-1`.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    if msbit >= lsbit then
        R[d]<msbit:lsbit> = Replicate('0', msbit-lsbit+1);
        // Other bits of R[d] are unchanged
    else
        UNPREDICTABLE;
```

Exceptions

None.

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4.6.14 BFI

Bit Field Insert copies any number of low order bits from a register into the same number of adjacent bits at any position in the destination register.

Encodings

T1 `BFI<c> <Rd>,<Rn>,#<lsb>,#<width>`

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	1	0	(0)	1	1	0	1	1	0	Rn				0	imm3			Rd				imm2		(0)	msb				

```
d = UInt(Rd);  n = UInt(Rn);  msbit = UInt(msb);  lsbit = UInt(imm3:imm2);
if n == 15 then SEE BFC on page 4-40;
if BadReg(d) || n == 13 then UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

```
BFI<c><q>  <Rd>, <Rn>, #<lsb>, #<width>
```

where:

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<Rd>` Specifies the destination register.

`<Rn>` Specifies the source register.

`<lsb>` Specifies the least significant destination bit.

`<width>` Specifies the number of bits to be copied.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    if msbit >= lsbit then
        R[d]<msbit:lsbit> = R[n]<(msbit-lsbit):0>;
        // Other bits of R[d] are unchanged
    else
        UNPREDICTABLE;
```

Exceptions

None.

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4.6.15 BIC (immediate)

Bit Clear (immediate) performs a bitwise AND of a register value and the complement of an immediate value, and writes the result to the destination register. It can optionally update the condition flags based on the result.

Encodings

T1 BIC{S}<c> <Rd>,<Rn>,#<const>

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	1	0	i	0	0	0	0	1	S	Rn				0	imm3			Rd				imm8							

```
d = UInt(Rd);  n = UInt(Rn);  setflags = (S == '1');
(imm32, carry) = ThumbExpandImmWithC(i:imm3:imm8, APSR.C);
if BadReg(d) || BadReg(n) then UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

```
BIC{S}<c><q>  {<Rd>,} <Rn>, #<const>
```

where:

`S` If present, specifies that the instruction updates the flags. Otherwise, the instruction does not update the flags.

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<Rd>` Specifies the destination register. If `<Rd>` is omitted, this register is the same as `<Rn>`.

`<Rn>` Specifies the register that contains the operand.

`<const>` Specifies the immediate value to be added to the value obtained from `<Rn>`. See *Immediate constants* on page 4-8 for the range of allowed values.

The pre-UAL syntax `BIC<c>S` is equivalent to `BICS<c>`.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    result = R[n] AND NOT(imm32);
    R[d] = result;
    if setflags then
        APSR.N = result<31>;
        APSR.Z = IsZeroBit(result);
        APSR.C = carry;
        // APSR.V unchanged
```

Exceptions

None.

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4.6.16 BIC (register)

Bit Clear (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. It can optionally update the condition flags based on the result.

Encodings

T1 `BICS <Rdn>,<Rm>` Outside IT block.

`BIC<c> <Rdn>,<Rm>` Inside IT block.

15	14	13	12	11	10	9	8	7	6	5 4 3	2 1 0
0	1	0	0	0	0	1	1	1	0	Rm	Rdn

```
d = UInt(Rdn);  n = UInt(Rdn);  m = UInt(Rm);  setflags = !InITBlock();
(shift_t, shift_n) = (SRType_None, 0);
```

T2 `BIC{S}<c>.W <Rd>,<Rn>,<Rm>{,<shift>}`

15	14	13	12	11	10	9	8	7	6	5	4	3 2 1 0	15	14 13 12	11 10 9 8	7 6	5 4	3 2 1 0
1	1	1	0	1	0	1	0	0	0	1	S	Rn	(0)	imm3	Rd	imm2	type	Rm

```
d = UInt(Rd);  n = UInt(Rn);  m = UInt(Rm);  setflags = (S == '1');
(shift_t, shift_n) = DecodeImmShift(type, imm3:imm2);
if BadReg(d) || BadReg(n) || BadReg(m) THEN UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set

Encoding T2 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

```
BIC{S}<c><q>  {<Rd>,} <Rn>, <Rm> {,<shift>}
```

where:

`S` If present, specifies that the instruction updates the flags. Otherwise, the instruction does not update the flags.

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<Rd>` Specifies the destination register. If `<Rd>` is omitted, this register is the same as `<Rn>`.

`<Rn>` Specifies the register that contains the first operand.

`<Rm>` Specifies the register that is optionally shifted and used as the second operand.

`<shift>` Specifies the shift to apply to the value read from `<Rm>`. If `<shift>` is omitted, no shift is applied and both encodings are permitted. If `<shift>` is specified, only encoding T2 is permitted. The possible shifts and how they are encoded are described in *Constant shifts applied to a register* on page 4-10.

The pre-UAL syntax `BIC<c>S` is equivalent to `BICS<c>`.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    (shifted, carry) = Shift_C(R[m], shift_t, shift_n, APSR.C);
    result = R[n] AND NOT(shifted);
    R[d] = result;
    if setflags then
        APSR.N = result<31>;
        APSR.Z = IsZeroBit(result);
        APSR.C = carry;
        // APSR.V unchanged
```

Exceptions

None.

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4.6.17 BKPT

Breakpoint causes a software breakpoint to occur.

Encodings

T1 `BKPT #<imm8>`

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	0	1	1	1	1	1	0	imm8							

```
imm32 = ZeroExtend(imm8, 32);
// imm32 is for assembly/disassembly only and is ignored by hardware.
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set from v5 onwards.

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Assembler syntax

```
BKPT<q>  #<imm8>
```

where:

<q> See *Standard assembler syntax fields* on page 4-6.

<imm8> Specifies an 8-bit value that is stored in the instruction. This value is ignored by the ARM hardware, but can be used by a debugger to store additional information about the breakpoint.

Operation

```
EncodingSpecificOperations();
Breakpoint();
```

Exceptions

Prefetch Abort.

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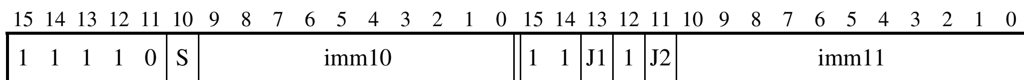
4.6.18 BL, BLX (immediate)

Branch with Link (immediate) calls a subroutine at a PC-relative address.

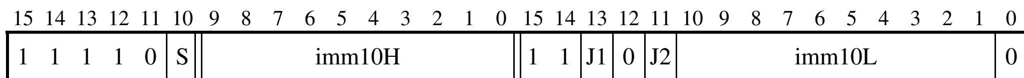
Encodings

T1 BL<c> <label> Outside or last in IT block




```
I1 = NOT(J1 EOR S);  I2 = NOT(J2 EOR S);
imm32 = SignExtend(S:I1:I2:imm10:imm11:'0', 32);
toARM = FALSE;
if InITBlock() && !LastInITBlock() then UNPREDICTABLE;
```

T2 BLX<c> <label> Outside or last in IT block




```
I1 = NOT(J1 EOR S);  I2 = NOT(J2 EOR S);
imm32 = SignExtend(S:I1:I2:imm10H:imm10L:'00', 32);
toARM = TRUE;
if InITBlock() && !LastInITBlock() then UNPREDICTABLE;
```

Architecture versions

Encodings T1, T2 All versions of the Thumb instruction set.

Before Thumb-2, J1 and J2 were both 1, resulting in a smaller branch range. The instructions could be executed as two separate 16-bit instructions, with the first instruction instr1 setting LR to PC + SignExtend(instr1<10:0>:'00000000000', 32) and the second instruction completing the operation. This is no longer possible in Thumb-2.

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Assembler syntax

```
BL{X}<c><q>  <label>
```

where:

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`X` If present, specifies a change to the ARM instruction set. If X is omitted, the processor remains in Thumb state.

`<label>` Specifies the label of the instruction that is to be branched to.

For `BL` (encoding T1), the assembler calculates the required value of the offset from the PC value of the `BL` instruction to this label, then selects an encoding that will set `imm32` to that offset. Allowed offsets are even numbers in the range -16777216 to 16777214.

For `BLX` (encoding T2), the assembler calculates the required value of the offset from the `Align(PC,4)` value of the `BLX` instruction to this label, then selects an encoding that will set `imm32` to that offset. Allowed offsets are multiples of 4 in the range -16777216 to 16777212.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    next_instr_addr = PC;
    LR = next_instr_addr<31:1> : '1';
    if toARM then
        SelectInstrSet(InstrSet_ARM);
        BranchWritePC(Align(PC,4) + imm32);
    else
        SelectInstrSet(InstrSet_Thumb);
        BranchWritePC(PC + imm32);
```

Exceptions

None.

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4.6.19 BLX (register)

Branch and Exchange calls a subroutine at an address and instruction set specified by a register.

Encodings

T1 `BLX<c> <Rm>` Outside or last in IT block

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0	1	0	0	0	1	1	1	1	Rm				(0)	(0)	(0)

```
m = UInt(Rm);
if m == 15 then UNPREDICTABLE;
if InITBlock() && !LastInITBlock() then UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set from v5 onwards.

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Assembler syntax

```
BLX<c><q>  <Rm>
```

where:

<c><q> See *Standard assembler syntax fields* on page 4-6.

<Rm> Specifies the register that contains the branch target address and instruction set selection bit.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    next_instr_addr = PC - 2;
    LR = next_instr_addr<31:1> : '1';
    BXWritePC(R[m]);
```

Exceptions

None.

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4.6.20 BX

Branch and Exchange causes a branch to an address and instruction set specified by a register.

Encodings

T1 `BX<c> <Rm>` Outside or last in IT block

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0	1	0	0	0	1	1	1	0	Rm				(0)	(0)	(0)

```
m = UInt(Rm);
if InITBlock() && !LastInITBlock() then UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set.

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Assembler syntax

```
BX<c><q>  <Rm>
```

where:

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<Rm>` Specifies the register that contains the branch target address and instruction set selection bit.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    BXWritePC(R[m]);
```

Exceptions

None.

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4.6.21 BXJ

Branch and Exchange Jazelle attempts to change to Jazelle state. If the attempt fails, it branches to an address and instruction set specified by a register as though it were a `BX` instruction.

Encodings

T1 `BXJ<c> <Rm>` Outside or last in IT block

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	1	0	0	1	1	1	1	0	0	Rm				1	0	(0)	0	(1)	(1)	(1)	(1)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)

```
m = UInt(Rm);
if BadReg(m) then UNPREDICTABLE;
if InITBlock() && !LastInITBlock() then UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

```
BXJ<c><q>  <Rm>
```

where:

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<Rm>` Specifies the register that specifies the branch target address and instruction set selection bit to be used if the attempt to switch to Jazelle state fails.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    if JazelleAcceptsExecution() then
        SwitchToJazelleExecution();
    else
        BXWritePC(R[m]);
```

Exceptions

None.

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4.6.22 CBNZ

Compare and Branch on Non-Zero compares the value in a register with zero, and conditionally branches forward a constant value. It does not affect the condition flags.

Encodings

T1 `CBNZ <Rn>,<label>` Not allowed in IT block.

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	0	1	1	1	0	i	1	imm5					Rn		

```
n = UInt(Rn);  imm32 = ZeroExtend(i:imm5:'0', 32);
if InITBlock() then UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

```
CBNZ<q>  <Rn>, <label>
```

where:

`<q>` See *Standard assembler syntax fields* on page 4-6.

`<Rn>` Specifies the register that contains the first operand.

`<label>` Specifies the label of the instruction that is to be branched to. The assembler calculates the required value of the offset from the PC value of the `CBNZ` instruction to this label, then selects an encoding that will set `imm32` to that offset. Allowed offsets are even numbers in the range 0 to 126.

Operation

```
EncodingSpecificOperations();
if IsZeroBit(R[n]) == '0' then
    BranchWritePC(PC + imm32);
```

Exceptions

None.

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4.6.23 CBZ

Compare and Branch on Zero compares the value in a register with zero, and conditionally branches forward a constant value. It does not affect the condition flags.

Encodings

T1 `CBZ <Rn>,<label>` Not allowed in IT block.

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	0	1	1	0	0	i	1	imm5					Rn		

```
n = UInt(Rn);  imm32 = ZeroExtend(i:imm5:'0', 32);
if InITBlock() then UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

```
CBZ<q>  <Rn>, <label>
```

where:

<q> See *Standard assembler syntax fields* on page 4-6.

<Rn> Specifies the register that contains the first operand.

<label> Specifies the label of the instruction that is to be branched to. The assembler calculates the required value of the offset from the PC value of the `CBZ` instruction to this label, then selects an encoding that will set `imm32` to that offset. Allowed offsets are even numbers in the range 0 to 126.

Operation

```
EncodingSpecificOperations();
if IsZeroBit(R[n]) == '1' then
    BranchWritePC(PC + imm32);
```

Exceptions

None.

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4.6.24 CDP, CDP2

Coprocessor Data Processing tells a coprocessor to perform an operation that is independent of ARM registers and memory.

If no coprocessor can execute the instruction, an Undefined Instruction exception is generated.

Encodings

T1 `CDP<c> <coproc>,<opc1>,<CRd>,<CRn>,<CRm>,<opc2>`

15	14	13	12	11	10	9	8	7 6 5 4	3 2 1 0	15 14 13 12	11 10 9 8	7 6 5	4	3 2 1 0
1	1	1	C	1	1	1	0	opc1	CRn	CRd	coproc	opc2	0	CRm

```
cp = UInt(coproc);  opc0 = C;  // CDP if C == '0', CDP2 if C == '1'
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

```
CDP{2}<c><q>  <coproc>, #<opc1>, <CRd>, <CRn>, <CRm> {,#<opc2>}
```

where:

`2`	If specified, selects the C == 1 form of the encoding. If omitted, selects the C == 0 form.
`<c><q>`	See *Standard assembler syntax fields* on page 4-6.
`<coproc>`	Specifies the name of the coprocessor, and causes the corresponding coprocessor number to be placed in the cp_num field of the instruction. The standard generic coprocessor names are p0, p1, ..., p15.
`<opc1>`	Is a coprocessor-specific opcode, in the range 0 to 15.
`<CRd>`	Specifies the destination coprocessor register for the instruction.
`<CRn>`	Specifies the coprocessor register that contains the first operand.
`<CRm>`	Specifies the coprocessor register that contains the second operand.
`<opc2>`	Is a coprocessor-specific opcode in the range 0 to 7. If it is omitted, `<opc2>` is assumed to be 0.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    if !Coproc_Accepted(cp, ThisInstr()) then
        RaiseCoprocessorException();
    else
        Coproc_InternalOperation(cp, ThisInstr());
```

Exceptions

Undefined Instruction.

Notes

Coprocessor fields Only instruction bits[31:24], bits[11:8], and bit[4] are architecturally defined. The remaining fields are recommendations.

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4.6.25 CLREX

Clear Exclusive clears the local record of the executing processor that an address has had a request for an exclusive access.

Encodings

T1 `CLREX<c>`

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	1	0	0	1	1	1	0	1	1	(1)	(1)	(1)	(1)	1	0	(0)	0	(1)	(1)	(1)	(1)	0	0	1	0	(1)	(1)	(1)	(1)

```
// Do nothing
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set from v6K onwards.

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Assembler syntax

```
CLREX<c><q>
```

where:

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    ClearExclusiveMonitors();
```

Exceptions

None.

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4.6.26 CLZ

Count Leading Zeros returns the number of binary zero bits before the first binary one bit in a value.

Encoding

T1 `CLZ<c> <Rd>,<Rm>`

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	1	1	0	1	0	1	0	1	1	Rm2				1	1	1	1	Rd				1	0	0	0	Rm			

```
d = UInt(Rd);  m = UInt(Rm);  m2 = UInt(Rm2);
if BadReg(d) || BadReg(m) || m2 != m then UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

```
CLZ<c><q>  <Rd>, <Rm>
```

where:

`<c><q>`	See *Standard assembler syntax fields* on page 4-6.
`<Rd>`	Specifies the destination register.
`<Rm>`	Specifies the register that contains the operand. Its number must be encoded twice in encoding T1, in both the `Rm` and `Rm2` fields.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    result = 31 - HighestSetBit(R[m]);  // = 32 if R[m] is zero
    R[d] = result<31:0>;
```

Exceptions

None.

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4.6.27 CMN (immediate)

Compare Negative (immediate) adds a register value and an immediate value. It updates the condition flags based on the result, and discards the result.

Encodings

T1 `CMN<c> <Rn>,#<const>`

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	1	0	i	0	1	0	0	0	1	Rn				0	imm3			1	1	1	1	imm8							

```
n = UInt(Rn);  imm32 = ThumbExpandImm(i:imm3:imm8);
if n == 15 then UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

```
CMN<c><q>  <Rn>, #<const>
```

where:

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<Rn>` Specifies the register that contains the operand.

`<const>` Specifies the immediate value to be added to the value obtained from `<Rn>`. See *Immediate constants* on page 4-8 for the range of allowed values.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    (result, carry, overflow) = AddWithCarry(R[n], imm32, '0');
    APSR.N = result<31>;
    APSR.Z = IsZeroBit(result);
    APSR.C = carry;
    APSR.V = overflow;
```

Exceptions

None.

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4.6.28 CMN (register)

Compare Negative (register) adds a register value and an optionally-shifted register value. It updates the condition flags based on the result, and discards the result.

Encodings

T1 `CMN<c> <Rn>,<Rm>`

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0	1	0	0	0	0	1	0	1	1	Rm			Rn		

```
n = UInt(Rn);  m = UInt(Rm);
(shift_t, shift_n) = (SRType_None, 0);
```

T2 `CMN<c>.W  <Rn>, <Rm> {,<shift>}`

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	0	1	0	1	1	0	0	0	1	Rn				(0)	imm3			1	1	1	1	imm2		type		Rm			

```
n = UInt(Rn);  m = UInt(Rm);
(shift_t, shift_n) = DecodeImmShift(type, imm3:imm2);
if n == 15 || BadReg(m) then UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set

Encoding T2 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

```
CMN<c><q>  <Rn>, <Rm> {,<shift>}
```

where:

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<Rn>` Specifies the register that contains the first operand.

`<Rm>` Specifies the register that is optionally shifted and used as the second operand.

`<shift>` Specifies the shift to apply to the value read from `<Rm>`. If `<shift>` is omitted, no shift is applied and both encodings are permitted. If `<shift>` is specified, only encoding T2 is permitted. The possible shifts and how they are encoded are described in *Constant shifts applied to a register* on page 4-10.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    shifted = Shift(R[m], shift_t, shift_n, APSR.C);
    (result, carry, overflow) = AddWithCarry(R[n], shifted, '0');
    APSR.N = result<31>;
    APSR.Z = IsZeroBit(result);
    APSR.C = carry;
    APSR.V = overflow;
```

Exceptions

None.

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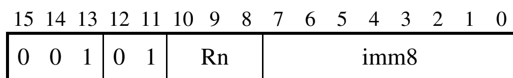
4.6.29 CMP (immediate)

Compare (immediate) subtracts an immediate value from a register value. It updates the condition flags based on the result, and discards the result.

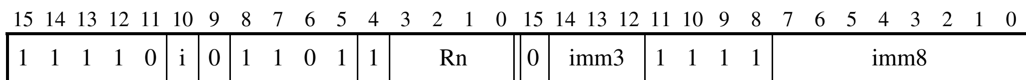
Encodings

T1 CMP <Rn>,#<imm8>




```
n = UInt(Rdn);  imm32 = ZeroExtend(imm8, 32);
```

T2 CMP<c>.W <Rn>,#<const>




```
n = UInt(Rn);  imm32 = ThumbExpandImm(i:imm3:imm8);
if n == 15 then UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set.

Encoding T2 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

```
CMP<c><q>  <Rn>, #<const>
```

where:

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<Rn>` Specifies the register that contains the operand.

`<const>` Specifies the immediate value to be added to the value obtained from `<Rn>`. The range of allowed values is 0-255 for encoding T1. See *Immediate constants* on page 4-8 for the range of allowed values for encoding T2.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    (result, carry, overflow) = AddWithCarry(R[n], NOT(imm32), '1');
    APSR.N = result<31>;
    APSR.Z = IsZeroBit(result);
    APSR.C = carry;
    APSR.V = overflow;
```

Exceptions

None.

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4.6.30 CMP (register)

Compare (register) subtracts an optionally-shifted register value from a register value. It updates the condition flags based on the result, and discards the result.

Encodings

T1 `CMP<c> <Rn>,<Rm>` <Rn> and <Rm> both from R0-R7

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0	1	0	0	0	0	1	0	1	0	Rm			Rn		

```
n = UInt(Rn);  m = UInt(Rm);
(shift_t, shift_n) = (SRType_None, 0);
```

T2 `CMP<c> <Rn>,<Rm>` <Rn> and <Rm> not both from R0-R7

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0	1	0	0	0	1	0	1	N	Rm				Rn		

```
n = UInt(N:Rn);  m = UInt(Rm);
(shift_t, shift_n) = (SRType_None, 0);
if n < 8 && m < 8 then UNPREDICTABLE;
if n == 15 then UNPREDICTABLE;
```

T3 `CMP<c>.W <Rn>, <Rm> {,<shift>}`

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	0	1	0	1	1	1	0	1	1	Rn				(0)	imm3			1	1	1	1	imm2		type		Rm			

```
n = UInt(Rn);  m = UInt(Rm);
(shift_t, shift_n) = DecodeImmShift(type, imm3:imm2);
if n == 15 || BadReg(m) then UNPREDICTABLE;
```

Architecture versions

Encodings T1, T2 All versions of the Thumb instruction set.

Encoding T3 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

```
CMN<c><q>  <Rn>, <Rm> {,<shift>}
```

where:

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<Rn>` Specifies the register that contains the first operand.

`<Rm>` Specifies the register that is optionally shifted and used as the second operand.

`<shift>` Specifies the shift to apply to the value read from `<Rm>`. If `<shift>` is omitted, no shift is applied and all encodings are permitted. If shift is specified, only encoding T3 is permitted. The possible shifts and how they are encoded are described in *Constant shifts applied to a register* on page 4-10.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    shifted = Shift(R[m], shift_t, shift_n, APSR.C);
    (result, carry, overflow) = AddWithCarry(R[n], NOT(shifted), '1');
    APSR.N = result<31>;
    APSR.Z = IsZeroBit(result);
    APSR.C = carry;
    APSR.V = overflow;
```

Exceptions

None.

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4.6.31 CPS

Change Processor State changes one or more of the A, I, and F interrupt disable bits and the mode bits of the CPSR, without changing the other CPSR bits.

Encodings

T1 `CPS<effect> <iflags>` Not allowed in IT block.

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	0	1	1	0	1	1	0	0	1	1	im	0	A	I	F

```
enable = (im == '0');  disable = (im == '1');  changemode = FALSE;
affectA = (A == '1');  affectI = (I == '1');  affectF = (F == '1');
// mode does not exist, but will not be used in Operation.
if InITBlock() then UNPREDICTABLE;
```

T2 `CPS<effect>.W <iflags>{,#<mode>}` Not allowed in IT block.

`CPS #<mode>` Not allowed in IT block.

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	1	0	0	1	1	1	0	1	0	(1)	(1)	(1)	(1)	1	0	(0)	0	(0)	imod		M	A	I	F	mode				

```
enable = (imod == '10');  disable = (imod == '11');  changemode = (M == '1');
affectA = (A == '1');  affectI = (I == '1');  affectF = (F == '1');
if imod == '00' && M == '0' then
    SEE Branches, miscellaneous control instructions on page 3-31;
if imod == '01' then UNPREDICTABLE;
if InITBlock() then UNPREDICTABLE;
```

Architecture versions

Encodings T1, T2 All versions of the Thumb instruction set from Thumb-2 onwards.

Assembler syntax

```
CPS<effect><q>  <iflags> {, #<mode>}
CPS<q>  #<mode>
```

where:

`<effect>` Specifies the effect required on the A, I, and F bits in the CPSR. This is one of:

- `IE` Interrupt Enable. This sets the specified bits to 0.
- `ID` Interrupt Disable. This sets the specified bits to 1.

If `<effect>` is specified, the bits to be affected are specified by `<iflags>`. The mode can optionally be changed by specifying a mode number as `<mode>`.

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If `<effect>` is not specified, then:

- `<iflags>` is not specified and interrupt settings are not changed
- `<mode>` specifies the new mode number.

`<q>` See *Standard assembler syntax fields* on page 4-6.

`<iflags>` Is a sequence of one or more of the following, specifying which interrupt disable flags are affected:

- `a` Sets the A bit in the instruction, causing the specified effect on the CPSR A (imprecise data abort) bit.
- `i` Sets the I bit in the instruction, causing the specified effect on the CPSR I (IRQ interrupt) bit.
- `f` Sets the F bit in the instruction, causing the specified effect on the CPSR F (FIQ interrupt) bit.

`<mode>` Specifies the number of the mode to change to. If this option is omitted, no mode change occurs.

Operation

```
EncodingSpecificOperations();
if CurrentModeIsPrivileged() then
    if enable then
        if affectA then CPSR.A = '0';
        if affectI then CPSR.I = '0';
        if affectF then CPSR.F = '0';
    if disable then
        if affectA then CPSR.A = '1';
        if affectI then CPSR.I = '1';
        if affectF then CPSR.F = '1';
    if changemode then
        CPSR.M[4:0] = mode;
```

Exceptions

None.

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4.6.32 CPY

Copy is a pre-UAL synonym for `MOV` (register).

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Assembler syntax

```
CPY  <Rd>, <Rn>
```

This is equivalent to:

```
MOV  <Rd>, <Rn>
```

Exceptions

None.

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4.6.33 DBG

Debug Hint provides a hint to debug and related systems. See their documentation for what use (if any) they make of this instruction.

Encodings

T1 `DBG<c> #<option>`

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	1	0	0	1	1	1	0	1	0	(1)	(1)	(1)	(1)	1	0	(0)	0	(0)	0	0	0	1	1	1	1	option			

```
// Do nothing
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set from v7 onwards.

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Assembler syntax

```
DBG<c><q>  #<option>
```

where:

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<option>` Provides extra information about the hint, and is in the range 0 to 15.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    Hint_Debug(option);
```

Exceptions

None.

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4.6.34 DMB

Data Memory Barrier acts as a memory barrier. It ensures that all explicit memory accesses that appear in program order before the DMB instruction are observed before any explicit memory accesses that appear in program order after the DMB instruction. It does not affect the ordering of any other instructions executing on the processor.

Encodings

T1 `DMB<c>`

<table>
<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><td>7</td><td>6</td><td>5</td><td>4</td><td>3</td><td>2</td><td>1</td><td>0</td><td>15</td><td>14</td><td>13</td><td>12</td><td>11</td><td>10</td><td>9</td><td>8</td><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>
<tr><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>1</td><td>1</td><td>(1)</td><td>(1)</td><td>(1)</td><td>(1)</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>0</td><td>1</td><td>0</td><td>1</td><td colspan="4">option</td></tr>
</table>

```
// Do nothing
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set from v7 onwards.

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Assembler syntax

```
DMB<c><q>  {<opt>}
```

where:

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<opt>` Specifies an optional limitation on the DMB operation. Allowed values are:

`SY` Full system DMB operation, encoded as option == '1111'. Can be omitted.

All other encodings of option are RESERVED. The corresponding instructions execute as full system DMB operations, but should not be relied upon by software.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    DataMemoryBarrier(option);
```

Exceptions

None.

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4.6.35 DSB

Data Synchronization Barrier acts as a special kind of memory barrier. No instruction in program order after this instruction can execute until this instruction completes. This instruction completes when:

- All explicit memory accesses before this instruction complete.
- All Cache, Branch predictor and TLB maintenance operations before this instruction complete.

Encodings

T1 `DSB<c>`

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	1	0	0	1	1	1	0	1	1	(1)	(1)	(1)	(1)	1	0	(0)	0	(1)	(1)	(1)	(1)	0	1	0	0	option			

```
// Do nothing
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set from v7 onwards.

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Assembler syntax

```
DSB<c><q>  {<opt>}
```

where:

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<opt>` Specifies an optional limitation on the DSB operation. Allowed values are:

- `SY` Full system DSB operation, encoded as option == '1111'. Can be omitted.
- `UN` DSB operation only out to the point of unification, encoded as option == '0111'.
- `ST` DSB operation that waits only for stores to complete, encoded as option == '1110'.
- `UNST` DSB operation that waits only for stores to complete and only out to the point of unification, encoded as option == '0110'.

All other encodings of option are RESERVED. The corresponding instructions execute as full system DSB operations, but should not be relied upon by software.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    DataSynchronizationBarrier(option);
```

Exceptions

None.

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4.6.36 EOR (immediate)

Exclusive OR (immediate) performs a bitwise Exclusive OR of a register value and an immediate value, and writes the result to the destination register. It can optionally update the condition flags based on the result.

Encodings

T1 `EOR{S}<c> <Rd>,<Rn>,#<const>`

15 14 13 12 11	10	9	8 7 6 5	4	3 2 1 0	15	14 13 12	11 10 9 8	7 6 5 4 3 2 1 0
1 1 1 1 0	i	0	0 1 0 0	S	Rn	0	imm3	Rd	imm8

```
d = UInt(Rd);  n = UInt(Rn);  setflags = (S == '1');
(imm32, carry) = ThumbExpandImmWithC(i:imm3:imm8, APSR.C);
if d == 15 && setflags then SEE TEQ (immediate) on page 4-393;
if BadReg(d) || BadReg(n) then UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

```
EOR{S}<c><q>  {<Rd>,} <Rn>, #<const>
```

where:

`S` If present, specifies that the instruction updates the flags. Otherwise, the instruction does not update the flags.

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<Rd>` Specifies the destination register. If `<Rd>` is omitted, this register is the same as `<Rn>`.

`<Rn>` Specifies the register that contains the operand.

`<const>` Specifies the immediate value to be added to the value obtained from `<Rn>`. See *Immediate constants* on page 4-8 for the range of allowed values.

The pre-UAL syntax `EOR<c>S` is equivalent to `EORS<c>`.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    result = R[n] EOR imm32;
    R[d] = result;
    if setflags then
        APSR.N = result<31>;
        APSR.Z = IsZeroBit(result);
        APSR.C = carry;
        // APSR.V unchanged
```

Exceptions

None.

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4.6.37 EOR (register)

Exclusive OR (register) performs a bitwise Exclusive OR of a register value and an optionally-shifted register value, and writes the result to the destination register. It can optionally update the condition flags based on the result.

Encodings

T1 `EORS <Rdn>,<Rm>` Outside IT block.

`EOR<c> <Rdn>,<Rm>` Inside IT block.

15	14	13	12	11	10	9	8	7	6	5 4 3	2 1 0
0	1	0	0	0	0	0	0	0	1	Rm	Rdn

```
d = UInt(Rdn);  n = UInt(Rdn);  m = UInt(Rm);  setflags = !InITBlock();
(shift_t, shift_n) = (SRType_None, 0);
```

T2 `EOR{S}<c>.W <Rd>,<Rn>,<Rm>{,<shift>}`

15	14	13	12	11	10	9	8	7	6	5	4	3 2 1 0	15	14 13 12	11 10 9 8	7 6	5 4	3 2 1 0
1	1	1	0	1	0	1	0	1	0	0	S	Rn	(0)	imm3	Rd	imm2	type	Rm

```
d = UInt(Rd);  n = UInt(Rn);  m = UInt(Rm);  setflags = (S == '1');
(shift_t, shift_n) = DecodeImmShift(type, imm3:imm2);
if d == 15 && setflags then SEE TEQ (register) on page 4-395;
if BadReg(d) || BadReg(n) || BadReg(m) THEN UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set

Encoding T2 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

```
EOR{S}<c><q>  {<Rd>,} <Rn>, <Rm> {,<shift>}
```

where:

`S` If present, specifies that the instruction updates the flags. Otherwise, the instruction does not update the flags.

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<Rd>` Specifies the destination register. If `<Rd>` is omitted, this register is the same as `<Rn>`.

`<Rn>` Specifies the register that contains the first operand.

`<Rm>` Specifies the register that is optionally shifted and used as the second operand.

`<shift>` Specifies the shift to apply to the value read from `<Rm>`. If `<shift>` is omitted, no shift is applied and both encodings are permitted. If `<shift>` is specified, only encoding T2 is permitted. The possible shifts and how they are encoded are described in *Constant shifts applied to a register* on page 4-10.

A special case is that if `EOR<c> <Rd>,<Rn>,<Rd>` is written with `<Rd>` and `<Rn>` both in the range R0-R7, it will be assembled using encoding T2 as though `EOR<c> <Rd>,<Rn>` had been written. To prevent this happening, use the .W qualifier.

The pre-UAL syntax `EOR<c>S` is equivalent to `EORS<c>`.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    (shifted, carry) = Shift_C(R[m], shift_t, shift_n, APSR.C);
    result = R[n] EOR shifted;
    R[d] = result;
    if setflags then
        APSR.N = result<31>;
        APSR.Z = IsZeroBit(result);
        APSR.C = carry;
        // APSR.V unchanged
```

Exceptions

None.

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4.6.38 ISB

Instruction Synchronization Barrier flushes the pipeline in the processor, so that all instructions following the ISB are fetched from cache or memory, after the instruction has been completed. It ensures that the effects of context altering operations, such as changing the ASID, or completed TLB maintenance operations, or branch predictor maintenance operations, as well as all changes to the CP15 registers, executed before the ISB instruction are visible to the instructions fetched after the ISB.

In addition, the ISB instruction ensures that any branches that appear in program order after it are always written into the branch prediction logic with the context that is visible after the ISB instruction. This is required to ensure correct execution of the instruction stream.

Encodings

T1 ISB<c>

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	1	0	0	1	1	1	0	1	1	(1)	(1)	(1)	(1)	1	0	(0)	0	(1)	(1)	(1)	(1)	0	1	1	0	option			

```
// Do nothing
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set from v7 onwards.

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Assembler syntax

```
ISB<c><q>  {<opt>}
```

where:

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<opt>` Specifies an optional limitation on the ISB operation. Allowed values are:

`SY` Full system ISB operation, encoded as option == '1111'. Can be omitted.

All other encodings of option are RESERVED. The corresponding instructions execute as full system ISB operations, but should not be relied upon by software.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    InstructionSynchronizationBarrier(option);
```

Exceptions

None.

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4.6.39 IT

If Then makes up to four following instructions (the *IT block*) conditional. The conditions for the instructions in the IT block can be the same, or some of them can be the inverse of others.

`IT` does not affect the condition code flags. Branches to any instruction in the IT block are not permitted, apart from those performed by exception returns.

16-bit instructions in the IT block, other than `CMP`, `CMN` and `TST`, do not set the condition code flags. The `AL` condition can be specified to get this changed behavior without conditional execution.

Encodings

T1 `IT{x{y{z}}} <firstcond>` Not allowed in IT block

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	0	1	1	1	1	1	1	firstcond				mask			

```
if mask == '0000' then SEE NOP-compatible hint instructions on page 3-32
if firstcond == '1111' then UNPREDICTABLE;
if firstcond == '1110' && BitCount(mask) != 1 then UNPREDICTABLE;
if InITBlock() then UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set from Thumb-2 onwards.

Assembler syntax

```
IT{x{y{z}}}<q>  <firstcond>
```

where:

`<x>` Specifies the condition for the second instruction in the IT block.

`<y>` Specifies the condition for the third instruction in the IT block.

`<z>` Specifies the condition for the fourth instruction in the IT block.

`<q>` See *Standard assembler syntax fields* on page 4-6.

`<firstcond>` Specifies the condition for the first instruction in the IT block.

Each of `<x>`, `<y>`, and `<z>` can be either:

`T` Then. The condition attached to the instruction is `<firstcond>`.

`E` Else. The condition attached to the instruction is the inverse of `<firstcond>`. The condition code is the same as `<firstcond>`, except that the least significant bit is inverted. `E` must not be specified if `<firstcond>` is `AL`.

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The values of <x>, <y>, and <z> determine the value of the `mask` field as shown in Table 4-1.

Table 4-1 Determination of mask [a] field

<x>	<y>	<z>	mask[3]	mask[2]	mask[1]	mask[0]
omitted	omitted	omitted	1	0	0	0
T	omitted	omitted	firstcond[0]	1	0	0
E	omitted	omitted	NOT firstcond[0]	1	0	0
T	T	omitted	firstcond[0]	firstcond[0]	1	0
E	T	omitted	NOT firstcond[0]	firstcond[0]	1	0
T	E	omitted	firstcond[0]	NOT firstcond[0]	1	0
E	E	omitted	NOT firstcond[0]	NOT firstcond[0]	1	0
T	T	T	firstcond[0]	firstcond[0]	firstcond[0]	1
E	T	T	NOT firstcond[0]	firstcond[0]	firstcond[0]	1
T	E	T	firstcond[0]	NOT firstcond[0]	firstcond[0]	1
E	E	T	NOT firstcond[0]	NOT firstcond[0]	firstcond[0]	1
T	T	E	firstcond[0]	firstcond[0]	NOT firstcond[0]	1
E	T	E	NOT firstcond[0]	firstcond[0]	NOT firstcond[0]	1
T	E	E	firstcond[0]	NOT firstcond[0]	NOT firstcond[0]	1
E	E	E	NOT firstcond[0]	NOT firstcond[0]	NOT firstcond[0]	1

a. Note that at least one bit is always 1 in mask.

See also *The IT execution state bits* on page 2-2.

Operation

```
StartITBlock(firstcond, mask);
```

Exceptions

None.

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4.6.40 LDC, LDC2

Load Coprocessor loads memory data from a sequence of consecutive memory addresses to a coprocessor.

If no coprocessor can execute the instruction, an Undefined Instruction exception is generated.

Encoding

T1

```
LDC{2}{L}<c> <coproc>,<CRd>,[<Rn>,#+/-<imm8>]
LDC{2}{L}<c> <coproc>,<CRd>,[<Rn>],#+/-<imm8>
LDC{2}{L}<c> <coproc>,<CRd>,[<Rn>,#+/-<imm8>]!
```

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	C	1	1	0	P	U	N	W	1	Rn				CRd				coproc				imm8							

```
n = UInt(Rn);  cp = UInt(coproc);  imm32 = ZeroExtend(imm8:'00', 32);
opc1 = N;  opc0 = C;  // LDC if C == '0', LDC2 if C == '1'
index = (P == '1');  add = (U == '1');  wback = (W == '1');
if P == '0' && U == '0' && N == '0' && W == '0' then UNDEFINED;
if P == '0' && U == '0' && N == '1' && W == '0' then
    SEE MRRC, MRRC2 on page 4-175;
if n == 15 && wback then UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set from Thumb-2 onwards.

Assembler syntax

`LDC{2}{L}<c><q>`	`<coproc>,<CRd>,[<Rn>{,#+/-<imm>}]`	index==TRUE, wback==FALSE
`LDC{2}{L}<c><q>`	`<coproc>,<CRd>,[<Rn>,#+/-<imm>]!`	index==TRUE, wback==TRUE
`LDC{2}{L}<c><q>`	`<coproc>,<CRd>,[<Rn>],#+/-<imm>`	index==FALSE, wback==TRUE

where:

`2` If specified, selects the C == 1 form of the encoding. If omitted, selects the C == 0 form.

`L` If specified, selects the N == 1 form of the encoding. If omitted, selects the N == 0 form.

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<coproc>` Specifies the name of the coprocessor. The standard generic coprocessor names are p0, p1, ..., p15.

`<CRd>` Specifies the coprocessor destination register.

`<Rn>` Specifies the base register. This register is allowed to be the SP or PC.

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`+/-` Is + or omitted to indicate that the immediate offset is added to the base register value (`add == TRUE`), or – to indicate that the offset is to be subtracted (`add == FALSE`). Different instructions are generated for `#0` and `#-0`.

`<imm>` Specifies the immediate offset added to or subtracted from the value of `<Rn>` to form the address. For the offset addressing syntax, `<imm>` can be omitted, meaning an offset of 0.

The pre-UAL syntax `LDC<c>L` is equivalent to `LDCL<c>`.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    if !Coproc_Accepted(cp, ThisInstr()) then
        RaiseCoprocessorException();
    else
        offset_addr = if add then (R[n] + imm32) else (R[n] - imm32);
        address = if index then offset_addr else R[n];
        if wback then R[n] = offset_addr;
        repeat
            value = MemA[address,4];
            Coproc_SendLoadedWord(value, cp, ThisInstr());
            address = address + 4;
        until Coproc_DoneLoading(cp, ThisInstr());
```

Exceptions

Undefined Instruction, Data Abort.

Notes

Coprocessor fields Only instruction bits[31:23], bits[21:16], and bits[11:0] are ARM architecture-defined. The remaining fields (bit[22] and bits[15:12]) are recommendations,

In the case of the Unindexed addressing mode (P==0, U==1, W==0), instruction bits[7:0] are also not defined by the ARM architecture, and can be used to specify additional coprocessor options.

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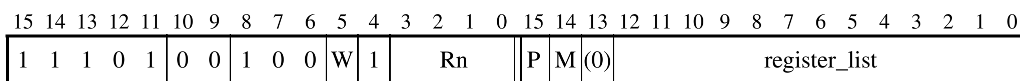
4.6.41 LDMDB / LDMEA

Load Multiple Decrement Before (Load Multiple Empty Ascending) loads multiple registers from sequential memory locations using an address from a base register. The sequential memory locations end just below this address, and the address of the first of those locations can optionally be written back to the base register.

The registers loaded can include the PC. If they do, the word loaded for the PC is treated as an address and a branch occurs to that address. Bit[0] of the loaded value determines whether execution continues after this branch in ARM state or in Thumb state.

Encoding

T1 `LDMDB<c> <Rn>{!},<registers>`




```
n = UInt(Rn);  registers = P:M:'0':register_list;  wback = (W == '1');
if n == 15 || BitCount(registers) < 2 then UNPREDICTABLE;
if P == 1 && M == 1 then UNPREDICTABLE;
if registers<15> == 1 && InITBlock() && !LastInITBlock() then UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set from Thumb-2 onwards.

Assembler syntax

```
LDMDB<c><q>  <Rn>{!}, <registers>
```

where:

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<Rn>` Specifies the base register. This register is allowed to be the SP.

`!` Causes the instruction to write a modified value back to `<Rn>`. If `!` is omitted, the instruction does not change `<Rn>` in this way. (However, if `<Rn>` is included in `<registers>`, it changes when a value is loaded into it.)

`<registers>`

Is a list of one or more registers, separated by commas and surrounded by `{` and `}`. It specifies the set of registers to be loaded. The registers are loaded with the lowest-numbered register from the lowest memory address, through to the highest-numbered register from the highest memory address. If the PC is specified in the register list, the instruction causes a branch to the address (data) loaded into the PC.

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Encoding T1 does not support a list containing only one register. If an `LDMDB` instruction with just one register `<Rt>` in the list is assembled to Thumb, it is assembled to the equivalent `LDR<c><q> <Rt>,[<Rn>,#-4]{!}` instruction.

The SP cannot be in the list.

If the PC is in the list, the LR must not be in the list and the instruction must either be outside an IT block or the last instruction in an IT block.

`LDMEA` is a synonym for `LDMDB`, referring to its use for popping data from Empty Ascending stacks.

The pre-UAL syntaxes `LDM<c>DB` and `LDM<c>EA` are equivalent to `LDMDB<c>`.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    originalRn = R[n];
    address = R[n] - 4*BitCount(registers);
    if wback then
        if registers<n> == '0' then
            R[n] = R[n] - 4*BitCount(registers);
        else
            R[n] = bits(32) UNKNOWN;
    for i = 0 to 14
        if registers<i> == '1' then
            loadedvalue = MemA[address,4];
            if !(i == n && wback) then
                R[i] = loadedvalue;
            // else R[i] set earlier to be bits[32] UNKNOWN
            address = address + 4;
    if registers<15> == '1' then
        LoadWritePC(MemA[address,4]);
        address = address + 4;
    assert address == originalRn;
```

Exceptions

Data Abort.

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4.6.42 LDMIA / LDMFD

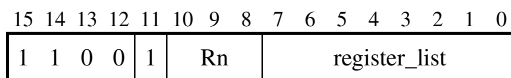
Load Multiple Increment After loads multiple registers from consecutive memory locations using an address from a base register. The sequential memory locations start at this address, and the address just above the last of those locations can optionally be written back to the base register.

The registers loaded can include the PC. If they do, the word loaded for the PC is treated as an address and a branch occurs to that address. Bit[0] of the loaded value determines whether execution continues after this branch in ARM state or in Thumb state.

Encoding

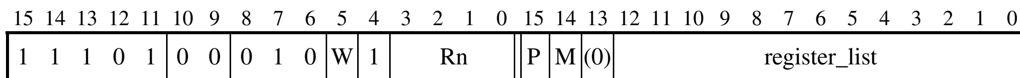
T1 `LDMIA<c> <Rn>!,<registers>` <Rn> not from <registers>

`LDMIA<c> <Rn>,<registers>` <Rn> from <registers>




```
n = UInt(Rn);  registers = '00000000':register_list;
wback = (registers<n> == '0');
if BitCount(registers) < 1 then UNPREDICTABLE;
```

T2 `LDMIA<c>.W <Rn>{!},<registers>`




```
n = UInt(Rn);  registers = P:M:'0':register_list;  wback = (W == '1');
if n == 13 && wback then SEE POP on page 4-209;
if n == 15 || BitCount(registers) < 2 then UNPREDICTABLE;
if P == 1 && M == 1 then UNPREDICTABLE;
if registers<15> == 1 && InITBlock() && !LastInITBlock() then UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set.

Encoding T2 All versions of the Thumb instruction set from Thumb-2 onwards.

Assembler syntax

```
LDMIA<c><q>  <Rn>{!}, <registers>
```

where:

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<Rn>` Specifies the base register. This register is allowed to be the SP. If it is the SP and ! is specified, it is treated as described in *POP* on page 4-209.

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`!` Causes the instruction to write a modified value back to `<Rn>`. If `!` is omitted, the instruction does not change `<Rn>` in this way. (However, if `<Rn>` is included in `<registers>`, it changes when a value is loaded into it.)

`<registers>` Is a list of one or more registers, separated by commas and surrounded by `{` and `}`. It specifies the set of registers to be loaded by the `LDM` instruction. The registers are loaded with the lowest-numbered register from the lowest memory address, through to the highest-numbered register from the highest memory address. If the PC is specified in the register list, the instruction causes a branch to the address (data) loaded into the PC.

Encoding T2 does not support a list containing only one register. If an `LDMIA` instruction with just one register `<Rt>` in the list is assembled to Thumb and encoding T1 is not available, it is assembled to the equivalent `LDR<c><q> <Rt>,[<Rn>]{,#-4}` instruction.

The SP cannot be in the list.

If the PC is in the list, the LR must not be in the list and the instruction must either be outside an IT block or the last instruction in an IT block.

`LDMFD` is a synonym for `LDMIA`, referring to its use for popping data from Full Descending stacks.

The pre-UAL syntaxes `LDM<c>IA` and `LDM<c>FD` are equivalent to `LDMIA<c>`.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    originalRn = R[n];
    address = R[n];
    if wback then
        if registers<n> == '0' then
            R[n] = R[n] + 4*BitCount(registers);
        else
            R[n] = bits(32) UNKNOWN;
    for i = 0 to 14
        if registers<i> == '1' then
            loadedvalue = MemA[address,4];
            if !(i == n && wback) then
                R[i] = loadedvalue;
            // else R[i] set earlier to be bits[32] UNKNOWN
            address = address + 4;
    if registers<15> == '1' then
        LoadWritePC(MemA[address,4]);
        address = address + 4;
    assert address == originalRn + 4*BitCount(registers);
```

Exceptions

Data Abort.

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4.6.43 LDR (immediate)

Load Register (immediate) calculates an address from a base register value and an immediate offset, loads a word from memory, and writes it to a register. It can use offset, post-indexed, or pre-indexed addressing. See *Memory accesses* on page 4-13 for information about memory accesses.

Encoding

T1

```
LDR<c> <Rt>, [<Rn>, #<imm>]
```

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0	1	1	0	1	imm5					Rn			Rt		

```
t = UInt(Rt);  n = UInt(Rn);  imm32 = ZeroExtend(imm5:'00', 32);
index = TRUE;  add = TRUE;  wback = FALSE;
```

T2

```
LDR<c> <Rt>,[SP,#<imm>]
```

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	0	0	1	1	Rt			imm8							

```
t = UInt(Rt);  n = 13;  imm32 = ZeroExtend(imm8:'00', 32);
index = TRUE;  add = TRUE;  wback = FALSE;
```

T3

```
LDR<c>.W <Rt>,[<Rn>,#<imm12>]
```

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	1	1	0	0	0	1	1	0	1	Rn				Rt				imm12											

```
t = UInt(Rt);  n = UInt(Rn);  imm32 = ZeroExtend(imm12, 32);
index = TRUE;  add = TRUE;  wback = FALSE;
if n == 15 then SEE LDR (literal) on page 4-102;
if t == 15 && InITBlock() && !LastInITBlock() then UNPREDICTABLE;
```

T4

```
LDR<c> <Rt>,[<Rn>,#-<imm8>]
LDR<c> <Rt>,[<Rn>],#+/-<imm8>
LDR<c> <Rt>,[<Rn>,#+/-<imm8>]!
```

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	1	1	0	0	0	0	1	0	1	Rn				Rt				1	P	U	W	imm8							

```
t = UInt(Rt);  n = UInt(Rn);  imm32 = ZeroExtend(imm8, 32);
index = (P == '1');  add = (U == '1');  wback = (W == '1');
if n == 15 then SEE LDR (literal) on page 4-102;
if P == '1' && U == '1' && W == '0' then SEE LDRT on page 4-148;
if P == '0' && W == '0' then UNDEFINED;
if wback && n == t then UNPREDICTABLE;
if t == 15 && InITBlock() && !LastInITBlock() then UNPREDICTABLE;
```

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Architecture versions

Encodings T1, T2 All versions of the Thumb instruction set.

Encodings T3, T4 All versions of the Thumb instruction set from Thumb-2 onwards.

Assembler syntax

`LDR<c><q> <Rt>, [<Rn> {, #+/-<imm>}]`	Offset: `index==TRUE`, `wback==FALSE`
`LDR<c><q> <Rt>, [<Rn>, #+/-<imm>]!`	Pre-indexed: `index==TRUE`, `wback==TRUE`
`LDR<c><q> <Rt>, [<Rn>], #+/-<imm>`	Post-indexed: `index==FALSE`, `wback==TRUE`

where:

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<Rt>` Specifies the destination register. This register is allowed to be the SP. It is also allowed to be the PC, provided the instruction is either outside an IT block or the last instruction of an IT block. If it is the PC, it causes a branch to the address (data) loaded into the PC.

`<Rn>` Specifies the base register. This register is allowed to be the SP. If this register is the PC, see *LDR (literal)* on page 4-102.

`+/-` Is + or omitted to indicate that the immediate offset is added to the base register value (`add == TRUE`), or – to indicate that the offset is to be subtracted (`add == FALSE`). Different instructions are generated for `#0` and `#-0`.

`<imm>` Specifies the immediate offset added to or subtracted from the value of `<Rn>` to form the address. For the offset addressing syntax, `<imm>` can be omitted, meaning an offset of 0.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    offset_addr = if add then (R[n] + imm32) else (R[n] - imm32);
    address = if index then offset_addr else R[n];
    if wback then R[n] = offset_addr;
    if t == 15 then
        if address<1:0> != '00' then UNPREDICTABLE;
        LoadWritePC(MemU[address,4]);
    else
        R[t] = MemU[address,4];
```

Exceptions

Data Abort.

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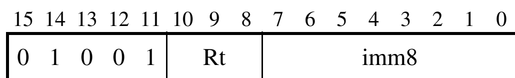
4.6.44 LDR (literal)

Load Register (literal) calculates an address from the PC value and an immediate offset, loads a word from memory, and writes it to a register. See *Memory accesses* on page 4-13 for information about memory accesses.

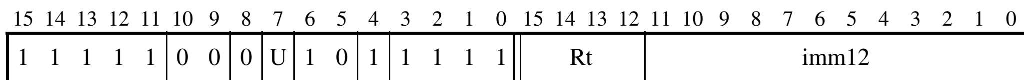
Encoding

T1 `LDR<c> <Rt>,[PC,#<imm>]`




```
t = UInt(Rt);  imm32 = ZeroExtend(imm8:'00', 32);  add = TRUE;
```

T2 `LDR<c>.W <Rt>,[PC,#+/-<imm12>]`




```
t = UInt(Rt);  imm32 = ZeroExtend(imm12, 32);  add = (U == '1');
if t == 15 && InITBlock() && !LastInITBlock() then UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set

Encoding T2 All versions of the Thumb instruction set from Thumb-2 onwards.

Assembler syntax

`LDR<c><q> <Rt>, <label>`	Normal form
`LDR<c><q> <Rt>, [PC, #+/-<imm>]`	Alternative form

where:

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<Rt>` Specifies the destination register. This register is allowed to be the SP. It is also allowed to be the PC, provided the instruction is either outside an IT block or the last instruction of an IT block. If it is the PC, it causes a branch to the address (data) loaded into the PC.

`<label>` Specifies the label of the literal data item that is to be loaded into `<Rt>`. The assembler calculates the required value of the offset from the `Align(PC,4)` value of this instruction to the label.

If the offset is positive, encodings T1 and T2 are permitted with imm32 equal to the offset and `add` == TRUE. Allowed values of the offset are multiples of four in the range 0 to 1020 for encoding T1 and any value in the range 0 to 4095 for encoding T2.

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If the offset is negative, encoding T2 is permitted with `imm32` equal to minus the offset and `add` == FALSE. Allowed values of the offset are –4095 to –1.

In the alternative syntax form:

`+/-` Is + or omitted to indicate that the immediate offset is added to the `Align(PC, 4)` value (`add` == TRUE), or `-` to indicate that the offset is to be subtracted (`add` == FALSE). Different instructions are generated for `#0` and `#-0`.

`<imm>` Specifies the immediate offset added to or subtracted from the `Align(PC, 4)` value of the instruction to form the address. Allowed values are multiples of four in the range 0 to 1020 for encoding T1 and any value in the range 0 to 4095 for encoding T2.

Note

It is recommended that the alternative syntax form is avoided where possible. However, the only possible syntax for encoding T2 with the U bit and all immediate bits zero is `LDR<c><q> <Rt>, [PC,#-0]`.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    base = Align(PC,4);
    address = if add then (base + imm32) else (base - imm32);
    if t == 15 then
        if address<1:0> != '00' then UNPREDICTABLE;
        LoadWritePC(MemU[address,4]);
    else
        R[t] = MemU[address,4];
```

Exceptions

Data Abort.

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4.6.45 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 be shifted left by 0, 1, 2, or 3 bits. See *Memory accesses* on page 4-13 for information about memory accesses.

Encoding

T1 `LDR<c> <Rt>,[<Rn>,<Rm>]`

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0	1	0	1	1	0	0	Rm			Rn			Rt		

```
t = UInt(Rt);  n = UInt(Rn);  m = UInt(Rm);
(shift_t, shift_n) = (SRType_None, 0);
```

T2 `LDR<c>.W <Rt>,[<Rn>,<Rm>{,LSL #<shift>}]`

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	1	1	0	0	0	0	1	0	1	Rn			

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Rt				0	0	0	0	0	0	shift		Rm			

```
t = UInt(Rt);  n = UInt(Rn);  m = UInt(Rm);
(shift_t, shift_n) = (SRType_LSL, UInt(shift));
if n == 15 then SEE LDR (literal) on page 4-102;
if BadReg(m) then UNPREDICTABLE;
if t == 15 && InITBlock() && !LastInITBlock() then UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set.

Encoding T2 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

```
LDR<c><q>  <Rt>, [<Rn>, <Rm> {, LSL #<shift>}]
```

where:

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<Rt>` Specifies the destination register. This register is allowed to be the SP. It is also allowed to be the PC, provided the instruction is either outside an IT block or the last instruction of an IT block. If it is the PC, it causes a branch to the address (data) loaded into the PC.

`<Rn>` Specifies the register that contains the base value. This register is allowed to be the SP.

`<Rm>` Contains the offset that is shifted left and added to the value of `<Rn>` to form the address.

`<shift>` Specifies the number of bits the value from `<Rm>` is shifted left, in the range 0-3. If this option is omitted, a shift by 0 is assumed and both encodings are permitted. If this option is specified, only encoding T2 is permitted.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    address = R[n] + LSL(R[m], shift_n);
    if t == 15 then
        if address<1:0> != '00' then UNPREDICTABLE;
        LoadWritePC(MemU[address,4]);
    else
        R[t] = MemU[address,4];
```

Exceptions

Data Abort.

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4.6.46 LDRB (immediate)

Load Register Byte (immediate) calculates an address from a base register value and an immediate offset, loads a byte from memory, zero-extends it to form a 32-bit word, and writes it to a register. It can use offset, post-indexed, or pre-indexed addressing. See *Memory accesses* on page 4-13 for information about memory accesses.

Encoding

T1

```
LDRB<c> <Rt>,[<Rn>,#<imm>]
```

15 14 13	12	11	10 9 8 7 6	5 4 3	2 1 0
0 1 1	1	1	imm5	Rn	Rt

```
t = UInt(Rt);  n = UInt(Rn);  imm32 = ZeroExtend(imm5, 32);
index = TRUE;  add = TRUE;  wback = FALSE;
```

T2

```
LDRB<c>.W <Rt,[<Rn>,#<imm12>]
```

15 14 13 12 11	10 9	8	7	6 5	4	3 2 1 0	15 14 13 12	11 10 9 8 7 6 5 4 3 2 1 0
1 1 1 1 1	0 0	0	1	0 0	1	Rn	Rt	imm12

```
t = UInt(Rt);  n = UInt(Rn);  imm32 = ZeroExtend(imm12, 32);
index = TRUE;  add = TRUE;  wback = FALSE;
if t == 15 then SEE PLD (immediate) on page 4-201;
if n == 15 then SEE LDRB (literal) on page 4-108;
if t == 13 then UNPREDICTABLE;
```

T3

```
LDRB<c> <Rt>,[<Rn>,#-<imm8>]
LDRB<c> <Rt>,[<Rn>],#+/-<imm8>
LDRB<c> <Rt>,[<Rn>,#+/-<imm8>]!
```

15 14 13 12 11	10 9	8	7	6 5	4	3 2 1 0	15 14 13 12	11	10 9 8	7 6 5 4 3 2 1 0
1 1 1 1 1	0 0	0	0	0 0	1	Rn	Rt	1	P U W	imm8

```
t = UInt(Rt);  n = UInt(Rn);  imm32 = ZeroExtend(imm8, 32);
index = (P == '1');  add = (U == '1');  wback = (W == '1');
if n == 15 then SEE LDRB (literal) on page 4-108;
if t == 15 && P == '1' && U == '0' && W == '0' then
    SEE PLD (immediate) on page 4-201;
if P == '1' && U == '1' && W == '0' then SEE LDRBT on page 4-112;
if P == '0' && W == '0' then UNDEFINED;
if BadReg(t) || (wback && n == t) then UNPREDICTABLE;
```

Architecture versions

Encodings T1 All versions of the Thumb instruction set.

Encodings T2, T3 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

`LDRB<c><q>  <Rt>, [<Rn> {, #+/-<imm>}]`	Offset: `index==TRUE`, `wback==FALSE`
`LDRB<c><q>  <Rt>, [<Rn>, #+/-<imm>]!`	Pre-indexed: `index==TRUE`, `wback==TRUE`
`LDRB<c><q>  <Rt>, [<Rn>], #+/-<imm>`	Post-indexed: `index==FALSE`, `wback==TRUE`

where:

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<Rt>` Specifies the destination register.

`<Rn>` Specifies the base register. This register is allowed to be the SP. If this register is the PC, see *LDRB (literal)* on page 4-108.

`+/-` Is + or omitted to indicate that the immediate offset is added to the base register value (`add == TRUE`), or – to indicate that the offset is to be subtracted (`add == FALSE`). Different instructions are generated for `#0` and `#-0`.

`<imm>` Specifies the immediate offset added to or subtracted from the value of `<Rn>` to form the address. For the offset addressing syntax, `<imm>` can be omitted, meaning an offset of 0.

The pre-UAL syntax `LDR<c>B` is equivalent to `LDRB<c>`.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    offset_addr = if add then (R[n] + imm32) else (R[n] - imm32);
    address = if index then offset_addr else R[n];
    if wback then R[n] = offset_addr;
    R[t] = ZeroExtend(MemU[address,1], 32);
```

Exceptions

Data Abort.

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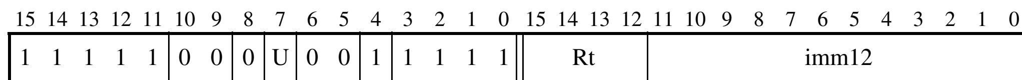
4.6.47 LDRB (literal)

Load Register Byte (literal) calculates an address from the PC value and an immediate offset, loads a byte from memory, zero-extends it to form a 32-bit word, and writes it to a register. See *Memory accesses* on page 4-13 for information about memory accesses.

Encoding

T1 `LDRB<c> <Rt>,[PC,#+/-<imm12>]`




```
t = UInt(Rt);  imm32 = ZeroExtend(imm12, 32);  add = (U == '1');
if t == 15 then SEE PLD (immediate) on page 4-201;
if t == 13 then UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

LDRB<c><q> <Rt>, <label>	Normal form
LDRB<c><q> <Rt>, [PC, #+/-<imm>]	Alternative form

where:

<c><q> See *Standard assembler syntax fields* on page 4-6.

<Rt> Specifies the destination register.

<label> Specifies the label of the literal data item that is to be loaded into <Rt>. The assembler calculates the required value of the offset from the Align(PC,4) value of this instruction to the label.

If the offset is positive, encoding T1 is permitted with imm32 equal to the offset and add == TRUE. Allowed values of the offset are 0 to 4095.

If the offset is negative, encoding T1 is permitted with imm32 equal to minus the offset and add == FALSE. Allowed values of the offset are –4095 to –1.

In the alternative syntax form:

+/- Is + or omitted to indicate that the immediate offset is added to the Align(PC, 4) value (add == TRUE), or - to indicate that the offset is to be subtracted (add == FALSE). Different instructions are generated for #0 and #-0.

<imm> Specifies the immediate offset added to or subtracted from the Align(PC, 4) value of the instruction to form the address.

Allowed values are 0 to 4095.

Note

It is recommended that the alternative syntax form is avoided where possible. However, the only possible syntax for encoding T1 with the U bit and all immediate bits zero is LDRB<c><q> <Rt>, [PC,#-0].

The pre-UAL syntax LDR<c>B is equivalent to LDRB<c>.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    base = Align(PC,4);
    address = if add then (base + imm32) else (base - imm32);
    R[t] = ZeroExtend(MemU[address,1], 32);
```

Exceptions

Data Abort.

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4.6.48 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 to form a 32-bit word, and writes it to a register. The offset register value can be shifted left by 0, 1, 2, or 3 bits. See *Memory accesses* on page 4-13 for information about memory accesses.

Encoding

T1 LDRB<c> <Rt>,[<Rn>,<Rm>]

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0	1	0	1	1	1	0	Rm			Rn			Rt		

```
t = UInt(Rt);  n = UInt(Rn);  m = UInt(Rm);
(shift_t, shift_n) = (SRType_None, 0);
```

T2 LDRB<c>.W <Rt>,[<Rn>,<Rm>{,LSL #<shift>}]

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	1	1	0	0	0	0	0	0	1	Rn				Rt				0	0	0	0	0	0	shift		Rm			

```
t = UInt(Rt);  n = UInt(Rn);  m = UInt(Rm);
(shift_t, shift_n) = (SRType_LSL, UInt(shift));
if t == 15 then SEE PLD (register) on page 4-203;
if n == 15 then SEE LDRB (literal) on page 4-108;
if t == 13 || BadReg(m) then UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set.

Encoding T2 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

```
LDRB<c><q>  <Rt>, [<Rn>, <Rm> {, LSL #<shift>}]
```

where:

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<Rn>` Specifies the register that contains the base value. This register is allowed to be the SP.

`<Rm>` Contains the offset that is shifted left and added to the value of `<Rn>` to form the address.

`<shift>` Specifies the number of bits the value from `<Rm>` is shifted left, in the range 0-3. If this option is omitted, a shift by 0 is assumed and both encodings are permitted. If this option is specified, only encoding T2 is permitted.

The pre-UAL syntax `LDR<c>B` is equivalent to `LDRB<c>`.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    address = R[n] + LSL(R[m], shift_n);
    R[t] = ZeroExtend(MemU[address,1], 32);
```

Exceptions

Data Abort.

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4.6.49 LDRBT

Load Register Byte Unprivileged calculates an address from a base register value and an immediate offset, loads a byte from memory, zero-extends it to form a 32-bit word, and writes it to a register. See *Memory accesses* on page 4-13 for information about memory accesses.

The memory access is restricted as if the processor were running in User mode. (This makes no difference if the processor is actually running in User mode.)

Encoding

T1 `LDRBT<c> <Rt>,[<Rn>,#<imm8>]`

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	1	1	0	0	0	0	0	0	1	Rn				Rt				1	1	1	0	imm8							

```
t = UInt(Rt);  n = UInt(Rn);  imm32 = ZeroExtend(imm8, 32);
if n == 15 then SEE LDRB (literal) on page 4-108;
if BadReg(t) then UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

```
LDRBT<c><q>  <Rt>, [<Rn> {, #<imm>}]
```

where:

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<Rt>` Specifies the destination register.

`<Rn>` Specifies the base register. This register is allowed to be the SP.

`<imm>` Specifies the immediate offset added to the value of `<Rn>` to form the address. `<imm>` can be omitted, meaning an offset of 0.

The pre-UAL syntax `LDR<c>BT` is equivalent to `LDRBT<c>`.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    address = R[n] + imm32;
    R[t] = ZeroExtend(MemU_unpriv[address,1],32);
```

Exceptions

Data Abort.

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4.6.50 LDRD (immediate)

Load Register Double (immediate) calculates an address from a base register value and an immediate offset, loads two words from memory, and writes them to two registers. It can use offset, post-indexed, or pre-indexed addressing. See *Memory accesses* on page 4-13 for information about memory accesses.

Encoding

T1 `LDRD<c> <Rt>,<Rt2>,[<Rn>,#+/-<imm>]{!}`

`LDRD<c> <Rt>,<Rt2>,[<Rn>],#+/-<imm>`

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	0	1	0	0	P	U	1	W	1	Rn				Rt				Rt2				imm8							

```
t = UInt(Rt);  t2 = UInt(Rt2);  n = UInt(Rn);  imm32 = ZeroExtend(imm8:'00');
index = (P == '1');  add = (U == '1');  wback = (W == '1');
if P == '0' && W == '0' then
    SEE Load/store double and exclusive, and table branch on page 3-28;
if wback && n == 15 then UNPREDICTABLE;
if BadReg(t) || BadReg(t2) || t1 == t2 then UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

`LDRD<c><q> <Rt>,<Rt2>,[<Rn>{,#+/-<imm>}]`	Offset: `index==TRUE`, `wback==FALSE`
`LDRD<c><q> <Rt>,<Rt2>,[<Rn>,#+/-<imm>]!`	Pre-indexed: `index==TRUE`, `wback==TRUE`
`LDRD<c><q> <Rt>,<Rt2>,[<Rn>],#+/-<imm>`	Post-indexed: `index==FALSE`, `wback==TRUE`

where:

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<Rt>` Specifies the first destination register.

`<Rt2>` Specifies the second destination register.

`<Rn>` Specifies the base register. This register is allowed to be the SP. It is also allowed to be the PC provided S is not specified.

`+/-` Is + or omitted to indicate that the immediate offset is added to the base register value (`add == TRUE`), or – to indicate that the offset is to be subtracted (`add == FALSE`). Different instructions are generated for `#0` and `#-0`.

`<imm>` Specifies the immediate offset added to or subtracted from the value of `<Rn>` to form the address. For the offset addressing syntax, `<imm>` can be omitted, meaning an offset of 0.

The pre-UAL syntax `LDR<c>D` is equivalent to `LDRD<c>`.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    base = if n == 15 then Align(PC,4) else R[n];
    offset_addr = if add then (base + imm32) else (base - imm32);
    address = if index then offset_addr else R[n];
    if wback then R[n] = offset_addr;
    R[t] = MemA[address,4];
    R[t2] = MemA[address+4,4];
```

Exceptions

Data Abort.

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4.6.51 LDREX

Load Register Exclusive calculates an address from a base register value and an immediate offset, loads a word from memory, writes it to a register and:

- if the address has the Shared Memory attribute, marks the physical address as exclusive access for the executing processor in a shared monitor
- causes the executing processor to indicate an active exclusive access in the local monitor.

See *Memory accesses* on page 4-13 for information about memory accesses.

Encoding

T1 LDREX<c> <Rt>,[<Rn>{,#<imm>}]

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	0	1	0	0	0	0	1	0	1	Rn				Rt				1	1	1	1	imm8							

```
t = UInt(Rt);  n = UInt(Rn);  imm32 = ZeroExtend(imm8:'00', 32);
if BadReg(t) || n == 15 then UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

```
LDREX<c><q>  <Rt>, [<Rn> {,#<imm>}]
```

where:

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<Rt>` Specifies the destination register.

`<Rn>` Specifies the base register. This register is allowed to be the SP.

`<imm>` Specifies the immediate offset added to or subtracted from the value of `<Rn>` to form the address. `<imm>` can be omitted, meaning an offset of 0.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    address = R[n] + imm32;
    SetExclusiveMonitors(address,4);
    R[t] = MemAA[address,4];
```

Exceptions

Data Abort.

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4.6.52 LDREXB

Load Register Exclusive Byte derives an address from a base register value, loads a byte from memory, zero-extends it to form a 32-bit word, writes it to a register and:

- if the address has the Shared Memory attribute, marks the physical address as exclusive access for the executing processor in a shared monitor
- causes the executing processor to indicate an active exclusive access in the local monitor.

See *Memory accesses* on page 4-13 for information about memory accesses.

Encoding

T1 `LDREXB<c> <Rt>, [<Rn>]`

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	0	1	0	0	0	1	1	0	1	Rn				Rt				(1)	(1)	(1)	(1)	0	1	0	0	(1)	(1)	(1)	(1)

```
t = UInt(Rt);  n = UInt(Rn);
if BadReg(t) || n == 15 then UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set from v6K onwards.

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Assembler syntax

```
LDREXB<c><q>  <Rt>, [<Rn>]
```

where:

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<Rt>` Specifies the destination register.

`<Rn>` Specifies the base register. This register is allowed to be the SP.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    address = R[n];
    SetExclusiveMonitors(address,1);
    R[t] = MemAA[address,1];
```

Exceptions

Data Abort.

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4.6.53 LDREXD

Load Register Exclusive Doubleword derives an address from a base register value, loads a 64-bit doubleword from memory, writes it to two registers and:

- if the address has the Shared Memory attribute, marks the physical address as exclusive access for the executing processor in a shared monitor
- causes the executing processor to indicate an active exclusive access in the local monitor.

See *Memory accesses* on page 4-13 for information about memory accesses.

Encoding

T1

```
LDREXD<c> <Rt>,<Rt2>,[<Rn>]
```

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	0	1	0	0	0	1	1	0	1	Rn				Rt				Rt2				0	1	1	1	(1)	(1)	(1)	(1)

```
t = UInt(Rt);  t2 = UInt(Rt2);  n = UInt(Rn);
if BadReg(t) || BadReg(t2) || t1 == t2 || n == 15 then UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set from v6K onwards.

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Assembler syntax

```
LDREXD<c><q>  <Rt>, [<Rn>]
```

where:

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<Rt>` Specifies the destination register.

`<Rn>` Specifies the base register. This register is allowed to be the SP.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    address = R[n];
    SetExclusiveMonitors(address,8);
    value = MemAA[address,8];
    // Extract words from 64-bit loaded value such that R[t] is
    // loaded from address and R[t2] from address+4.
    if BigEndian() then
        R[t]  = value<63:32>;  // = contents of word at address
        R[t2] = value<31:0>;   // = contents of word at address+4
    else
        R[t]  = value<31:0>;   // = contents of word at address
        R[t2] = value<63:32>;  // = contents of word at address+4
```

Exceptions

Data Abort.

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4.6.54 LDREXH

Load Register Exclusive Halfword derives an address from a base register value, loads a halfword from memory, zero-extends it to form a 32-bit word, writes it to a register and:

- if the address has the Shared Memory attribute, marks the physical address as exclusive access for the executing processor in a shared monitor
- causes the executing processor to indicate an active exclusive access in the local monitor.

See *Memory accesses* on page 4-13 for information about memory accesses.

Encoding

T1 `LDREXH<c> <Rt>, [<Rn>]`

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	0	1	0	0	0	1	1	0	1	Rn				Rt				(1)	(1)	(1)	(1)	0	1	0	1	(1)	(1)	(1)	(1)

```
t = UInt(Rt);  n = UInt(Rn);
if BadReg(t) || n == 15 then UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set from v6K onwards.

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Assembler syntax

```
LDREXH<c><q>  <Rt>, [<Rn>]
```

where:

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<Rt>` Specifies the destination register.

`<Rn>` Specifies the base register. This register is allowed to be the SP.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    address = R[n];
    SetExclusiveMonitors(address,2);
    R[t] = MemAA[address,2];
```

Exceptions

Data Abort.

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4.6.55 LDRH (immediate)

Load Register Halfword (immediate) calculates an address from a base register value and an immediate offset, loads a halfword from memory, zero-extends it to form a 32-bit word, and writes it to a register. It can use offset, post-indexed, or pre-indexed addressing. See *Memory accesses* on page 4-13 for information about memory accesses.

Encoding

T1
```
LDRH<c> <Rt>,[<Rn>,#<imm>]
```

15 14 13 12	11	10 9 8 7 6	5 4 3	2 1 0
1 0 0 0	1	imm5	Rn	Rt

```
t = UInt(Rt);  n = UInt(Rn);  imm32 = ZeroExtend(imm5:'0', 32);
index = TRUE;  add = TRUE;  wback = FALSE;
```

T2
```
LDRH<c>.W <Rt,[<Rn>,#<imm12>]
```

15 14 13 12 11	10 9	8	7	6 5	4	3 2 1 0	15 14 13 12	11 10 9 8 7 6 5 4 3 2 1 0
1 1 1 1 1	0 0	0	1	0 1	1	Rn	Rt	imm12

```
t = UInt(Rt);  n = UInt(Rn);  imm32 = ZeroExtend(imm12, 32);
index = TRUE;  add = TRUE;  wback = FALSE;
if n == 15 then SEE LDRH (literal) on page 4-126;
if t == 15 then SEE Memory hints on page 4-14
if t == 13 then UNPREDICTABLE;
```

T3
```
LDRH<c> <Rt>,[<Rn>,#-<imm8>]
LDRH<c> <Rt>,[<Rn>],#+/-<imm8>
LDRH<c> <Rt>,[<Rn>,#+/-<imm8>]!
```

15 14 13 12 11	10 9	8	7	6 5	4	3 2 1 0	15 14 13 12	11	10	9	8	7 6 5 4 3 2 1 0
1 1 1 1 1	0 0	0	0	0 1	1	Rn	Rt	1	P	U	W	imm8

```
t = UInt(Rt);  n = UInt(Rn);  imm32 = ZeroExtend(imm8, 32);
index = (P == '1');  add = (U == '1');  wback = (W == '1');
if n == 15 then SEE LDRH (literal) on page 4-126;
if t == 15 && P == '1' && U == '0' && W == '0' then
    SEE Memory hints on page 4-14
if P == '1' && U == '1' && W == '0' then SEE LDRHT on page 4-130;
if P == '0' && W == '0' then UNDEFINED;
if BadReg(t) || (wback && n == t) then UNPREDICTABLE;
```

Architecture versions

Encodings T1, T2 All versions of the Thumb instruction set.

Encodings T3, T4 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

LDRH<c><q> <Rt>, [<Rn> {, #+/-<imm>}]	Offset: index==TRUE, wback==FALSE
LDRH<c><q> <Rt>, [<Rn>, #+/-<imm>]!	Pre-indexed: index==TRUE, wback==TRUE
LDRH<c><q> <Rt>, [<Rn>], #+/-<imm>	Post-indexed: index==FALSE, wback==TRUE

where:

<c><q> See *Standard assembler syntax fields* on page 4-6.

<Rt> Specifies the destination register.

<Rn> Specifies the base register. This register is allowed to be the SP. If this register is the PC, see *LDRH (literal)* on page 4-126.

+/- Is + or omitted to indicate that the immediate offset is added to the base register value (add == TRUE), or – to indicate that the offset is to be subtracted (add == FALSE). Different instructions are generated for #0 and #-0.

<imm> Specifies the immediate offset added to or subtracted from the value of <Rn> to form the address. For the offset addressing syntax, <imm> can be omitted, meaning an offset of 0.

The pre-UAL syntax LDR<c>H is equivalent to LDRH<c>.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    offset_addr = if add then (R[n] + imm32) else (R[n] - imm32);
    address = if index then offset_addr else R[n];
    if wback then R[n] = offset_addr;
    R[t] = ZeroExtend(MemU[address,2], 32);
```

Exceptions

Data Abort.

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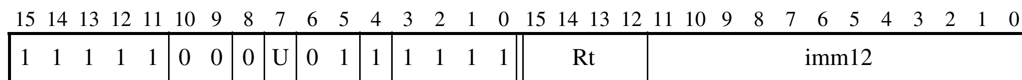
4.6.56 LDRH (literal)

Load Register Halfword (literal) calculates an address from the PC value and an immediate offset, loads a halfword from memory, zero-extends it to form a 32-bit word, and writes it to a register. See *Memory accesses* on page 4-13 for information about memory accesses.

Encoding

T1 `LDRH<c> <Rt>,[PC,#+/-<imm12>]`




```
t = UInt(Rt);  imm32 = ZeroExtend(imm12, 32);  add = (U == '1');
if t == 15 then SEE Memory hints on page 4-14;
if t == 13 then UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

`LDRH<c><q>  <Rt>, <label>`	Normal form
`LDRH<c><q>  <Rt>, [PC, #+/-<imm>]`	Alternative form

where:

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<Rd>` Specifies the destination register.

`<label>` Specifies the label of the literal data item that is to be loaded into `<Rt>`. The assembler calculates the required value of the offset from the `Align(PC,4)` value of the `ADR` instruction to this label.

If the offset is positive, encoding T1 is permitted with `imm32` equal to the offset and `add == TRUE`. Allowed values of the offset are 0 to 4095.

If the offset is negative, encoding T1 is permitted with `imm32` equal to minus the offset and `add == FALSE`. Allowed values of the offset are -4095 to -1.

In the alternative syntax form:

`+/-` Is + or omitted to indicate that the immediate offset is added to the `Align(PC, 4)` value (`add == TRUE`), or – to indicate that the offset is to be subtracted (`add == FALSE`). Different instructions are generated for `#0` and `#-0`.

`<imm>` Specifies the immediate offset added to or subtracted from the `Align(PC, 4)` value of the instruction to form the address. Allowed values are 0 to 4095.

——— Note ———

It is recommended that the alternative syntax forms are avoided where possible. However, the only possible syntax for encoding T1 with the U bit and all immediate bits zero is `LDRH<c><q> <Rt>,[PC,#0]`.

———————————

The pre-UAL syntax `LDR<c>H` is equivalent to `LDRH<c>`.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    base = Align(PC,4);
    address = if add then (base + imm32) else (base - imm32);
    R[t] = ZeroExtend(MemU[address,2], 32);
```

Exceptions

Data Abort.

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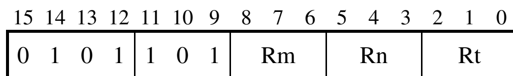
4.6.57 LDRH (register)

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 to form a 32-bit word, and writes it to a register. The offset register value can be shifted left by 0, 1, 2, or 3 bits. See *Memory accesses* on page 4-13 for information about memory accesses.

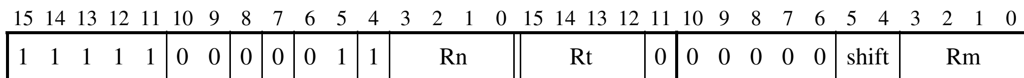
Encoding

T1 LDRH<c> <Rt>,[<Rn>,<Rm>]




```
t = UInt(Rt);  n = UInt(Rn);  m = UInt(Rm);
(shift_t, shift_n) = (SRType_None, 0);
```

T2 LDRH<c>.W <Rt>,[<Rn>,<Rm>{,LSL #<shift>}]




```
t = UInt(Rt);  n = UInt(Rn);  m = UInt(Rm);
(shift_t, shift_n) = (SRType_LSL, UInt(shift));
if n == 15 then SEE LDRH (literal) on page 4-126;
if t == 15 then SEE Memory hints on page 4-14;
if t == 13 || BadReg(m) then UNPREDICTABLE;;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set.

Encoding T2 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

```
LDRH<c><q>  <Rt>, [<Rn>, <Rm> {, LSL #<shift>}]
```

where:

<c><q> See *Standard assembler syntax fields* on page 4-6.

<Rn> Specifies the register that contains the base value. This register is allowed to be the SP.

<Rm> Contains the offset that is shifted left and added to the value of <Rn> to form the address.

<shift> Specifies the number of bits the value from <Rm> is shifted left, in the range 0-3. If this option is omitted, a shift by 0 is assumed and both encodings are permitted. If this option is specified, only encoding T2 is permitted.

The pre-UAL syntax LDR<c>H is equivalent to LDRH<c>.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    address = R[n] + LSL(R[m], shift_n);
    R[t] = ZeroExtend(MemU[address,2], 32);
```

Exceptions

Data Abort.

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4.6.58 LDRHT

Load Register Halfword Unprivileged calculates an address from a base register value and an immediate offset, loads a halfword from memory, zero-extends it to form a 32-bit word, and writes it to a register. See *Memory accesses* on page 4-13 for information about memory accesses.

The memory access is restricted as if the processor were running in User mode. (This makes no difference if the processor is actually running in User mode.)

Encoding

T1 `LDRHT<c> <Rt>,[<Rn>,#<imm8>]`

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	1	1	0	0	0	0	0	1	1	Rn				Rt				1	1	1	0	imm8							

```
t = UInt(Rt);  n = UInt(Rn);  imm32 = ZeroExtend(imm8, 32);
if n == 15 then SEE LDRH (literal) on page 4-126;
if BadReg(t) then UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

```
LDRHT<c><q>  <Rt>, [<Rn> {, #<imm>}]
```

where:

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<Rt>` Specifies the destination register.

`<Rn>` Specifies the base register. This register is allowed to be the SP.

`<imm>` Specifies the immediate offset added to the value of `<Rn>` to form the address. `<imm>` can be omitted, meaning an offset of 0.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    address = R[n] + imm32;
    R[t] = ZeroExtend(MemU_unpriv[address,2], 32);
```

Exceptions

Data Abort.

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4.6.59 LDRSB (immediate)

Load Register Signed Byte (immediate) calculates an address from a base register value and an immediate offset, loads a byte from memory, sign-extends it to form a 32-bit word, and writes it to a register. It can use offset, post-indexed, or pre-indexed addressing. See *Memory accesses* on page 4-13 for information about memory accesses.

Encoding

T1

```
LDRSB<c> <Rt,[<Rn>,#<imm12>]
```

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	1	1	0	0	1	1	0	0	1	Rn				Rt				imm12											

```
t = UInt(Rt);  n = UInt(Rn);  imm32 = ZeroExtend(imm12, 32); index = TRUE;
add = TRUE;  wback = FALSE;
if t == 15 then SEE PLI (immediate) on page 4-205;
if n == 15 then SEE LDRSB (literal) on page 4-134;
if t == 13 then UNPREDICTABLE;
```

T2

```
LDRSB<c> <Rt>,[<Rn>,#-<imm8>]
LDRSB<c> <Rt>,[<Rn>],#+/-<imm8>
LDRSB<c> <Rt>,[<Rn>,#+/-<imm8>]!
```

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	1	1	0	0	1	0	0	0	1	Rn				Rt				1	P	U	W	imm8							

```
t = UInt(Rt);  n = UInt(Rn);  imm32 = ZeroExtend(imm8, 32); index = (P == '1');
add = (U == '1');  wback = (W == '1');
if n == 15 then SEE LDRSB (literal) on page 4-134;
if t == 15 && P == '1' && U == '0' && W == '0' then
    SEE PLI (immediate) on page 4-205;
if P == '1' && U == '1' && W == '0' then SEE LDRSBT on page 4-138;
if P == '0' && W == '0' then UNDEFINED;
if BadReg(t) || (wback && n == t) then UNPREDICTABLE;
```

Architecture versions

Encodings T1, T2 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

`LDRSB<c><q> <Rt>, [<Rn> {, #+/-<imm>}]`	Offset: `index==TRUE`, `wback==FALSE`
`LDRSB<c><q> <Rt>, [<Rn>, #+/-<imm>]!`	Pre-indexed: `index==TRUE`, `wback==TRUE`
`LDRSB<c><q> <Rt>, [<Rn>], #+/-<imm>`	Post-indexed: `index==FALSE`, `wback==TRUE`

where:

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<Rt>` Specifies the destination register.

`<Rn>` Specifies the base register. This register is allowed to be the SP. If this register is the PC, see *LDRSB (literal)* on page 4-134.

`+/-` Is + or omitted to indicate that the immediate offset is added to the base register value (`add == TRUE`), or – to indicate that the offset is to be subtracted (`add == FALSE`). Different instructions are generated for `#0` and `#-0`.

`<imm>` Specifies the immediate offset added to or subtracted from the value of `<Rn>` to form the address. For the offset addressing syntax, `<imm>` can be omitted, meaning an offset of 0.

The pre-UAL syntax `LDR<c>SB` is equivalent to `LDRSB<c>`.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    offset_addr = if add then (R[n] + imm32) else (R[n] - imm32);
    address = if index then offset_addr else R[n];
    if wback then R[n] = offset_addr;
    R[t] = SignExtend(MemU[address,1], 32);
```

Exceptions

Data Abort.

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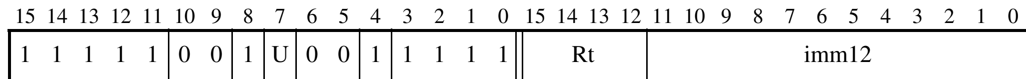
4.6.60 LDRSB (literal)

Load Register Signed Byte (literal) calculates an address from the PC value and an immediate offset, loads a byte from memory, sign-extends it to form a 32-bit word, and writes it to a register. See *Memory accesses* on page 4-13 for information about memory accesses.

Encoding

T1 `LDRSB<c> <Rt>,[PC,#+/-<imm12>]`




```
t = UInt(Rt);  imm32 = ZeroExtend(imm12, 32);  add = (U == '1');
if t == 15 then SEE PLI (immediate) on page 4-205;
if t == 13 then UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

`LDRSB<c><q>  <Rt>, <label>`	Normal form
`LDRSB<c><q>  <Rt>, [PC, #+/-<imm>]`	Alternative form

where:

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<Rd>` Specifies the destination register.

`<label>` Specifies the label of the literal data item that is to be loaded into `<Rt>`. The assembler calculates the required value of the offset from the `Align(PC,4)` value of the `ADR` instruction to this label.

If the offset is positive, encoding T1 is permitted with `imm32` equal to the offset and `add == TRUE`. Allowed values of the offset are 0 to 4095.

If the offset is negative, encoding T1 is permitted with `imm32` equal to minus the offset and `add == FALSE`. Allowed values of the offset are -4095 to -1.

In the alternative syntax form:

`+/-` Is + or omitted to indicate that the immediate offset is added to the `Align(PC, 4)` value (`add == TRUE`), or – to indicate that the offset is to be subtracted (`add == FALSE`). Different instructions are generated for `#0` and `#-0`.

`<imm>` Specifies the immediate offset added to or subtracted from the `Align(PC,4)` value of the instruction to form the address. Allowed values are 0 to 4095.

Note

It is recommended that the alternative syntax forms are avoided where possible. However, the only possible syntax for encoding T1 with the U bit and all immediate bits zero is `LDRSB<c><q> <Rt>,[PC,#0]`.

The pre-UAL syntax `LDR<c>SB` is equivalent to `LDRSB<c>`.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    base = Align(PC,4);
    address = if add then (base + imm32) else (base - imm32);
    R[t] = SignExtend(MemU[address,1], 32);
```

Exceptions

Data Abort.

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4.6.61 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 to form a 32-bit word, and writes it to a register. The offset register value can be shifted left by 0, 1, 2, or 3 bits. See *Memory accesses* on page 4-13 for information about memory accesses.

Encoding

T1 `LDRSB<c> <Rt>,[<Rn>,<Rm>]`

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0	1	0	1	0	1	1	Rm			Rn			Rt		

```
t = UInt(Rt);  n = UInt(Rn);  m = UInt(Rm);
(shift_t, shift_n) = (SRType_None, 0);
```

T2 `LDRSB<c>.W <Rt>,[<Rn>,<Rm>{,LSL #<shift>}]`

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	1	1	0	0	1	0	0	0	1	Rn				Rt				0	0	0	0	0	0	shift		Rm			

```
t = UInt(Rt);  n = UInt(Rn);  m = UInt(Rm);
(shift_t, shift_n) = (SRType_LSL, UInt(shift));
if t == 15 then SEE PLI (register) on page 4-207;
if n == 15 then SEE LDRSB (literal) on page 4-134;
if t == 13 || BadReg(m) then UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set.

Encoding T2 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

```
LDRSB<c><q>  <Rt>, [<Rn>, <Rm> {, LSL #<shift>}]
```

where:

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<Rn>` Specifies the register that contains the base value. This register is allowed to be the SP.

`<Rm>` Contains the offset that is shifted left and added to the value of `<Rn>` to form the address.

`<shift>` Specifies the number of bits the value from `<Rm>` is shifted left, in the range 0-3. If this option is omitted, a shift by 0 is assumed and both encodings are permitted. If this option is specified, only encoding T2 is permitted.

The pre-UAL syntax `LDR<c>SB` is equivalent to `LDRSB<c>`.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    address = R[n] + LSL(R[m], shift_n);
    R[t] = SignExtend(MemU[address,1], 32);
```

Exceptions

Data Abort.

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4.6.62 LDRSBT

Load Register Signed Byte Unprivileged calculates an address from a base register value and an immediate offset, loads a byte from memory, sign-extends it to form a 32-bit word, and writes it to a register. See *Memory accesses* on page 4-13 for information about memory accesses.

The memory access is restricted as if the processor were running in User mode. (This makes no difference if the processor is actually running in User mode.)

Encoding

T1 `LDRSBT<c> <Rt>,[<Rn>,#<imm8>]`

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	1	1	0	0	1	0	0	0	1	Rn				Rt				1	1	1	0	imm8							

```
t = UInt(Rt);  n = UInt(Rn);  imm32 = ZeroExtend(imm8, 32);
if n == 15 then SEE LDRSB (literal) on page 4-134;
if BadReg(t) then UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

```
LDRSBT<c><q>  <Rt>, [<Rn> {, #<imm>}]
```

where:

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<Rt>` Specifies the destination register.

`<Rn>` Specifies the base register. This register is allowed to be the SP.

`<imm>` Specifies the immediate offset added to the value of `<Rn>` to form the address. `<imm>` can be omitted, meaning an offset of 0.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    address = R[n] + imm32;
    R[t] = SignExtend(MemU_unpriv[address,1], 32);
```

Exceptions

Data Abort.

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4.6.63 LDRSH (immediate)

Load Register Signed Halfword (immediate) calculates an address from a base register value and an immediate offset, loads a halfword from memory, sign-extends it to form a 32-bit word, and writes it to a register. It can use offset, post-indexed, or pre-indexed addressing. See *Memory accesses* on page 4-13 for information about memory accesses.

Encoding

T1 `LDRSH<c> <Rt,[<Rn>,#<imm12>]`

15	14	13	12	11	10	9	8	7	6	5	4	3–0	15–12	11–0
1	1	1	1	1	0	0	1	1	0	1	1	Rn	Rt	imm12

```
t = UInt(Rt);  n = UInt(Rn);  imm32 = ZeroExtend(imm12, 32);
index = TRUE;  add = TRUE;  wback = FALSE;
if n == 15 then SEE LDRSH (literal) on page 4-142;
if t == 15 then SEE Memory hints on page 4-14;
if t == 13 then UNPREDICTABLE;
```

T2 `LDRSH<c> <Rt>,[<Rn>,#-<imm8>]`

`LDRSH<c> <Rt>,[<Rn>],#+/-<imm8>`

`LDRSH<c> <Rt>,[<Rn>,#+/-<imm8>]!`

15	14	13	12	11	10	9	8	7	6	5	4	3–0	15–12	11	10	9	8	7–0
1	1	1	1	1	0	0	1	0	0	1	1	Rn	Rt	1	P	U	W	imm8

```
t = UInt(Rt);  n = UInt(Rn);  imm32 = ZeroExtend(imm8, 32);
index = (P == '1');  add = (U == '1');  wback = (W == '1');
if n == 15 then SEE LDRSH (literal) on page 4-142;
if t == 15 && P == '1' && U == '0' && W == '0' then
    SEE Memory hints on page 4-14;
if P == '1' && U == '1' && W == '0' then SEE LDRSHT on page 4-146;
if P == '0' && W == '0' then UNDEFINED;
if BadReg(t) || (wback && n == t) then UNPREDICTABLE;
```

Architecture versions

Encodings T1, T2 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

`LDRSH<c><q> <Rt>, [<Rn> {, #+/-<imm>}]`	Offset: `index==TRUE`, `wback==FALSE`
`LDRSH<c><q> <Rt>, [<Rn>, #+/-<imm>]!`	Pre-indexed: `index==TRUE`, `wback==TRUE`
`LDRSH<c><q> <Rt>, [<Rn>], #+/-<imm>`	Post-indexed: `index==FALSE`, `wback==TRUE`

where:

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<Rt>` Specifies the destination register.

`<Rn>` Specifies the base register. This register is allowed to be the SP. If this register is the PC, see *LDRSH (literal)* on page 4-142.

`+/-` Is + or omitted to indicate that the immediate offset is added to the base register value (`add == TRUE`), or – to indicate that the offset is to be subtracted (`add == FALSE`). Different instructions are generated for `#0` and `#-0`.

`<imm>` Specifies the immediate offset added to or subtracted from the value of `<Rn>` to form the address. For the offset addressing syntax, `<imm>` can be omitted, meaning an offset of 0.

The pre-UAL syntax `LDR<c>SH` is equivalent to `LDRSH<c>`.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    offset_addr = if add then (R[n] + imm32) else (R[n] - imm32);
    address = if index then offset_addr else R[n];
    if wback then R[n] = offset_addr;
    R[t] = SignExtend(MemU[address,2], 32);
```

Exceptions

Data Abort.

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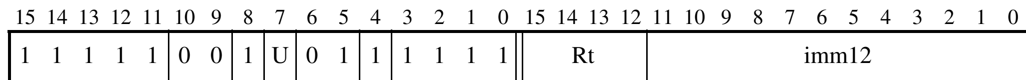
4.6.64 LDRSH (literal)

Load Register Signed Halfword (literal) calculates an address from the PC value and an immediate offset, loads a halfword from memory, sign-extends it to form a 32-bit word, and writes it to a register. See *Memory accesses* on page 4-13 for information about memory accesses.

Encoding

T1 `LDRSH<c> <Rt>,[PC,#+/-<imm12>]`




```
t = UInt(Rt);  imm32 = ZeroExtend(imm12, 32);  add = (U == '1');
if t == 15 then SEE Memory hints on page 4-14;
if t == 13 then UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

`LDRSH<c><q>  <Rt>, <label>`	Normal form
`LDRSH<c><q>  <Rt>, [PC, #+/-<imm>]`	Alternative form

where:

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<Rd>` Specifies the destination register.

`<label>` Specifies the label of the literal data item that is to be loaded into `<Rt>`. The assembler calculates the required value of the offset from the `Align(PC,4)` value of the `ADR` instruction to this label.

If the offset is positive, encoding T1 is permitted with `imm32` equal to the offset and `add == TRUE`. Allowed values of the offset are 0 to 4095.

If the offset is negative, encoding T1 is permitted with `imm32` equal to minus the offset and `add == FALSE`. Allowed values of the offset are -4095 to -1.

In the alternative syntax form:

`+/-` Is + or omitted to indicate that the immediate offset is added to the `Align(PC, 4)` value (`add == TRUE`), or – to indicate that the offset is to be subtracted (`add == FALSE`). Different instructions are generated for `#0` and `#-0`.

`<imm>` Specifies the immediate offset added to or subtracted from the `Align(PC, 4)` value of the instruction to form the address. Allowed values are 0 to 4095.

Note

It is recommended that the alternative syntax forms are avoided where possible. However, the only possible syntax for encoding T1 with the U bit and all immediate bits zero is `LDRSH<c><q> <Rt>,[PC,#0]`.

The pre-UAL syntax `LDR<c>SH` is equivalent to `LDRSH<c>`.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    base = Align(PC,4);
    address = if add then (base + imm32) else (base - imm32);
    R[t] = SignExtend(MemU[address,2], 32);
```

Exceptions

Data Abort.

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4.6.65 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 to form a 32-bit word, and writes it to a register. The offset register value can be shifted left by 0, 1, 2, or 3 bits. See *Memory accesses* on page 4-13 for information about memory accesses.

Encoding

T1 `LDRSH<c> <Rt>,[<Rn>,<Rm>]`

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0	1	0	1	1	1	1	Rm			Rn			Rt		

```
t = UInt(Rt);  n = UInt(Rn);  m = UInt(Rm);
(shift_t, shift_n) = (SRType_None, 0);
```

T2 `LDRSH<c>.W <Rt>,[<Rn>,<Rm>{,LSL #<shift>}]`

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	1	1	0	0	1	0	0	1	1	Rn				Rt				0	0	0	0	0	0	shift		Rm			

```
t = UInt(Rt);  n = UInt(Rn);  m = UInt(Rm);
(shift_t, shift_n) = (SRType_LSL, UInt(shift));
if n == 15 then SEE LDRSH (literal) on page 4-142;
if t == 15 then SEE Memory hints on page 4-14;
if t == 13 || BadReg(m) then UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set.

Encoding T2 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

```
LDRSH<c><q>  <Rt>, [<Rn>, <Rm> {, LSL #<shift>}]
```

where:

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<Rt>` Specifies the destination register.

`<Rn>` Specifies the register that contains the base value. This register is allowed to be the SP.

`<Rm>` Contains the offset that is shifted left and added to the value of `<Rn>` to form the address.

`<shift>` Specifies the number of bits the value from `<Rm>` is shifted left, in the range 0-3. If this option is omitted, a shift by 0 is assumed and both encodings are permitted. If this option is specified, only encoding T2 is permitted.

The pre-UAL syntax `LDR<c>SH` is equivalent to `LDRSH<c>`.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    address = R[n] + LSL(R[m], shift_n);
    R[t] = SignExtend(MemU[address,2], 32);
```

Exceptions

Data Abort.

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4.6.66 LDRSHT

Load Register Signed Halfword Unprivileged calculates an address from a base register value and an immediate offset, loads a halfword from memory, sign-extends it to form a 32-bit word, and writes it to a register. See *Memory accesses* on page 4-13 for information about memory accesses.

The memory access is restricted as if the processor were running in User mode. (This makes no difference if the processor is actually running in User mode.)

Encoding

T1
```
LDRSHT<c> <Rt>,[<Rn>,#<imm8>]
```

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	1	1	0	0	1	0	0	1	1	Rn			

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Rt				1	1	1	0	imm8							

```
t = UInt(Rt);  n = UInt(Rn);  imm32 = ZeroExtend(imm8, 32);
if n == 15 then SEE LDRSH (literal) on page 4-142;
if BadReg(t) then UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

```
LDRSHT<c><q>  <Rt>, [<Rn> {, #<imm>}]
```

where:

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<Rt>` Specifies the destination register.

`<Rn>` Specifies the base register. This register is allowed to be the SP.

`<imm>` Specifies the immediate offset added to the value of `<Rn>` to form the address. `<imm>` can be omitted, meaning an offset of 0.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    address = R[n] + imm32;
    R[t] = SignExtend(MemU_unpriv[address,2], 32);
```

Exceptions

Data Abort.

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4.6.67 LDRT

Load Register Unprivileged calculates an address from a base register value and an immediate offset, loads a word from memory, and writes it to a register. See *Memory accesses* on page 4-13 for information about memory accesses.

The memory access is restricted as if the processor were running in User mode. (This makes no difference if the processor is actually running in User mode.)

Encoding

T1 `LDRT<c> <Rt>,[<Rn>,#<imm8>]`

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	1	1	0	0	0	0	1	0	1	Rn				Rt				1	1	1	0	imm8							

```
t = UInt(Rt);  n = UInt(Rn);  imm32 = ZeroExtend(imm8, 32);
if n == 15 then SEE LDR (literal) on page 4-102;
if BadReg(t) then UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

```
LDRT<c><q>  <Rt>, [<Rn> {, #<imm>}]
```

where:

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<Rt>` Specifies the destination register.

`<Rn>` Specifies the base register. This register is allowed to be the SP.

`<imm>` Specifies the immediate offset added to the value of `<Rn>` to form the address. `<imm>` can be omitted, meaning an offset of 0.

The pre-UAL syntax `LDR<c>T` is equivalent to `LDRT<c>`.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    address = R[n] + imm32;
    R[t] = MemU_unpriv[address,4];
```

Exceptions

Data Abort.

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4.6.68 LSL (immediate)

Logical Shift Left (immediate) shifts a register value left by an immediate number of bits, shifting in zeros, and writes the result to the destination register. It can optionally update the condition flags based on the result.

Encodings

T1 `LSLS <Rd>,<Rm>,#<imm5>` Outside IT block.

`LSL<c> <Rd>,<Rm>,#<imm5>` Inside IT block.

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0	0	0	0	0	imm5					Rm			Rd		

```
d = UInt(Rd);  m = UInt(Rm);  setflags = !InITBlock();
if imm5 == '00000' then SEE MOV (register) on page 4-168;
(-, shift_n) = DecodeImmShift('00', imm5);
```

T2 `LSL{S}<c>.W <Rd>,<Rm>,#<imm5>`

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	0	1	0	1	0	0	1	0	S	1	1	1	1

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
(0)	imm3			Rd				imm2		0	0	Rm			

```
d = UInt(Rd);  m = UInt(Rm);  setflags = (S == '1');
if imm3:imm2 == '00000' then SEE MOV (register) on page 4-168;
(-, shift_n) = DecodeImmShift('00', imm3:imm2);
if BadReg(d) || BadReg(m) THEN UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set.

Encoding T2 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

```
LSL{S}<c><q>  <Rd>, <Rm>, #<imm5>
```

where:

`S` If present, specifies that the instruction updates the flags. Otherwise, the instruction does not update the flags.

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<Rd>` Specifies the destination register.

`<Rm>` Specifies the register that contains the first operand.

`<imm5>` Specifies the shift amount, in the range 0 to 31. See *Constant shifts applied to a register* on page 4-10.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    (result, carry) = Shift_C(R[m], SRType_LSL, shift_n, APSR.C);
    R[d] = result;
    if setflags then
        APSR.N = result<31>;
        APSR.Z = IsZeroBit(result);
        APSR.C = carry;
        // APSR.V unchanged
```

Exceptions

None.

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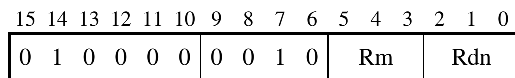
4.6.69 LSL (register)

Logical Shift Left (register) shifts a register value left by a variable number of bits, shifting in zeros, and writes the result to the destination register. The variable number of bits is read from the bottom byte of a register. It can optionally update the condition flags based on the result.

Encodings

T1

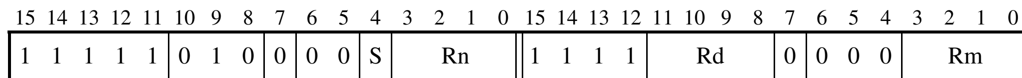
```
LSLS    <Rdn>,<Rm>        Outside IT block.
LSL<c>  <Rdn>,<Rm>        Inside IT block.
```




```
d = UInt(Rdn);  n = UInt(Rdn);  m = UInt(Rm);  setflags = !InITBlock();
```

T2

```
LSL{S}<c>.W <Rd>,<Rn>,<Rm>
```




```
d = UInt(Rd);  n = UInt(Rn);  m = UInt(Rm);  setflags = (S == '1');
if BadReg(d) || BadReg(n) || BadReg(m) then UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set

Encoding T2 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

```
LSL{S}<c><q>  <Rd>, <Rn>, <Rm>
```

where:

`S` If present, specifies that the instruction updates the flags. Otherwise, the instruction does not update the flags.

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<Rd>` Specifies the destination register.

`<Rn>` Specifies the register that contains the first operand.

`<Rm>` Specifies the register whose bottom byte contains the amount to shift by.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    shift_n = UInt(R[m]<7:0>);
    (result, carry) = Shift_C(R[n], SRType_LSL, shift_n, APSR.C);
    R[d] = result;
    if setflags then
        APSR.N = result<31>;
        APSR.Z = IsZeroBit(result);
        APSR.C = carry;
        // APSR.V unchanged
```

Exceptions

None.

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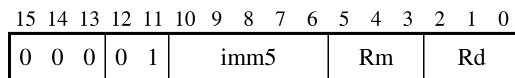
4.6.70 LSR (immediate)

Logical Shift Right (immediate) shifts a register value right by an immediate number of bits, shifting in zeros, and writes the result to the destination register. It can optionally update the condition flags based on the result.

Encodings

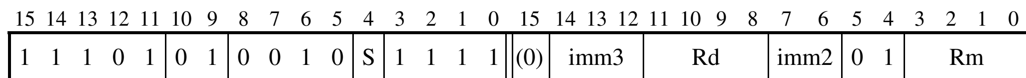
T1 `LSRS <Rd>,<Rm>,#<imm5>` Outside IT block.

`LSR<c> <Rd>,<Rm>,#<imm5>` Inside IT block.




```
d = UInt(Rd);  m = UInt(Rm);  setflags = !InITBlock();
(-, shift_n) = DecodeImmShift('01', imm5);
```

T2 `LSR{S}<c>.W <Rd>,<Rm>,#<imm5>`




```
d = UInt(Rd);  m = UInt(Rm);  setflags = (S == '1');
(-, shift_n) = DecodeImmShift('01', imm3:imm2);
if BadReg(d) || BadReg(m) THEN UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set.

Encoding T2 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

```
LSR{S}<c><q>  <Rd>, <Rm>, #<imm5>
```

where:

`S` If present, specifies that the instruction updates the flags. Otherwise, the instruction does not update the flags.

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<Rd>` Specifies the destination register.

`<Rm>` Specifies the register that contains the first operand.

`<imm5>` Specifies the shift amount, in the range 1 to 32. See *Constant shifts applied to a register* on page 4-10.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    (result, carry) = Shift_C(R[m], SRType_LSR, shift_n, APSR.C);
    R[d] = result;
    if setflags then
        APSR.N = result<31>;
        APSR.Z = IsZeroBit(result);
        APSR.C = carry;
        // APSR.V unchanged
```

Exceptions

None.

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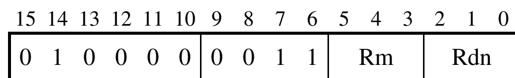
4.6.71 LSR (register)

Logical Shift Left (register) shifts a register value right by a variable number of bits, shifting in zeros, and writes the result to the destination register. The variable number of bits is read from the bottom byte of a register. It can optionally update the condition flags based on the result.

Encodings

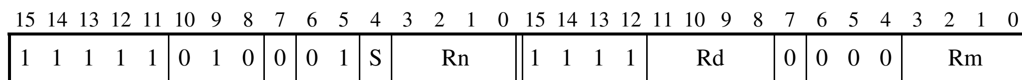
T1 LSRS <Rdn>,<Rm> Outside IT block.

LSR<c> <Rdn>,<Rm> Inside IT block.




```
d = UInt(Rdn);  n = UInt(Rdn);  m = UInt(Rm);  setflags = !InITBlock();
```

T2 LSR{S}<c>.W <Rd>,<Rn>,<Rm>




```
d = UInt(Rd);  n = UInt(Rn);  m = UInt(Rm);  setflags = (S == '1');
if BadReg(d) || BadReg(n) || BadReg(m) then UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set

Encoding T2 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

`LSR{S}<c><q>  <Rd>, <Rn>, <Rm>`

where:

`S` If present, specifies that the instruction updates the flags. Otherwise, the instruction does not update the flags.

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<Rd>` Specifies the destination register.

`<Rn>` Specifies the register that contains the first operand.

`<Rm>` Specifies the register whose bottom byte contains the amount to shift by.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    shift_n = UInt(R[m]<7:0>);
    (result, carry) = Shift_C(R[n], SRType_LSR, shift_n, APSR.C);
    R[d] = result;
    if setflags then
        APSR.N = result<31>;
        APSR.Z = IsZeroBit(result);
        APSR.C = carry;
        // APSR.V unchanged
```

Exceptions

None.

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4.6.72 MCR, MCR2

Move to Coprocessor from ARM Register passes the value of an ARM register to a coprocessor.

If no coprocessor can execute the instruction, an Undefined Instruction exception is generated.

Encodings

T1 `MCR<c> <coproc>,<opc1>,<Rt>,<CRn>,<CRm>{,<opc2>}`

15 14 13	12	11 10 9 8	7 6 5	4	3 2 1 0	15 14 13 12	11 10 9 8	7 6 5	4	3 2 1 0
1 1 1	C	1 1 1 0	opc1	0	CRn	Rt	coproc	opc2	1	CRm

```
t = UInt(Rt); cp = UInt(coproc); opc0 = C; // MCR if C == '0', MCR2 if C == '1'
if BadReg(t) then UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

```
MCR{2}<c><q>  <coproc>, #<opc1>, <Rt>, <CRn>, <CRm>{, #<opc2>}
```

where:

2	If specified, selects the C == 1 form of the encoding. If omitted, selects the C == 0 form.
`<c><q>`	See *Standard assembler syntax fields* on page 4-6.
`<coproc>`	Specifies the name of the coprocessor. The standard generic coprocessor names are p0, p1, ..., p15.
`<opc1>`	Is a coprocessor-specific opcode in the range 0 to 7.
`<Rt>`	Is the ARM register whose value is transferred to the coprocessor.
`<CRn>`	Is the destination coprocessor register.
`<CRm>`	Is an additional destination coprocessor register.
`<opc2>`	Is a coprocessor-specific opcode in the range 0-7. If it is omitted, `<opc2>` is assumed to be 0.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    if !Coproc_Accepted(cp, ThisInstr()) then
        RaiseCoprocessorException();
    else
        Coproc_SendOneWord(R[t], cp, ThisInstr());
```

Exceptions

Undefined Instruction.

Notes

Coprocessor fields Only instruction bits[31:24], bit[20], bits[15:8], and bit[4] are defined by the ARM architecture. The remaining fields are recommendations.

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4.6.73 MCRR, MCRR2

Move to Coprocessor from two ARM Registers passes the values of two ARM registers to a coprocessor.

If no coprocessor can execute the instruction, an Undefined Instruction exception is generated.

Encodings

T1 MCRR<c> <coproc>,<opc1>,<Rt>,<Rt2>,<CRm>

<table>
<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><td>7</td><td>6</td><td>5</td><td>4</td><td>3</td><td>2</td><td>1</td><td>0</td><td>15</td><td>14</td><td>13</td><td>12</td><td>11</td><td>10</td><td>9</td><td>8</td><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>
<tr><td>1</td><td>1</td><td>1</td><td>C</td><td>1</td><td>1</td><td>0</td><td>0</td><td>0</td><td>1</td><td>0</td><td>0</td><td colspan="4">Rt2</td><td colspan="4">Rt</td><td colspan="4">coproc</td><td colspan="4">opc1</td><td colspan="4">CRm</td></tr>
</table>

```
t = UInt(Rt);  t2 = UInt(Rt2);
cp = UInt(coproc);  opc0 = C;  // MCRR if C == '0', MCRR2 if C == '1'
if BadReg(t) || BadReg(t2) then UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

```
MCRR{2}<c><q>  <coproc>, #<opc1>, <Rt>, <Rt2>, <CRm>
```

where:

2	If specified, selects the C ==1 form of the encoding. If omitted, selects the C == 0 form.
<c><q>	See *Standard assembler syntax fields* on page 4-6.
<coproc>	Specifies the name of the coprocessor. The standard generic coprocessor names are p0, p1, ..., p15.
<opc1>	Is a coprocessor-specific opcode in the range 0 to 15.
<Rt>	Is the first ARM register whose value is transferred to the coprocessor.
<Rt2>	Is the second ARM register whose value is transferred to the coprocessor.
<CRm>	Is the destination coprocessor register.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    if !Coproc_Accepted(cp, ThisInstr()) then
        RaiseCoprocessorException();
    else
        Coproc_SendTwoWords(R[t], R[t2], cp, ThisInstr());
```

Exceptions

Undefined Instruction.

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4.6.74 MLA

Multiply Accumulate multiplies two register values, and adds a third register value. The least significant 32 bits of the result are written to the destination register. These 32 bits do not depend on whether signed or unsigned calculations are performed.

Encodings

T1 MLA<c> <Rd>,<Rn>,<Rm>,<Ra>

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	1	1	0	1	1	0	0	0	0	Rn				Ra				Rd				0	0	0	0	Rm			

```
d = UInt(Rd);  n = UInt(Rn);  m = UInt(Rm);  a = UInt(Ra);
if a == 15 then SEE MUL on page 4-181;
if BadReg(d) || BadReg(n) || BadReg(m) || a == 13 then UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

```
MLA<c><q>  <Rd>, <Rn>, <Rm>, <Ra>
```

where:

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<Rd>` Specifies the destination register.

`<Rn>` Specifies the register that contains the first operand.

`<Rm>` Specifies the register that contains the second operand.

`<Ra>` Specifies the register containing the accumulate value.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    operand1 = SInt(R[n]);  // or UInt(R[n]) without functionality change
    operand2 = SInt(R[m]);  // or UInt(R[m]) without functionality change
    addend   = SInt(R[a]);  // or UInt(R[a]) without functionality change
    result = operand1 * operand2 + addend;
    R[d] = result<31:0>;
```

Exceptions

None.

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4.6.75 MLS

Multiply and Subtract multiplies two register values, and subtracts the least significant 32 bits of the result from a third register value. These 32 bits do not depend on whether signed or unsigned calculations are performed. The result is written to the destination register.

Encodings

T1 MLS<c> <Rd>,<Rn>,<Rm>,<Ra>

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	1	1	0	1	1	0	0	0	0	Rn				Ra				Rd				0	0	0	1	Rm			

```
d = UInt(Rd);  n = UInt(Rn);  m = UInt(Rm);  a = UInt(Ra);
if BadReg(d) || BadReg(n) || BadReg(m) || BadReg(a) then UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

```
MLS<c><q>  <Rd>, <Rn>, <Rm>, <Ra>
```

where:

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<Rd>` Specifies the destination register.

`<Rn>` Specifies the register that contains the first operand.

`<Rm>` Specifies the register that contains the second operand.

`<Ra>` Specifies the register containing the accumulate value.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    operand1 = SInt(R[n]);  // or UInt(R[n]) without functionality change
    operand2 = SInt(R[m]);  // or UInt(R[m]) without functionality change
    addend   = SInt(R[a]);  // or UInt(R[a]) without functionality change
    result = addend - operand1 * operand2;
    R[d] = result<31:0>;
```

Exceptions

None.

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4.6.76 MOV (immediate)

Move (immediate) writes an immediate value to the destination register. It can optionally update the condition flags based on the value.

Encodings

T1 `MOVS <Rd>,#<imm8>` Outside IT block.

`MOV<c> <Rd>,#<imm8>` Inside IT block.

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0	0	1	0	0	Rd			imm8							

```
d = UInt(Rd);  setflags = !InITBlock();
(imm32, carry) = (ZeroExtend(imm8, 32), APSR.C);
```

T2 `MOV{S}<c>.W <Rd>,#<const>`

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	1	0	i	0	0	0	1	0	S	1	1	1	1	0	imm3			Rd				imm8							

```
d = UInt(Rd);  setflags = (S == '1');
(imm32, carry) = ThumbExpandImmWithC(i:imm3:imm8, APSR.C);
if BadReg(d) then UNPREDICTABLE;
```

T3 `MOVW<c> <Rd>,#<imm16>`

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	1	0	i	1	0	0	1	0	0	imm4				0	imm3			Rd				imm8							

```
d = UInt(Rd);  setflags = FALSE;
(imm32, carry) = (ZeroExtend(imm4:i:imm3:imm8, 32), APSR.C);
    // carry is a "don't care" value
if BadReg(d) then UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set.

Encodings T2, T3 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

`MOV{S}<c><q>  <Rd>, #<const>`	All encodings permitted
`MOVW<c><q>  <Rd>, #<const>`	Only encoding T3 permitted

where:

`S` If present, specifies that the instruction updates the flags. Otherwise, the instruction does not update the flags.

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<Rd>` Specifies the destination register.

`<const>` Specifies the immediate value to be placed in `<Rd>`. The range of allowed values is 0-255 for encoding T1 and 0-65535 for encoding T3. See *Immediate constants* on page 4-8 for the range of allowed values for encoding T2.

When both 32-bit encodings are available for an instruction, encoding T2 is preferred to encoding T3 (if encoding T3 is required, use the `MOVW` syntax).

The pre-UAL syntax `MOV<c>S` is equivalent to `MOVS<c>`.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    result = imm32;
    R[d] = result;
    if setflags then
        APSR.N = result<31>;
        APSR.Z = IsZeroBit(result);
        APSR.C = carry;
        // APSR.V unchanged
```

Exceptions

None.

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4.6.77 MOV (register)

Move (register) copies a value from a register to the destination register. It can optionally update the condition flags based on the value.

Encodings

T1 `MOV<c> <Rd>,<Rm>`

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0	1	0	0	0	1	1	0	D	Rm				Rd		

```
d = UInt(D:Rd);  m = UInt(Rm);  setflags = FALSE;
if d == 15 && InITBlock() && !LastInITBlock() then UNPREDICTABLE;
```

T2 `MOVS <Rd>,<Rm>` Not allowed inside IT block

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	Rm			Rd		

```
d = UInt(Rd);  m = UInt(Rm);  setflags = TRUE;
if InITBlock() then UNPREDICTABLE;
```

T3 `MOV{S}<c>.W <Rd>,<Rm>`

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	0	1	0	1	0	0	1	0	S	1	1	1	1

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
(0)	0	0	0	Rd				0	0	0	0	Rm			

```
d = UInt(Rd);  m = UInt(Rm);  setflags = (S == '1');
if (BadReg(d) || BadReg(m)) && setflags THEN UNPREDICTABLE
if BadReg(d) && BadReg(m) then UNPREDICTABLE;
if d == 15 && InITBlock() && !LastInITBlock() then UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set. Before Thumb-2, encoding T1 required that either `<Rdn>`, or `<Rm>`, or both, had to be from {R8-R12, SP, LR}.

Encoding T2 All versions of the Thumb instruction set. Before UAL, this encoding was documented as an `LSL` instruction with an immediate shift by 0.

Encoding T3 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

```
MOV{S}<c><q>  <Rd>, <Rm>
```

where:

`S` If present, specifies that the instruction updates the flags. Otherwise, the instruction does not update the flags.

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<Rd>` Specifies the destination register. This register is permitted to be SP or PC, provided S is not specified and `<Rm>` is neither of SP and PC. If it is the PC, it causes a branch to the address (data) moved to the PC, and the instruction must either be outside an IT block or the last instruction of an IT block.

`<Rm>` Specifies the source register. This register is permitted to be SP or PC, provided S is not specified and `<Rd>` is neither of SP and PC.

The pre-UAL syntax `MOV<c>S` is equivalent to `MOVS<c>`.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    result = R[m];    if d == 15 then
        ALUWritePC(result);  // setflags is always FALSE here
    else
        R[d] = result;
        if setflags then
            APSR.N = result<31>;
            APSR.Z = IsZeroBit(result);
            APSR.C = carry;
            // APSR.V unchanged
```

Exceptions

None.

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4.6.78 MOV (shifted register)

Move (shifted register) is a synonym for ASR, LSL, LSR, ROR, and RRX.

See the following sections for details:

- *ASR (immediate)* on page 4-34
- *ASR (register)* on page 4-36
- *LSL (immediate)* on page 4-150
- *LSL (register)* on page 4-152
- *LSR (immediate)* on page 4-154
- *LSR (register)* on page 4-156
- *ROR (immediate)* on page 4-243
- *ROR (register)* on page 4-245
- *RRX* on page 4-247.

Assembler syntax

Table 4-2 shows the equivalences between MOV (shifted register) and other instructions.

Table 4-2 MOV (shift, register shift) equivalences)

MOV instruction	Canonical form
`MOV{S} <Rd>,<Rm>,ASR #<n>`	`ASR{S} <Rd>,<Rm>,#<n>`
`MOV{S} <Rd>,<Rm>,LSL #<n>`	`LSL{S} <Rd>,<Rm>,#<n>`
`MOV{S} <Rd>,<Rm>,LSR #<n>`	`LSR{S} <Rd>,<Rm>,#<n>`
`MOV{S} <Rd>,<Rm>,ROR #<n>`	`ROR{S} <Rd>,<Rm>,#<n>`
`MOV{S} <Rd>,<Rm>,ASR <Rs>`	`ASR{S} <Rd>,<Rm>,<Rs>`
`MOV{S} <Rd>,<Rm>,LSL <Rs>`	`LSL{S} <Rd>,<Rm>,<Rs>`
`MOV{S} <Rd>,<Rm>,LSR <Rs>`	`LSR{S} <Rd>,<Rm>,<Rs>`
`MOV{S} <Rd>,<Rm>,ROR <Rs>`	`ROR{S} <Rd>,<Rm>,<Rs>`
`MOV{S} <Rd>,<Rm>,RRX`	`RRX{S} <Rd>,<Rm>`

The canonical form of the instruction is produced on disassembly.

Exceptions

None.

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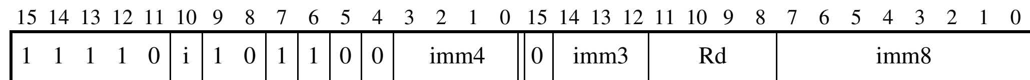
4.6.79 MOVT

Move Top writes an immediate value to the top halfword of the destination register. It does not affect the contents of the bottom halfword.

Encodings

T1 `MOVT<c> <Rd>,#<imm16>`



15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	1	0	i	1	0	1	1	0	0	imm4				0	imm3			Rd				imm8							

```
d = UInt(Rd);  imm16 = imm4:i:imm3:imm8;
if BadReg(d) then UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

```
MOVT<c><q>  <Rd>, #<imm16>
```

where:

`S` If present, specifies that the instruction updates the flags. Otherwise, the instruction does not update the flags.

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<Rd>` Specifies the destination register.

`<imm16>` Specifies the immediate value to be written to `<Rd>`. It must be in the range 0-65535.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    R[d]<31:16> = imm16;
    // R[d]<15:0> unchanged
```

Exceptions

None.

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4.6.80 MRC, MRC2

Move to ARM Register from Coprocessor causes a coprocessor to transfer a value to an ARM register or to the condition flags.

If no coprocessors can execute the instruction, an Undefined Instruction exception is generated.

Encodings

T1 `MRC{2}<c> <coproc>,<opc1>,<Rt>,<CRn>,<CRm>{,<opc2>}`

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	C	1	1	1	0	opc1			1	CRn				Rt				coproc				opc2			1	CRm			

```
t = UInt(Rt);  cp = UInt(coproc);
opc0 = C;  // MRC if C == '0', MRC2 if C == '1'
if t == 13 then UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

```
MRC{2}<c><q>  <coproc>, #<opc1>, <Rt>, <CRn>, <CRm>{, #<opc2>}
```

where:

`2` If specified, selects the C == 1 form of the encoding. If omitted, selects the C == 0 form.

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<coproc>` Specifies the name of the coprocessor. The standard generic coprocessor names are p0, p1, ..., p15.

`<opc1>` Is a coprocessor-specific opcode in the range 0 to 7.

`<Rt>` Is the destination ARM register. This register is allowed to be R0-R14 or APSR_nzcv. The last form writes bits[31:28] of the transferred value to the N, Z, C and V condition flags and is specified by setting the Rt field of the encoding to 0b1111. In pre-UAL assembler syntax, PC was written instead of APSR_nzcv to select this form.

`<CRn>` Is the coprocessor register that contains the first operand.

`<CRm>` Is an additional source or destination coprocessor register.

`<opc2>` Is a coprocessor-specific opcode in the range 0 to 7. If it is omitted, `<opc2>` is assumed to be 0.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    if !Coproc_Accepted(cp, ThisInstr()) then
        RaiseCoprocessorException();
    else
        value = Coproc_GetOneWord(cp, ThisInstr());
        if t != 15 then
            R[t] = value;
        else
            APSR.N = value<31>;
            APSR.Z = value<30>;
            APSR.C = value<29>;
            APSR.V = value<28>;
            // value<27:0> are not used.
```

Exceptions

Undefined Instruction.

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4.6.81 MRRC, MRRC2

Move to two ARM Registers from Coprocessor causes a coprocessor to transfer values to two ARM registers.

If no coprocessors can execute the instruction, an Undefined Instruction exception is generated.

Encodings

T1 `MRRC<c> <coproc>,<opc>,<Rt>,<Rt2>,<CRm>`

15	14	13	12	11	10	9	8	7	6	5	4	3 2 1 0	15 14 13 12	11 10 9 8	7 6 5 4	3 2 1 0
1	1	1	C	1	1	0	0	0	1	0	1	Rt2	Rt	coproc	opc1	CRm

```
t = UInt(Rt);  t2 = UInt(Rt2);
cp = UInt(coproc);  opc0 = C;  // MRRC if C == '0', MRRC2 if C == '1'
if BadReg(t) || BadReg(t2) || t1 == t2 then UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

```
MRRC{2}<c><q>  <coproc>, #<opc1>, <Rt>, <Rt2>, <CRm>
```

where:

2 — If specified, selects the C == 1 form of the encoding. If omitted, selects the C == 0 form.

`<c><q>` — See *Standard assembler syntax fields* on page 4-6.

`<coproc>` — Specifies the name of the coprocessor. The standard generic coprocessor names are p0, p1, ..., p15.

`<opc1>` — Is a coprocessor-specific opcode in the range 0 to 15.

`<Rt>` — Is the first destination ARM register.

`<Rt2>` — Is the second destination ARM register.

`<CRm>` — Is the coprocessor register that supplies the data to be transferred.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    if !Coproc_Accepted(cp, ThisInstr()) then
        RaiseCoprocessorException();
    else
        (R[t], R[t2]) = Coproc_GetTwoWords(cp, ThisInstr());
```

Exceptions

Undefined Instruction.

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4.6.82 MRS

Move to Register from Special register moves the value from the CPSR or SPSR of the current mode into a general purpose register.

Encodings

T1 `MRS<c> <Rd>,<spec_reg>`

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	1	0	0	1	1	1	1	1	R	(1)	(1)	(1)	(1)	1	0	(0)	0	Rd				(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)

```
d = UInt(Rd);  readSPSR = (R == '1');
if BadReg(d) then UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

```
MRS<c><q>  <Rd>, <spec_reg>
```

where:

`<c><q>`	See *Standard assembler syntax fields* on page 4-6.
`<Rd>`	Specifies the destination register.
`<spec_reg>`	Is `APSR`, `CPSR`, or `SPSR`. `APSR` is the recommended form when only the N, Z, C, V, Q, or GE[3:0] bits of the read value are going to be used (see *The Application Program Status Register* on page 2-2).

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    if readSPSR then
        if CurrentModeHasSPSR() then
            R[d] = SPSR;
        else
            UNPREDICTABLE;
    else
        R[d] = CPSR;
```

Exceptions

None.

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4.6.83 MSR (register)

Move to Special Register from ARM Register moves the value of a general-purpose register to the CPSR or the SPSR of the current mode.

Encodings

T1 `MSR<c> <spec_reg>,<Rn>`

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	1	0	0	1	1	1	0	0	R	Rn				1	0	(0)	0	mask				(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)

```
n = UInt(Rn);  writeSPSR = (R == '1');
if BadReg(n) then UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

```
MSR<c><q>  <spec_reg>, <Rn>
```

where:

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<spec_reg>` Is one of `APSR_<bits>`, `CPSR_<fields>`, or `SPSR_<fields>`. The `APSR` forms are recommended when only the N, Z, C, V, Q, and GE[3:0] bits are being written (see *The Application Program Status Register* on page 2-2).

`<fields>` Is a sequence of one or more of the following: `c`, `x`, `s`, `f`.

`<Rn>` Is the general-purpose register to be transferred to the special register.

`<bits>` Is one of `nzcvq`, `g`, or `nzcvqg`.

In the A and R profiles:

- `APSR_nzcvq` is the same as `CPSR_f`
- `APSR_g` is the same as `CPSR_s`
- `APSR_nzcvqg` is the same as `CPSR_fs`.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    if writeSPSR then
        if CurrentModeHasSPSR() then
            WriteSPSRUnderMask(R[n], mask);
        else
            UNPREDICTABLE;
    else
        WriteCPSRUnderMask(R[n], mask);
```

Exceptions

None.

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4.6.84 MUL

Multiply multiplies two register values. The least significant 32 bits of the result are written to the destination register. These 32 bits do not depend on whether signed or unsigned calculations are performed.

It can optionally update the condition flags based on the result. This option is limited to only a few forms of the instruction in the Thumb instruction set, and use of it will adversely affect performance on many processor implementations.

Encodings

T1 `MULS <Rdm>,<Rn>,<Rdm>` Outside IT block.

`MUL<c> <Rdm>,<Rn>,<Rdm>` Inside IT block.

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0	1	0	0	0	0	1	1	0	1	Rn			Rdm		

```
d = UInt(Rdm);  n = UInt(Rn);  m = UInt(Rdm);  setflags = !InITBlock();
if ArchVersion() < 6 && d == m then UNPREDICTABLE;
```

T2 `MUL<c> <Rd>,<Rn>,<Rm>`

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	1	1	0	1	1	0	0	0	0	Rn				1	1	1	1	Rd				0	0	0	0	Rm			

```
d = UInt(Rd);  n = UInt(Rn);  m = UInt(Rm);  setflags = FALSE;
if BadReg(d) || BadReg(n) || BadReg(m) then UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set.

Encoding T2 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

```
MUL<c><q>  {<Rd>,} <Rn>, <Rm>
```

where:

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<Rd>` Specifies the destination register. If `<Rd>` is omitted, this register is the same as `<Rn>`.

`<Rn>` Specifies the register that contains the first operand.

`<Rm>` Specifies the register that contains the second operand.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    operand1 = SInt(R[n]);  // or UInt(R[n]) without functionality change
    operand2 = SInt(R[m]);  // or UInt(R[m]) without functionality change
    result = operand1 * operand2;
    R[d] = result<31:0>;
    if setflags then
        APSR.N = result<31>;
        APSR.Z = IsZeroBit(result);
        if ArchVersion() == 4 then
            APSR.C = UNKNOWN;
        // else APSR.C unchanged
        // APSR.V always unchanged
```

Exceptions

None.

Notes

Early termination

If the multiplier implementation supports early termination, it must be implemented on the value of the `<Rm>` operand. The type of early termination used (signed or unsigned) is IMPLEMENTATION DEFINED. This implies that `MUL{S}<c> {<Rdn>,}<Rdn>,<Rm>` cannot be assembled correctly using encoding T1, unless `<Rdn>` and `<Rm>` are the same register.

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4.6.85 MVN (immediate)

Move Negative (immediate) writes the logical ones complement of an immediate value to the destination register. It can optionally update the condition flags based on the value.

Encodings

T1 `MVN{S}<c> <Rd>,#<const>`

<table>
<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><td>7</td><td>6</td><td>5</td><td>4</td><td>3</td><td>2</td><td>1</td><td>0</td><td>15</td><td>14</td><td>13</td><td>12</td><td>11</td><td>10</td><td>9</td><td>8</td><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>
<tr><td>1</td><td>1</td><td>1</td><td>1</td><td>0</td><td>i</td><td>0</td><td>0</td><td>0</td><td>1</td><td>1</td><td>S</td><td>1</td><td>1</td><td>1</td><td>1</td><td>0</td><td colspan="3">imm3</td><td colspan="4">Rd</td><td colspan="8">imm8</td></tr>
</table>

```
d = UInt(Rd);  setflags = (S == '1');
(imm32, carry) = ThumbExpandImmWithC(i:imm3:imm8, APSR.C);
if BadReg(d) then UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

```
MVN{S}<c><q>  <Rd>, #<const>
```

where:

`S` If present, specifies that the instruction updates the flags. Otherwise, the instruction does not update the flags.

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<Rd>` Specifies the destination register.

`<const>` Specifies the immediate value to be added to the value obtained from `<Rn>`. See *Immediate constants* on page 4-8 for the range of allowed values.

The pre-UAL syntax `MVN<c>S` is equivalent to `MVNS<c>`.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    result = NOT(imm32);
    R[d] = result;
    if setflags then
        APSR.N = result<31>;
        APSR.Z = IsZeroBit(result);
        APSR.C = carry;
        // APSR.V unchanged
```

Exceptions

None.

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4.6.86 MVN (register)

Move Negative (register) writes the logical ones complement of a register value to the destination register. It can optionally update the condition flags based on the result.

Encodings

T1 `MVNS <Rd>,<Rm>` Outside IT block.

`MVN<c> <Rd>,<Rm>` Inside IT block.

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0	1	0	0	0	0	1	1	1	1	Rm			Rd		

```
d = UInt(Rd);  m = UInt(Rm);  setflags = !InITBlock();
(shift_t, shift_n) = (SRType_None, 0);
```

T2 `MVN{S}<c>.W <Rd>,<Rm>{,shift>}`

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	0	1	0	1	0	0	1	1	S	1	1	1	1	(0)	imm3			Rd				imm2		type		Rm			

```
d = UInt(Rd);  m = UInt(Rm);  setflags = (S == '1');
(shift_t, shift_n) = DecodeImmShift(type, imm3:imm2);
if BadReg(d) || BadReg(m) THEN UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set.

Encoding T2 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

```
MVN{S}<c><q>  <Rd>, <Rm> {, <shift>}
```

where:

`S` If present, specifies that the instruction updates the flags. Otherwise, the instruction does not update the flags.

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<Rd>` Specifies the destination register.

`<Rm>` Specifies the register that is optionally shifted and used as the source register.

`<shift>` Specifies the shift to apply to the value read from `<Rm>`. If `<shift>` is omitted, no shift is applied and both encodings are permitted. If `<shift>` is specified, only encoding T2 is permitted. The possible shifts and how they are encoded are described in *Constant shifts applied to a register* on page 4-10.

The pre-UAL syntax `MVN<c>S` is equivalent to `MVNS<c>`.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    (shifted, carry) = Shift_C(R[m], shift_t, shift_n, APSR.C);
    result = NOT(shifted);
    R[d] = result;
    if setflags then
        APSR.N = result<31>;
        APSR.Z = IsZeroBit(result);
        APSR.C = carry;
        // APSR.V unchanged
```

Exceptions

None.

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4.6.87 NEG

Negate is a pre-UAL synonym for `RSB` (immediate) with an immediate value of 0. See *RSB (immediate)* on page 4-249 for details.

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Assembler syntax

```
NEG<c><q>  {<Rd>,} <Rm>
```

This is equivalent to:

```
RSBS<c><q>  {<Rd>,} <Rm>, #0
```

Exceptions

None.

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4.6.88 NOP

No Operation does nothing.

Encodings

T1 NOP<c>

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	0	1	1	1	1	1	1	0	0	0	0	0	0	0	0

```
// Do nothing
```

T2 NOP<c>.W

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	1	0	0	1	1	1	0	1	0	(1)	(1)	(1)	(1)	1	0	(0)	0	(0)	0	0	0	0	0	0	0	0	0	0	0

```
// Do nothing
```

Architecture versions

Encodings T1, T2 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

```
NOP<c><q>
```

where:

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    // Do nothing
```

Exceptions

None.

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4.6.89 ORN (immediate)

Logical OR NOT (immediate) performs a bitwise (inclusive) OR of a register value and the complement of an immediate value, and writes the result to the destination register. It can optionally update the condition flags based on the result.

Encodings

T1 `ORN{S}<c> <Rd>,<Rn>,#<const>`

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	1	0	i	0	0	0	1	1	S	Rn				0	imm3			Rd				imm8							

```
d = UInt(Rd);  n = UInt(Rn);  setflags = (S == '1');
(imm32, carry) = ThumbExpandImmWithC(i:imm3:imm8, APSR.C);
if n == 15 then SEE MVN (immediate) on page 4-183;
if BadReg(d) || n == 13 then UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

```
ORN{S}<c><q>  {<Rd>,} <Rn>, #<const>
```

where:

`S` If present, specifies that the instruction updates the flags. Otherwise, the instruction does not update the flags.

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<Rd>` Specifies the destination register. If `<Rd>` is omitted, this register is the same as `<Rn>`.

`<Rn>` Specifies the register that contains the operand.

`<const>` Specifies the immediate value to be added to the value obtained from `<Rn>`. See *Immediate constants* on page 4-8 for the range of allowed values.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    result = R[n] OR NOT(imm32);
    R[d] = result;
    if setflags then
        APSR.N = result<31>;
        APSR.Z = IsZeroBit(result);
        APSR.C = carry;
        // APSR.V unchanged
```

Exceptions

None.

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4.6.90 ORN (register)

Logical OR NOT (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. It can optionally update the condition flags based on the result.

Encodings

T1
```
ORN{S}<c> <Rd>,<Rn>,<Rm>{,<shift>}
```

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	0	1	0	1	0	0	1	1	S	Rn				(0)	imm3			Rd				imm2		type		Rm			

```
d = UInt(Rd);  n = UInt(Rn);  m = UInt(Rm);  setflags = (S == '1');
(shift_t, shift_n) = DecodeImmShift(type, imm3:imm2);
if n == 15 then SEE MVN (register) on page 4-185;
if BadReg(d) || n == 13 || BadReg(m) THEN UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

```
ORN{S}<c><q>  {<Rd>,} <Rn>, <Rm> {,<shift>}
```

where:

S — If present, specifies that the instruction updates the flags. Otherwise, the instruction does not update the flags.

<c><q> — See *Standard assembler syntax fields* on page 4-6.

<Rd> — Specifies the destination register. If <Rd> is omitted, this register is the same as <Rn>.

<Rn> — Specifies the register that contains the first operand.

<Rm> — Specifies the register that is optionally shifted and used as the second operand.

<shift> — Specifies the shift to apply to the value read from <Rm>. If <shift> is omitted, no shift is applied. The possible shifts and how they are encoded are described in *Constant shifts applied to a register* on page 4-10.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    (shifted, carry) = Shift_C(R[m], shift_t, shift_n, APSR.C);
    result = R[n] OR NOT(shifted);
    R[d] = result;
    if setflags then
        APSR.N = result<31>;
        APSR.Z = IsZeroBit(result);
        APSR.C = carry;
        // APSR.V unchanged
```

Exceptions

None.

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4.6.91 ORR (immediate)

Logical OR (immediate) performs a bitwise (inclusive) OR of a register value and an immediate value, and writes the result to the destination register. It can optionally update the condition flags based on the result.

Encodings

T1 `ORR{S}<c> <Rd>,<Rn>,#<const>`

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	1	0	i	0	0	0	1	0	S	Rn				0	imm3			Rd				imm8							

```
d = UInt(Rd);  n = UInt(Rn);  setflags = (S == '1');
(imm32, carry) = ThumbExpandImmWithC(i:imm3:imm8, APSR.C);
if n == 15 then SEE MOV (immediate) on page 4-166;
if BadReg(d) || n == 13 then UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

```
ORR{S}<c><q>  {<Rd>,} <Rn>, #<const>
```

where:

`S` If present, specifies that the instruction updates the flags. Otherwise, the instruction does not update the flags.

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<Rd>` Specifies the destination register. If `<Rd>` is omitted, this register is the same as `<Rn>`.

`<Rn>` Specifies the register that contains the operand.

`<const>` Specifies the immediate value to be added to the value obtained from `<Rn>`. See *Immediate constants* on page 4-8 for the range of allowed values.

The pre-UAL syntax `ORR<c>S` is equivalent to `ORRS<c>`.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    result = R[n] OR imm32;
    R[d] = result;
    if setflags then
        APSR.N = result<31>;
        APSR.Z = IsZeroBit(result);
        APSR.C = carry;
        // APSR.V unchanged
```

Exceptions

None.

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4.6.92 ORR (register)

Logical OR (register) performs a bitwise (inclusive) OR of a register value and an optionally-shifted register value, and writes the result to the destination register. It can optionally update the condition flags based on the result.

Encodings

T1 `ORRS <Rdn>,<Rm>` Outside IT block.

`ORR<c> <Rdn>,<Rm>` Inside IT block.

15	14	13	12	11	10	9	8	7	6	5 4 3	2 1 0
0	1	0	0	0	0	1	1	0	0	Rm	Rdn

```
d = UInt(Rdn);  n = UInt(Rdn);  m = UInt(Rm);  setflags = !InITBlock();
(shift_t, shift_n) = (SRType_None, 0);
```

T2 `ORR{S}<c>.W <Rd>,<Rn>,<Rm>{,<shift>}`

15	14	13	12	11	10	9	8	7	6	5	4	3 2 1 0	15	14 13 12	11 10 9 8	7 6	5 4	3 2 1 0
1	1	1	0	1	0	1	0	0	1	0	S	Rn	(0)	imm3	Rd	imm2	type	Rm

```
d = UInt(Rd);  n = UInt(Rn);  m = UInt(Rm);  setflags = (S == '1');
(shift_t, shift_n) = DecodeImmShift(type, imm3:imm2);
if n == 15 then SEE MOV (register) on page 4-168;
if BadReg(d) || n == 13 || BadReg(m) THEN UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set

Encoding T2 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

```
ORR{S}<c><q>  {<Rd>,} <Rn>, <Rm> {,<shift>}
```

where:

`S` If present, specifies that the instruction updates the flags. Otherwise, the instruction does not update the flags.

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<Rd>` Specifies the destination register. If `<Rd>` is omitted, this register is the same as `<Rn>`.

`<Rn>` Specifies the register that contains the first operand.

`<Rm>` Specifies the register that is optionally shifted and used as the second operand.

`<shift>` Specifies the shift to apply to the value read from `<Rm>`. If `<shift>` is omitted, no shift is applied and both encodings are permitted. If `<shift>` is specified, only encoding T2 is permitted. The possible shifts and how they are encoded are described in *Constant shifts applied to a register* on page 4-10.

A special case is that if `ORR<c> <Rd>,<Rn>,<Rd>` is written with `<Rd>` and `<Rn>` both in the range R0-R7, it will be assembled using encoding T2 as though `ORR<c> <Rd>,<Rn>` had been written. To prevent this happening, use the .W qualifier.

The pre-UAL syntax `ORR<c>S` is equivalent to `ORRS<c>`.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    (shifted, carry) = Shift_C(R[m], shift_t, shift_n, APSR.C);
    result = R[n] OR shifted;
    R[d] = result;
    if setflags then
        APSR.N = result<31>;
        APSR.Z = IsZeroBit(result);
        APSR.C = carry;
        // APSR.V unchanged
```

Exceptions

None.

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4.6.93 PKH

Pack Halfword combines one halfword of its first operand with the other halfword of its shifted second operand.

Encodings

T1

```
PKHBT<c> <Rd>,<Rn>,<Rm>{,LSL #<imm>}
PKHTB<c> <Rd>,<Rn>,<Rm>{,ASR #<imm>}
```

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	0	1	0	1	0	1	1	0	0	Rn				(0)	imm3			Rd				imm2		tb	0	Rm			

```
d = UInt(Rd);  n = UInt(Rn);  m = UInt(Rm);  tbform = (tb == '1');
(shift_t, shift_n) = DecodeImmShift(tb:'0', imm3:imm2);
if BadReg(d) || BadReg(n) || BadReg(m) then UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

`PKHBT<c><q>  {<Rd>,} <Rn>, <Rm> {, LSL #<imm>}`	tbform == FALSE
`PKHTB<c><q>  {<Rd>,} <Rn>, <Rm> {, ASR #<imm>}`	tbform == TRUE

where:

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<Rd>` Specifies the destination register. If `<Rd>` is omitted, this register is the same as `<Rn>`.

`<Rn>` Specifies the register that contains the first operand.

`<Rm>` Specifies the register that is optionally shifted and used as the second operand.

`<imm>` Specifies the shift to apply to the value read from `<Rm>`.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    operand2 = Shift(R[m], shift_t, shift_n, APSR.C);  // APSR.C ignored
    R[d]<15:0>  = if tbform then operand2<15:0> else R[n]<15:0>;
    R[d]<31:16> = if tbform then R[n]<31:16>    else operand2<31:16>;
```

Exceptions

None.

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4.6.94 PLD (immediate)

Preload Data signals the memory system that data memory accesses from a specified address are likely 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 pre-loading the cache line containing the specified address into the data cache.

Encodings

T1 `PLD<c> [<Rn>,#<imm12>]`

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	1	1	0	0	0	1	0	0	1	Rn				1	1	1	1	imm12											

```
n = UInt(Rn);  imm32 = ZeroExtend(imm12, 32);  add = TRUE;
if n == 15 then SEE encoding T3;
```

T2 `PLD<c> [<Rn>,#-<imm8>]`

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	1	1	0	0	0	0	0	0	1	Rn				1	1	1	1	1	1	0	0	imm8							

```
n = UInt(Rn);  imm32 = ZeroExtend(imm8, 32);  add = FALSE;
if n == 15 then SEE encoding T3;
```

T3 `PLD<c> [PC,#+/-<imm12>]`

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	1	1	0	0	0	U	0	0	1	1	1	1	1	1	1	1	1	imm12											

```
n = 15;  imm32 = ZeroExtend(imm12, 32);  add = (U == '1');
```

Architecture versions

Encodings T1, T2, T3

All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

```
PLD<c><q>  [<Rn>, #+/-<imm>]
PLD<c><q>  [PC, #+/-<imm>]
```

where:

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<Rn>` Is the base register. This register is allowed to be the SP.

`+/-` Is + or omitted to indicate that the immediate offset is added to the base register value (`add == TRUE`), or – to indicate that the offset is to be subtracted (`add == FALSE`). Different instructions are generated for `#0` and `#-0`.

`<imm>` Specifies the offset from the base register. It must be in the range:

- –4095 to 4095 if the base register is the PC
- –255 to 4095 otherwise.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    base = if n == 15 then Align(PC,4) else R[n];
    address = if add then (base + imm32) else (base - imm32);
    Hint_PreloadData(address);
```

Exceptions

None.

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4.6.95 PLD (register)

Preload Data signals the memory system that data memory accesses from a specified address are likely 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 pre-loading the cache line containing the specified address into the data cache.

Encodings

T1 `PLD<c> [<Rn>,<Rm>{,LSL #<shift>}]`

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	1	1	0	0	0	0	0	0	1	Rn				1	1	1	1	0	0	0	0	0	0	shift		Rm			

```
n = UInt(Rn);  m = UInt(Rm);
(shift_t, shift_n) = (SRType_LSL, UInt(shift));
if n == 15 then SEE PLD (immediate) on page 4-201;
if BadReg(m) then UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

```
PLD<c><q>  [<Rn>, <Rm> {, LSL #<shift>}]
```

where:

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<Rn>` Is the base register. This register is allowed to be the SP.

`<Rm>` Is the optionally shifted offset register.

`<shift>` Specifies the shift to apply to the value read from `<Rm>`, in the range 0-3. If this option is omitted, a shift by 0 is assumed.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    address = R[n] + Shift(R[m], shift_t, shift_n, APSR.C);
    Hint_PreloadData(address);
```

Exceptions

None.

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4.6.96 PLI (immediate)

Preload Instruction signals the memory system that instruction memory accesses from a specified address are likely 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 pre-loading the cache line containing the specified address into the instruction cache.

Encodings

T1 `PLI<c> [<Rn>,#<imm12>]`

15 14 13 12 11	10 9	8	7	6 5	4	3 2 1 0	15 14 13 12	11 10 9 8 7 6 5 4 3 2 1 0
1 1 1 1 1	0 0	1	1	0 0	1	Rn	1 1 1 1	imm12

```
n = UInt(Rn);  imm32 = ZeroExtend(imm12, 32);  add = TRUE;
if n == 15 then SEE encoding T3;
```

T2 `PLI<c> [<Rn>,#-<imm8>]`

15 14 13 12 11	10 9	8	7	6 5	4	3 2 1 0	15 14 13 12	11	10 9 8	7 6 5 4 3 2 1 0
1 1 1 1 1	0 0	1	0	0 0	1	Rn	1 1 1 1	1	1 0 0	imm8

```
n = UInt(Rn);  imm32 = ZeroExtend(imm8, 32);  add = FALSE;
if n == 15 then SEE encoding T3;
```

T3 `PLI<c> [PC,#+/-<imm12>]`

15 14 13 12 11	10 9	8	7	6 5	4	3 2 1 0	15 14 13 12	11 10 9 8 7 6 5 4 3 2 1 0
1 1 1 1 1	0 0	1	U	0 0	1	1 1 1 1	1 1 1 1	imm12

```
n = 15;  imm32 = ZeroExtend(imm12, 32);  add = (U == '1');
```

Architecture versions

Encodings T1, T2, T3

All versions of the Thumb instruction set from v7 onwards.

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Assembler syntax

```
PLI<c><q>  [<Rn>, #+/-<imm>]
PLI<c><q>  [PC, #+/-<imm>]
```

where:

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<Rn>` Is the base register. This register is allowed to be the SP.

`+/-` Is + or omitted to indicate that the immediate offset is added to the base register value (`add == TRUE`), or – to indicate that the offset is to be subtracted (`add == FALSE`). Different instructions are generated for `#0` and `#-0`.

`<imm>` Specifies the offset from the base register. It must be in the range:

- –4095 to 4095 if the base register is the PC
- –255 to 4095 otherwise.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    base = if n == 15 then Align(PC,4) else R[n];
    address = if add then (base + imm32) else (base - imm32);
    Hint_PreloadInstr(address);
```

Exceptions

None.

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4.6.97 PLI (register)

Preload Instruction signals the memory system that instruction memory accesses from a specified address are likely 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 pre-loading the cache line containing the specified address into the instruction cache.

Encodings

T1 PLI<c> [<Rn>,<Rm>{,LSL #<shift>}]

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	1	1	0	0	1	0	0	0	1	Rn				1	1	1	1	0	0	0	0	0	0	shift		Rm			

```
n = UInt(Rn);  m = UInt(Rm);
(shift_t, shift_n) = (SRType_LSL, UInt(shift));
if n == 15 then SEE PLI (immediate) on page 4-205;
if BadReg(m) then UNPREDICTABLE;
```

Architecture versions

Encodings T1, T2 All versions of the Thumb instruction set from v7 onwards.

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Assembler syntax

```
PLI<c><q>  [<Rn>, <Rm> {, LSL #<shift>}]
```

where:

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<Rn>` Is the base register. This register is allowed to be the SP.

`<Rm>` Is the optionally shifted offset register.

`<shift>` Specifies the shift to apply to the value read from `<Rm>`, in the range 0-3. If this option is omitted, a shift by 0 is assumed.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    address = R[n] + Shift(R[m], shift_t, shift_n, APSR.C);
    Hint_PreloadInstr(address);
```

Exceptions

None.

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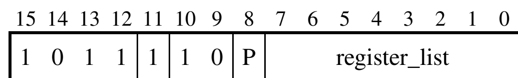
4.6.98 POP

Pop Multiple Registers loads a subset (or possibly all) of the general-purpose registers R0-R12 and the PC or the LR from the stack.

If the registers loaded include the PC, the word loaded for the PC is treated as an address and a branch occurs to that address. Bit[0] of the loaded value determines whether execution continues after this branch in ARM state or in Thumb state.

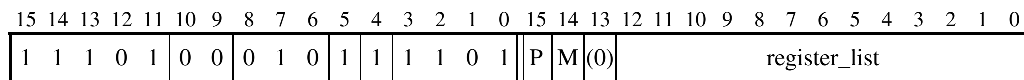
Encoding

T1 POP<c> <registers>




```
registers = P:'0000000':register_list;
if BitCount(registers) < 1 then UNPREDICTABLE;
```

T2 POP<c>.W <registers>




```
registers = P:M:'0':register_list;
if BitCount(registers) < 2 then UNPREDICTABLE;
if P == 1 && M == 1 then UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set.

Encoding T2 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

`POP<c><q>  <registers>`	Standard syntax
`LDMIA<c><q>  SP!, <registers>`	Equivalent `LDM` syntax

where:

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<registers>`

Is a list of one or more registers, separated by commas and surrounded by `{` and `}`. It specifies the set of registers to be loaded. The registers are loaded in sequence, the lowest-numbered register from the lowest memory address, through to the highest-numbered register from the highest memory address. If the PC is specified in the register list, the instruction causes a branch to the address (data) loaded into the PC.

Encoding T2 does not support a list containing only one register. If a `POP` instruction with just one register `<Rt>` in the list is assembled to Thumb and encoding T1 is not available, it is assembled to the equivalent `LDR<c><q> <Rt>,[SP],#-4` instruction.

The SP cannot be in the list.

If the PC is in the list, the LR must not be in the list.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    originalSP = SP;
    address = SP;
    SP = SP + 4*BitCount(registers);
    for i = 0 to 14
        if registers<i> == '1' then
            loadedvalue = MemA[address,4];
            address = address + 4;
    if registers<15> == '1' then
        LoadWritePC(MemA[address,4]);
        address = address + 4;
    assert address == originalSP + 4*BitCount(registers);
```

Exceptions

Data Abort.

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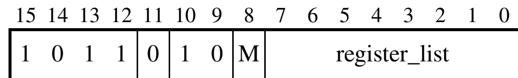
4.6.99 PUSH

Push Multiple Registers stores a subset (or possibly all) of the general-purpose registers R0-R12 and the LR to the stack.

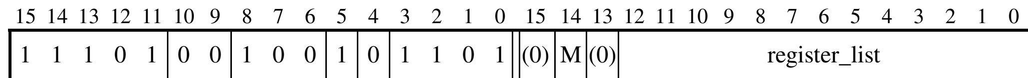
Encoding

T1 PUSH<c> <registers>




```
registers = '0':M:'000000':register_list;
if BitCount(registers) < 1 then UNPREDICTABLE;
```

T2 PUSH<c>.W <registers>




```
registers = '0':M:'0':register_list;
if BitCount(registers) < 2 then UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set.

Encoding T2 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

`PUSH<c><q> <registers>`	Standard syntax
`STMDB<c><q> SP!, <registers>`	Equivalent `STM` syntax

where:

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<registers>`

Is a list of one or more registers, separated by commas and surrounded by `{` and `}`. It specifies the set of registers to be stored. The registers are stored in sequence, the lowest-numbered register to the lowest memory address, through to the highest-numbered register to the highest memory address.

Encoding T2 does not support a list containing only one register. If a `PUSH` instruction with just one register `<Rt>` in the list is assembled to Thumb and encoding T1 is not available, it is assembled to the equivalent `STR<c><q> <Rt>,[SP,#-4]!` instruction.

The SP and PC cannot be in the list.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    originalSP = SP;
    address = SP - 4*BitCount(registers);
    SP = SP - 4*BitCount(registers);
    for i = 0 to 14
        if registers<i> == '1' then
            MemA[address,4] = R[i];
            address = address + 4;
    assert address == originalSP;
```

Exceptions

Data Abort.

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4.6.100 QADD

Saturating Add adds two register values, saturates the result to the 32-bit signed integer range $-2^{31} \leq x \leq 2^{31} - 1$, and writes the result to the destination register. If saturation occurs, it sets the Q flag in the CPSR.

Encodings

T1 QADD<c> <Rd>,<Rn>,<Rm>

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	1	1	0	1	0	1	0	0	0	Rn				1	1	1	1	Rd				1	0	0	0	Rm			

```
d = UInt(Rd);  n = UInt(Rn);  m = UInt(Rm);
if BadReg(d) || BadReg(n) || BadReg(m) then UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

```
QADD<c><q>  {<Rd>,} <Rn>, <Rm>
```

where:

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<Rd>` Specifies the destination register. If `<Rd>` is omitted, this register is the same as `<Rn>`.

`<Rn>` Specifies the register that contains the first operand.

`<Rm>` Specifies the register that contains the second operand.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    (R[d], sat) = SignedSatQ(SInt(R[m]) + SInt(R[n]), 32);
    if sat then
        APSR.Q = '1';
```

Exceptions

None.

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4.6.101 QADD16

Saturating Add 16 performs two 16-bit integer additions, saturates the results to the 16-bit signed integer range $-2^{15} \leq x \leq 2^{15} - 1$, and writes the results to the destination register. It does not affect any flags.

Encodings

T1 `QADD16<c> <Rd>,<Rn>,<Rm>`

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	1	1	0	1	0	1	0	0	1	Rn				1	1	1	1	Rd				0	0	0	1	Rm			

```
d = UInt(Rd);  n = UInt(Rn);  m = UInt(Rm);
if BadReg(d) || BadReg(n) || BadReg(m) then UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

```
QADD16<c><q>  {<Rd>,} <Rn>, <Rm>
```

where:

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<Rd>` Specifies the destination register. If `<Rd>` is omitted, this register is the same as `<Rn>`.

`<Rn>` Specifies the register that contains the first operand.

`<Rm>` Specifies the register that contains the second operand.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    sum1 = SInt(R[n]<15:0>) + SInt(R[m]<15:0>);
    sum2 = SInt(R[n]<31:16>) + SInt(R[m]<31:16>);
    R[d]<15:0>  = SignedSat(sum1, 16);
    R[d]<31:16> = SignedSat(sum2, 16);
```

Exceptions

None.

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4.6.102 QADD8

Saturating Add 8 performs four 8-bit integer additions, saturates the results to the 8-bit signed integer range $-2^7 \leq x \leq 2^7 - 1$, and writes the results to the destination register. It does not affect any flags.

Encodings

T1 `QADD8<c> <Rd>,<Rn>,<Rm>`

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	1	1	0	1	0	1	0	0	0	Rn				1	1	1	1	Rd				0	0	0	1	Rm			

```
d = UInt(Rd);  n = UInt(Rn);  m = UInt(Rm);
if BadReg(d) || BadReg(n) || BadReg(m) then UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

```
QADD8<c><q>  {<Rd>,} <Rn>, <Rm>
```

where:

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<Rd>` Specifies the destination register. If `<Rd>` is omitted, this register is the same as `<Rn>`.

`<Rn>` Specifies the register that contains the first operand.

`<Rm>` Specifies the register that contains the second operand.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    sum1 = SInt(R[n]<7:0>) + SInt(R[m]<7:0>);
    sum2 = SInt(R[n]<15:8>) + SInt(R[m]<15:8>);
    sum3 = SInt(R[n]<23:16>) + SInt(R[m]<23:16>);
    sum4 = SInt(R[n]<31:24>) + SInt(R[m]<31:24>);
    R[d]<7:0>   = SignedSat(sum1, 8);
    R[d]<15:8>  = SignedSat(sum2, 8);
    R[d]<23:16> = SignedSat(sum3, 8);
    R[d]<31:24> = SignedSat(sum4, 8);
```

Exceptions

None.

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4.6.103 QASX

Saturating Add and Subtract with Exchange exchanges the two halfwords of the second operand, performs one 16-bit integer addition and one 16-bit subtraction, saturates the results to the 16-bit signed integer range $-2^{15} \le x \le 2^{15} - 1$, and writes the results to the destination register. It does not affect any flags.

Encodings

T1 `QASX<c> <Rd>,<Rn>,<Rm>`

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	1	1	0	1	0	1	0	1	0	Rn				1	1	1	1	Rd				0	0	0	1	Rm			

```
d = UInt(Rd);  n = UInt(Rn);  m = UInt(Rm);
if BadReg(d) || BadReg(n) || BadReg(m) then UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

```
QASX<c><q>  {<Rd>,} <Rn>, <Rm>
```

where:

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<Rd>` Specifies the destination register. If `<Rd>` is omitted, this register is the same as `<Rn>`.

`<Rn>` Specifies the register that contains the first operand.

`<Rm>` Specifies the register that contains the second operand.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    diff = SInt(R[n]<15:0>) - SInt(R[m]<31:16>);
    sum  = SInt(R[n]<31:16>) + SInt(R[m]<15:0>);
    R[d]<15:0>  = SignedSat(diff, 16);
    R[d]<31:16> = SignedSat(sum, 16);
```

Exceptions

None.

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4.6.104 QDADD

Saturating Double and Add adds a doubled register value to another register value, and writes the result to the destination register. Both the doubling and the addition have their results saturated to the 32-bit signed integer range $-2^{31} \leq x \leq 2^{31} - 1$. If saturation occurs in either operation, it sets the Q flag in the CPSR.

Encodings

T1 `QDADD<c> <Rd>,<Rn>,<Rm>`

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	1	1	0	1	0	1	0	0	0	Rn				1	1	1	1	Rd				1	0	0	1	Rm			

```
d = UInt(Rd);  n = UInt(Rn);  m = UInt(Rm);
if BadReg(d) || BadReg(n) || BadReg(m) then UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

```
QDADD<c><q>  {<Rd>,} <Rn>, <Rm>
```

where:

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<Rd>` Specifies the destination register. If `<Rd>` is omitted, this register is the same as `<Rn>`.

`<Rn>` Specifies the register that contains the first operand.

`<Rm>` Specifies the register that contains the second operand.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    (doubled, sat1) = SignedSatQ(2 * SInt(R[n]), 32);
    (R[d], sat2) = SignedSatQ(SInt(R[m]) + SInt(doubled), 32);
    if sat1 || sat2 then
        APSR.Q = '1';
```

Exceptions

None.

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4.6.105 QDSUB

Saturating Double and Subtract subtracts a doubled register value from another register value, and writes the result to the destination register. Both the doubling and the subtraction have their results saturated to the 32-bit signed integer range $-2^{31} \le x \le 2^{31} - 1$. If saturation occurs in either operation, it sets the Q flag in the CPSR.

Encodings

T1 `QDSUB<c> <Rd>,<Rn>,<Rm>`

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	1	1	0	1	0	1	0	0	0	Rn				1	1	1	1	Rd				1	0	1	1	Rm			

```
d = UInt(Rd);  n = UInt(Rn);  m = UInt(Rm);
if BadReg(d) || BadReg(n) || BadReg(m) then UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

```
QDSUB<c><q>  {<Rd>,} <Rn>, <Rm>
```

where:

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<Rd>` Specifies the destination register. If `<Rd>` is omitted, this register is the same as `<Rn>`.

`<Rn>` Specifies the register that contains the first operand.

`<Rm>` Specifies the register that contains the second operand.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    (doubled, sat1) = SignedSatQ(2 * SInt(R[n]), 32);
    (R[d], sat2)  = SignedSatQ(SInt(R[m]) - SInt(doubled), 32);
    if sat1 || sat2 then
        APSR.Q = '1';
```

Exceptions

None.

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4.6.106 QSAX

Saturating Subtract and Add with Exchange exchanges the two halfwords of the second operand, performs one 16-bit integer subtraction and one 16-bit addition, saturates the results to the 16-bit signed integer range $-2^{15} \leq x \leq 2^{15} - 1$, and writes the results to the destination register. It does not affect any flags.

Encodings

T1 `QSAX<c> <Rd>,<Rn>,<Rm>`

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	1	1	0	1	0	1	1	1	0	Rn				1	1	1	1	Rd				0	0	0	1	Rm			

```
d = UInt(Rd);  n = UInt(Rn);  m = UInt(Rm);
if BadReg(d) || BadReg(n) || BadReg(m) then UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

```
QSAX<c><q>  {<Rd>,} <Rn>, <Rm>
```

where:

`<c><q>`	See *Standard assembler syntax fields* on page 4-6.
`<Rd>`	Specifies the destination register. If `<Rd>` is omitted, this register is the same as `<Rn>`.
`<Rn>`	Specifies the register that contains the first operand.
`<Rm>`	Specifies the register that contains the second operand.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    sum  = SInt(R[n]<15:0>) + SInt(R[m]<31:16>);
    diff = SInt(R[n]<31:16>) - SInt(R[m]<15:0>);
    R[d]<15:0>  = SignedSat(sum, 16);
    R[d]<31:16> = SignedSat(diff, 16);
```

Exceptions

None.

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4.6.107 QSUB

Saturating Subtract subtracts one register value from another register value, saturates the result to the 32-bit signed integer range $-2^{31} \leq x \leq 2^{31} - 1$, and writes the result to the destination register. If saturation occurs, it sets the Q flag in the CPSR.

Encodings

T1 `QSUB<c> <Rd>,<Rn>,<Rm>`

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	1	1	0	1	0	1	0	0	0	Rn				1	1	1	1	Rd				1	0	1	0	Rm			

```
d = UInt(Rd);  n = UInt(Rn);  m = UInt(Rm);
if BadReg(d) || BadReg(n) || BadReg(m) then UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

```
QSUB<c><q>  {<Rd>,} <Rn>, <Rm>
```

where:

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<Rd>` Specifies the destination register. If `<Rd>` is omitted, this register is the same as `<Rn>`.

`<Rn>` Specifies the register that contains the first operand.

`<Rm>` Specifies the register that contains the second operand.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    (R[d], sat) = SignedSatQ(SInt(R[m]) - SInt(R[n]), 32);
    if sat then
        APSR.Q = '1';
```

Exceptions

None.

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4.6.108 QSUB16

Saturating Subtract 16 performs two 16-bit integer subtractions, saturates the results to the 16-bit signed integer range $-2^{15} \leq x \leq 2^{15} - 1$, and writes the results to the destination register. It does not affect any flags.

Encodings

T1 `QSUB16<c> <Rd>,<Rn>,<Rm>`

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	1	1	0	1	0	1	1	0	1	Rn				1	1	1	1	Rd				0	0	0	1	Rm			

```
d = UInt(Rd);  n = UInt(Rn);  m = UInt(Rm);
if BadReg(d) || BadReg(n) || BadReg(m) then UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

```
QSUB16<c><q>  {<Rd>,} <Rn>, <Rm>
```

where:

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<Rd>` Specifies the destination register. If `<Rd>` is omitted, this register is the same as `<Rn>`.

`<Rn>` Specifies the register that contains the first operand.

`<Rm>` Specifies the register that contains the second operand.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    diff1 = SInt(R[n]<15:0>) - SInt(R[m]<15:0>);
    diff2 = SInt(R[n]<31:16>) - SInt(R[m]<31:16>);
    R[d]<15:0>  = SignedSat(diff1, 16);
    R[d]<31:16> = SignedSat(diff2, 16);
```

Exceptions

None.

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4.6.109 QSUB8

Saturating Subtract 8 performs four 8-bit integer subtractions, saturates the results to the 8-bit signed integer range $-2^7 \leq x \leq 2^7 - 1$, and writes the results to the destination register. It does not affect any flags.

Encodings

T1 `QSUB8<c> <Rd>,<Rn>,<Rm>`

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	1	1	0	1	0	1	1	0	0	Rn				1	1	1	1	Rd				0	0	0	1	Rm			

```
d = UInt(Rd);  n = UInt(Rn);  m = UInt(Rm);
if BadReg(d) || BadReg(n) || BadReg(m) then UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

```
QSUB8<c><q>  {<Rd>,} <Rn>, <Rm>
```

where:

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<Rd>` Specifies the destination register. If `<Rd>` is omitted, this register is the same as `<Rn>`.

`<Rn>` Specifies the register that contains the first operand.

`<Rm>` Specifies the register that contains the second operand.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    diff1 = SInt(R[n]<7:0>) - SInt(R[m]<7:0>);
    diff2 = SInt(R[n]<15:8>) - SInt(R[m]<15:8>);
    diff3 = SInt(R[n]<23:16>) - SInt(R[m]<23:16>);
    diff4 = SInt(R[n]<31:24>) - SInt(R[m]<31:24>);
    R[d]<7:0>   = SignedSat(diff1, 8);
    R[d]<15:8>  = SignedSat(diff2, 8);
    R[d]<23:16> = SignedSat(diff3, 8);
    R[d]<31:24> = SignedSat(diff4, 8);
```

Exceptions

None.

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4.6.110 RBIT

Reverse Bits reverses the bit order in a 32-bit register.

Encodings

T1 RBIT<c> <Rd>,<Rm>

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	1	1	0	1	0	1	0	0	1	Rm2				1	1	1	1	Rd				1	0	1	0	Rm			

```
d = UInt(Rd);  m = UInt(Rm);  m2 = UInt(Rm2);
if BadReg(d) || BadReg(m) || m2 != m then UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

```
RBIT<c><q>  <Rd>, <Rm>
```

where:

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<Rd>` Specifies the destination register.

`<Rm>` Specifies the register that contains the operand. Its number must be encoded twice in encoding T1, in both the Rm and Rm2 fields.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    bits(32) result;
    for i = 0 to 31 do
        result<31-i> = R[m]<i>;
    R[d] = result;
```

Exceptions

None.

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4.6.111 REV

Byte-Reverse Word reverses the byte order in a 32-bit register.

Encodings

T1
```
REV<c> <Rd>,<Rm>
```

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	0	1	1	1	0	1	0	0	0	Rm			Rd		

```
d = UInt(Rd);  m = UInt(Rm);
```

T2
```
REV<c>.W <Rd>,<Rm>
```

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	1	1	0	1	0	1	0	0	1	Rm2				1	1	1	1	Rd				1	0	0	0	Rm			

```
d = UInt(Rd);  m = UInt(Rm);  m2 = UInt(Rm2);
if BadReg(d) || BadReg(m) || m2 != m then UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set from ARMv6 onwards.

Encoding T2 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

```
REV<c><q>  <Rd>, <Rm>
```

where:

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<Rd>` Specifies the destination register.

`<Rm>` Specifies the register that contains the operand. Its number must be encoded twice in encoding T2, in both the Rm and Rm2 fields.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    bits(32) result;
    result<31:24> = R[m]<7:0>;
    result<23:16> = R[m]<15:8>;
    result<15:8>  = R[m]<23:16>;
    result<7:0>   = R[m]<31:24>;
    R[d] = result;
```

Exceptions

None.

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4.6.112 REV16

Byte-Reverse Packed Halfword reverses the byte order in each 16-bit halfword of a 32-bit register.

Encodings

T1 `REV16<c> <Rd>,<Rm>`

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	0	1	1	1	0	1	0	0	1	Rm			Rd		

```
d = UInt(Rd);  m = UInt(Rm);
```

T2 `REV16<c>.W <Rd>,<Rm>`

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	1	1	0	1	0	1	0	0	1	Rm2			

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	1	Rd				1	0	0	1	Rm			

```
d = UInt(Rd);  m = UInt(Rm);  m2 = UInt(Rm2);
if BadReg(d) || BadReg(m) || m2 != m then UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set from ARMv6 onwards.

Encoding T2 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

```
REV16<c><q>  <Rd>, <Rm>
```

where:

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<Rd>` Specifies the destination register.

`<Rm>` Specifies the register that contains the operand. Its number must be encoded twice in encoding T2, in both the Rm and Rm2 fields.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    bits(32) result;
    result<31:24> = R[m]<23:16>;
    result<23:16> = R[m]<31:24>;
    result<15:8>  = R[m]<7:0>;
    result<7:0>   = R[m]<15:8>;
    R[d] = result;
```

Exceptions

None.

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4.6.113 REVSH

Byte-Reverse Signed Halfword reverses the byte order in the lower 16-bit halfword of a 32-bit register, and sign extends the result to 32 bits.

Encodings

T1 `REVSH<c> <Rd>,<Rm>`

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	0	1	1	1	0	1	0	1	1	Rm			Rd		

```
d = UInt(Rd);  m = UInt(Rm);
```

T2 `REVSH<c>.W <Rd>,<Rm>`

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	1	1	0	1	0	1	0	0	1	Rm2				1	1	1	1	Rd				1	0	1	1	Rm			

```
d = UInt(Rd);  m = UInt(Rm);  m2 = UInt(Rm2);
if BadReg(d) || BadReg(m) || m2 != m then UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set from ARMv6 onwards.

Encoding T2 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

```
REVSH<c><q>  <Rd>, <Rm>
```

where:

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<Rd>` Specifies the destination register.

`<Rm>` Specifies the register that contains the operand. Its number must be encoded twice in encoding T2, in both the Rm and Rm2 fields.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    bits(32) result;
    result<31:8>  = SignExtend(R[m]<7:0>, 24);
    result<7:0>   = R[m]<15:8>;
    R[d] = result;
```

Exceptions

None.

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4.6.114 RFE

Return From Exception loads the PC and the CPSR from the word at the specified address and the following word respectively. See *Memory accesses* on page 4-13 for information about memory accesses.

Encodings

T1 `RFEDB<c> <Rn>{!}` Outside or last in IT block

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	0	1	0	0	0	0	0	W	1	Rn				(1)	(1)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)

```
n = UInt(Rn);  wback = (W == '1');  increment = FALSE;
if n == 15 then UNPREDICTABLE;
if InITBlock() && !LastInITBlock() then UNPREDICTABLE;
```

T2 `RFE{IA}<c> <Rn>{!}` Outside or last in IT block

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	0	1	0	0	1	1	0	W	1	Rn				(1)	(1)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)

```
n = UInt(Rn);  wback = (W == '1');  increment = TRUE;
if n == 15 then UNPREDICTABLE;
if InITBlock() && !LastInITBlock() then UNPREDICTABLE;
```

Architecture versions

Encodings T1, T2 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

```
RFE{IA|DB}<c><q>  <Rn>{!}
```

where:

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`IA` Means Increment After. The memory address is incremented after each load operation. This is the default. For this instruction, `FD`, meaning Full Descending, is equivalent to `IA`.

`DB` Means Decrement Before. The memory address is decremented before each load operation. For this instruction, `EA`, meaning Empty Ascending, is equivalent to DB.

`<Rn>` Specifies the base register.

`!` Causes the instruction to write a modified value back to `<Rn>`. If `!` is omitted, the instruction does not change `<Rn>`.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    if !CurrentModeIsPrivileged() then
        UNPREDICTABLE;
    else
        address = if increment then R[n] else R[n]-8;
        wbvalue = if increment then R[n]+8 else R[n]-8;
        if wback then R[n] = wbvalue;
        BranchWritePC(MemA[address,4]);
        CPSR = MemA[address+4,4];
```

Exceptions

Data Abort.

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4.6.115 ROR (immediate)

Rotate Right (immediate) provides the value of the contents of a register rotated by a constant value. The bits that are rotated off the right end are inserted into the vacated bit positions on the left. It can optionally update the condition flags based on the result.

Encodings

T1 `ROR{S}<c> <Rd>,<Rm>,#<imm5>`

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	0	1	0	1	0	0	1	0	S	1	1	1	1	(0)	imm3			Rd				imm2		1	1	Rm			

```
d = UInt(Rd);  m = UInt(Rm);  setflags = (S == '1');
if imm3:imm2 == '00000' then SEE RRX on page 4-247;
(-, shift_n) = DecodeImmShift('11', imm3:imm2);
if BadReg(d) || BadReg(m) THEN UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

```
ROR{S}<c><q>  <Rd>, <Rm>, #<imm5>
```

where:

`S`	If present, specifies that the instruction updates the flags. Otherwise, the instruction does not update the flags.
`<c><q>`	See *Standard assembler syntax fields* on page 4-6.
`<Rd>`	Specifies the destination register.
`<Rm>`	Specifies the register that contains the first operand.
`<imm5>`	Specifies the shift amount, in the range 1 to 31. See *Constant shifts applied to a register* on page 4-10.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    (result, carry) = Shift_C(R[m], SRType_ROR, shift_n, APSR.C);
    R[d] = result;
    if setflags then
        APSR.N = result<31>;
        APSR.Z = IsZeroBit(result);
        APSR.C = carry;
        // APSR.V unchanged
```

Exceptions

None.

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4.6.116 ROR (register)

Rotate Right (register) provides the value of the contents of a register rotated by a variable number of bits. The bits that are rotated off the right end are inserted into the vacated bit positions on the left. The variable number of bits is read from the bottom byte of a register. It can optionally update the condition flags based on the result.

Encodings

T1 `RORS <Rdn>,<Rm>` — Outside IT block.

`ROR<c> <Rdn>,<Rm>` — Inside IT block.

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0	1	0	0	0	0	0	1	1	1	Rm			Rdn		

```
d = UInt(Rdn);  n = UInt(Rdn);  m = UInt(Rm);  setflags = !InITBlock();
```

T2 `ROR{S}<c>.W <Rd>,<Rn>,<Rm>`

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	1	1	0	1	0	0	1	1	S	Rn				1	1	1	1	Rd				0	0	0	0	Rm			

```
d = UInt(Rd);  n = UInt(Rn);  m = UInt(Rm);  setflags = (S == '1');
if BadReg(d) || BadReg(n) || BadReg(m) then UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set

Encoding T2 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

```
ROR{S}<c><q>  <Rd>, <Rn>, <Rm>
```

where:

`S`	If present, specifies that the instruction updates the flags. Otherwise, the instruction does not update the flags.
`<c><q>`	See *Standard assembler syntax fields* on page 4-6.
`<Rd>`	Specifies the destination register.
`<Rn>`	Specifies the register that contains the first operand.
`<Rm>`	Specifies the register whose bottom byte contains the amount to rotate by.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    shift_n = UInt(R[m]<7:0>);
    (result, carry) = Shift_C(R[n], SRType_ROR, shift_n, APSR.C);
    R[d] = result;
    if setflags then
        APSR.N = result<31>;
        APSR.Z = IsZeroBit(result);
        APSR.C = carry;
        // APSR.V unchanged
```

Exceptions

None.

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4.6.117 RRX

Rotate Right with Extend provides the value of the contents of a register shifted right by one place, with the carry flag shifted into bit[31].

`RRX` can optionally update the condition flags based on the result. In that case, bit[0] is shifted into the carry flag.

Encodings

T1

```
RRX{S}<c> <Rd>,<Rm>
```

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	0	1	0	1	0	0	1	0	S	1	1	1	1	(0)	0	0	0	Rd				0	0	1	1	Rm			

```
d = UInt(Rd);  m = UInt(Rm);  setflags = (S == '1');
if BadReg(d) || BadReg(m) THEN UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

```
RRX{S}<c><q>  <Rd>, <Rm>
```

where:

`S`	If present, specifies that the instruction updates the flags. Otherwise, the instruction does not update the flags.
`<c><q>`	See *Standard assembler syntax fields* on page 4-6.
`<Rd>`	Specifies the destination register.
`<Rm>`	Specifies the register that contains the operand.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    (result, carry) = Shift_C(R[m], SRType_RRX, 1, APSR.C);
    R[d] = result;
    if setflags then
        APSR.N = result<31>;
        APSR.Z = IsZeroBit(result);
        APSR.C = carry;
        // APSR.V unchanged
```

Exceptions

None.

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4.6.118 RSB (immediate)

Reverse Subtract (immediate) subtracts a register value from an immediate value, and writes the result to the destination register. It can optionally update the condition flags based on the result.

Encodings

T1 `RSBS <Rd>,<Rn>,#0` Outside IT block.

`RSB<c> <Rd>,<Rn>,#0` Inside IT block.

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0	1	0	0	0	0	1	0	0	1	Rn			Rd		

```
d = UInt(Rd);  n = UInt(Rn);  setflags = !InITBlock();
imm32 = ZeroExtend('0', 32); // Implicit zero immediate
```

T2 `RSB{S}<c>.W <Rd>,<Rn>,#<const>`

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	1	0	i	0	1	1	1	0	S	Rn				0	imm3			Rd				imm8							

```
d = UInt(Rd);  n = UInt(Rn);  setflags = (S == '1');
imm32 = ThumbExpandImm(i:imm3:imm8);
if BadReg(d) || BadReg(n) then UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set.

Encoding T2 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

```
RSB{S}<c><q>  {<Rd>,} <Rn>, #<const>
```

where:

`S` If present, specifies that the instruction updates the flags. Otherwise, the instruction does not update the flags.

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<Rd>` Specifies the destination register. If `<Rd>` is omitted, this register is the same as `<Rn>`.

`<Rn>` Specifies the register that contains the first operand.

`<const>` Specifies the immediate value to be added to the value obtained from `<Rn>`. The only allowed value for encoding T1 is 0. See *Immediate constants* on page 4-8 for the range of allowed values for encoding T2.

The pre-UAL syntax `RSB<c>S` is equivalent to `RSBS<c>`.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    (result, carry, overflow) = AddWithCarry(NOT(R[n]), imm32, '1');
    R[d] = result;
    if setflags then
        APSR.N = result<31>;
        APSR.Z = IsZeroBit(result);
        APSR.C = carry;
        APSR.V = overflow;
```

Exceptions

None.

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4.6.119 RSB (register)

Reverse Subtract (register) subtracts a register value from an optionally-shifted register value, and writes the result to the destination register. It can optionally update the condition flags based on the result.

Encodings

T1 `RSB{S}<c> <Rd>,<Rn>,<Rm>{,<shift>}`

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	0	1	0	1	1	1	1	0	S	Rn				(0)	imm3			Rd				imm2		type		Rm			

```
d = UInt(Rd);  n = UInt(Rn);  m = UInt(Rm);  setflags = (S == '1');
(shift_t, shift_n) = DecodeImmShift(type, imm3:imm2);
if BadReg(d) || BadReg(n) || BadReg(m) THEN UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

```
RSB{S}<c><q>  {<Rd>,} <Rn>, <Rm> {,<shift>}
```

where:

`S` If present, specifies that the instruction updates the flags. Otherwise, the instruction does not update the flags.

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<Rd>` Specifies the destination register. If `<Rd>` is omitted, this register is the same as `<Rn>`.

`<Rn>` Specifies the register that contains the first operand.

`<Rm>` Specifies the register that is optionally shifted and used as the second operand.

`<shift>` Specifies the shift to apply to the value read from `<Rm>`. If `<shift>` is omitted, no shift is applied. The possible shifts and how they are encoded are described in *Constant shifts applied to a register* on page 4-10.

The pre-UAL syntax `RSB<c>S` is equivalent to `RSBS<c>`.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    shifted = Shift(R[m], shift_t, shift_n, APSR.C);
    (result, carry, overflow) = AddWithCarry(NOT(R[n]), shifted, '1');
    R[d] = result;
    if setflags then
        APSR.N = result<31>;
        APSR.Z = IsZeroBit(result);
        APSR.C = carry;
        APSR.V = overflow;
```

Exceptions

None.

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4.6.120 SADD16

Signed Add 16 performs two 16-bit signed integer additions, and writes the results to the destination register. It sets the GE bits in the APSR according to the results of the additions.

Encodings

T1 `SADD16<c> <Rd>,<Rn>,<Rm>`

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	1	1	0	1	0	1	0	0	1	Rn				1	1	1	1	Rd				0	0	0	0	Rm			

```
d = UInt(Rd);  n = UInt(Rn);  m = UInt(Rm);
if BadReg(d) || BadReg(n) || BadReg(m) then UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

```
SADD16<c><q>  {<Rd>,} <Rn>, <Rm>
```

where:

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<Rd>` Specifies the destination register. If `<Rd>` is omitted, this register is the same as `<Rn>`.

`<Rn>` Specifies the register that contains the first operand.

`<Rm>` Specifies the register that contains the second operand.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    sum1 = SInt(R[n]<15:0>) + SInt(R[m]<15:0>);
    sum2 = SInt(R[n]<31:16>) + SInt(R[m]<31:16>);
    R[d]<15:0>  = sum1<15:0>;
    R[d]<31:16> = sum2<15:0>;
    APSR.GE<1:0> = if sum1 >= 0 then '11' else '00';
    APSR.GE<3:2> = if sum2 >= 0 then '11' else '00';
```

Exceptions

None.

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4.6.121 SADD8

Signed Add 8 performs four 8-bit signed integer additions, and writes the results to the destination register. It sets the GE bits in the APSR according to the results of the additions.

Encodings

T1 `SADD8<c> <Rd>,<Rn>,<Rm>`

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	1	1	0	1	0	1	0	0	0	Rn				1	1	1	1	Rd				0	0	0	0	Rm			

```
d = UInt(Rd);  n = UInt(Rn);  m = UInt(Rm);
if BadReg(d) || BadReg(n) || BadReg(m) then UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

```
SADD8<c><q>  {<Rd>,} <Rn>, <Rm>
```

where:

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<Rd>` Specifies the destination register. If `<Rd>` is omitted, this register is the same as `<Rn>`.

`<Rn>` Specifies the register that contains the first operand.

`<Rm>` Specifies the register that contains the second operand.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    sum1 = SInt(R[n]<7:0>) + SInt(R[m]<7:0>);
    sum2 = SInt(R[n]<15:8>) + SInt(R[m]<15:8>);
    sum3 = SInt(R[n]<23:16>) + SInt(R[m]<23:16>);
    sum4 = SInt(R[n]<31:24>) + SInt(R[m]<31:24>);
    R[d]<7:0>   = sum1<7:0>;
    R[d]<15:8>  = sum2<7:0>;
    R[d]<23:16> = sum3<7:0>;
    R[d]<31:24> = sum4<7:0>;
    APSR.GE<0>  = if sum1 >= 0 then '1' else '0';
    APSR.GE<1>  = if sum2 >= 0 then '1' else '0';
    APSR.GE<2>  = if sum3 >= 0 then '1' else '0';
    APSR.GE<3>  = if sum4 >= 0 then '1' else '0';
```

Exceptions

None.

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4.6.122 SASX

Signed Add and Subtract with Exchange exchanges the two halfwords of the second operand, performs one 16-bit integer addition and one 16-bit subtraction, and writes the results to the destination register. It sets the GE bits in the APSR according to the results.

Encodings

T1 `SASX<c> <Rd>,<Rn>,<Rm>`

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	1	1	0	1	0	1	0	1	0	Rn				1	1	1	1	Rd				0	0	0	0	Rm			

```
d = UInt(Rd);  n = UInt(Rn);  m = UInt(Rm);
if BadReg(d) || BadReg(n) || BadReg(m) then UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

```
SASX<c><q>  {<Rd>,} <Rn>, <Rm>
```

where:

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<Rd>` Specifies the destination register. If `<Rd>` is omitted, this register is the same as `<Rn>`.

`<Rn>` Specifies the register that contains the first operand.

`<Rm>` Specifies the register that contains the second operand.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    diff = SInt(R[n]<15:0>) - SInt(R[m]<31:16>);
    sum  = SInt(R[n]<31:16>) + SInt(R[m]<15:0>);
    R[d]<15:0>  = diff<15:0>;
    R[d]<31:16> = sum<15:0>;
    APSR.GE<1:0> = if diff >= 0 then '11' else '00';
    APSR.GE<3:2> = if sum  >= 0 then '11' else '00';
```

Exceptions

None.

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4.6.123 SBC (immediate)

Subtract with Carry (immediate) subtracts an immediate value and the value of NOT(Carry flag) from a register value, and writes the result to the destination register. It can optionally update the condition flags based on the result.

Encodings

T1 `SBC{S}<c> <Rd>,<Rn>,#<const>`

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	1	0	i	0	1	0	1	1	S	Rn				0	imm3			Rd				imm8							

```
d = UInt(Rd);  n = UInt(Rn);  setflags = (S == '1');
imm32 = ThumbExpandImm(i:imm3:imm8);
if BadReg(d) || BadReg(n) then UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

```
SBC{S}<c><q>  {<Rd>,} <Rn>, #<const>
```

where:

`S` If present, specifies that the instruction updates the flags. Otherwise, the instruction does not update the flags.

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<Rd>` Specifies the destination register. If `<Rd>` is omitted, this register is the same as `<Rn>`.

`<Rn>` Specifies the register that contains the first operand.

`<const>` Specifies the immediate value to be added to the value obtained from `<Rn>`. See *Immediate constants* on page 4-8 for the range of allowed values.

The pre-UAL syntax `SBC<c>S` is equivalent to `SBCS<c>`.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    (result, carry, overflow) = AddWithCarry(R[n], NOT(imm32), APSR.C);
    R[d] = result;
    if setflags then
        APSR.N = result<31>;
        APSR.Z = IsZeroBit(result);
        APSR.C = carry;
        APSR.V = overflow;
```

Exceptions

None.

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4.6.124 SBC (register)

Subtract with Carry (register) subtracts an optionally-shifted register value and the value of NOT(Carry flag) from a register value, and writes the result to the destination register. It can optionally update the condition flags based on the result.

Encodings

T1 `SBCS <Rdn>,<Rm>` Outside IT block.

`SBC<c> <Rdn>,<Rm>` Inside IT block.

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0	1	0	0	0	0	0	1	1	0	Rm			Rdn		

```
d = UInt(Rdn);  n = UInt(Rdn);  m = UInt(Rm);  setflags = !InITBlock();
(shift_t, shift_n) = (SRType_None, 0);
```

T2 `SBC{S}<c>.W <Rd>,<Rn>,<Rm>{,<shift>}`

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	0	1	0	1	1	0	1	1	S	Rn				(0)	imm3			Rd				imm2		type		Rm			

```
d = UInt(Rd);  n = UInt(Rn);  m = UInt(Rm);  setflags = (S == '1');
(shift_t, shift_n) = DecodeImmShift(type, imm3:imm2);
if BadReg(d) || BadReg(n) || BadReg(m) THEN UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set

Encoding T2 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

```
SBC{S}<c><q>  {<Rd>,} <Rn>, <Rm> {,<shift>}
```

where:

S — If present, specifies that the instruction updates the flags. Otherwise, the instruction does not update the flags.

<c><q> — See *Standard assembler syntax fields* on page 4-6.

<Rd> — Specifies the destination register. If `<Rd>` is omitted, this register is the same as `<Rn>`.

<Rn> — Specifies the register that contains the first operand.

<Rm> — Specifies the register that is optionally shifted and used as the second operand.

<shift> — Specifies the shift to apply to the value read from `<Rm>`. If `<shift>` is omitted, no shift is applied and both encodings are permitted. If <shift> is specified, only encoding T2 is permitted. The possible shifts and how they are encoded are described in *Constant shifts applied to a register* on page 4-10.

The pre-UAL syntax `SBC<c>S` is equivalent to `SBCS<c>`.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    shifted = Shift(R[m], shift_t, shift_n, APSR.C);
    (result, carry, overflow) = AddWithCarry(R[n], NOT(shifted), APSR.C);
    R[d] = result;
    if setflags then
        APSR.N = result<31>;
        APSR.Z = IsZeroBit(result);
        APSR.C = carry;
        APSR.V = overflow;
```

Exceptions

None.

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4.6.125 SBFX

Signed Bit Field Extract extracts any number of adjacent bits at any position from one register, sign extends them to 32 bits, and writes the result to the destination register.

Encodings

T1 `SBFX<c> <Rd>,<Rn>,#<lsb>,#<width>`

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	1	0	(0)	1	1	0	1	0	0	Rn			

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0	imm3			Rd				imm2		(0)	widthm1				

```
d = UInt(Rd);  n = UInt(Rn);
lsbit = UInt(imm3:imm2);  widthminus1 = UInt(widthm1);
if BadReg(d) || BadReg(n) then UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

```
SBFX<c><q>  <Rd>, <Rn>, #<lsb>, #<width>
```

where:

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<Rd>` Specifies the destination register.

`<Rn>` Specifies the register that contains the first operand.

`<lsb>` is the bit number of the least significant bit in the bitfield, in the range 0-31. This determines the required value of `lsbit`.

`<width>` is the width of the bitfield, in the range 1 to 32-`<lsb>`. The required value of `widthminus1` is `<width>-1`.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    msbit = lsbit + widthminus1;
    if msbit <= 31 then
        R[d] = SignExtend(R[n]<msbit:lsbit>, 32);
    else
        UNPREDICTABLE;
```

Exceptions

None.

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4.6.126 SDIV

Signed Divide divides a 32-bit signed integer register value by a 32-bit signed integer register value, and writes the result to the destination register. The condition code flags are not affected.

Encodings

T1 `SDIV<c> <Rd>,<Rn>,<Rm>`

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	1	1	0	1	1	1	0	0	1	Rn				(1)	(1)	(1)	(1)	Rd				1	1	1	1	Rm			

```
d = UInt(Rd);  n = UInt(Rn);  m = UInt(Rm);
if BadReg(d) || BadReg(n) || BadReg(m) then UNPREDICTABLE;
```

Architecture versions

Encoding T1 Profile R versions of the Thumb instruction set from ARMv7 onwards.

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Assembler syntax

```
SDIV<c><q>  {<Rd>,} <Rn>, <Rm>
```

where:

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<Rd>` Specifies the destination register. If `<Rd>` is omitted, this register is the same as `<Rn>`.

`<Rn>` Specifies the register that contains the dividend.

`<Rm>` Specifies the register that contains the divisor.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    if SInt(R[m]) == 0 then
        if IntegerZeroDivideTrappingEnabled() then
            RaiseIntegerZeroDivide();
        else
            result = 0;
    else
        result = RoundTowardsZero(SInt(R[n]) / SInt(R[m]));
    R[d] = result<31:0>;
```

Exceptions

Undefined Instruction.

Notes

Overflow If the signed integer division `0x80000000 / 0xFFFFFFFF` is performed, the pseudo-code produces the intermediate integer result $+2^{31}$, which overflows the 32-bit signed integer range. No indication of this overflow case is produced, and the 32-bit result written to `R[d]` is required to be the bottom 32 bits of the binary representation of $+2^{31}$. So the result of the division is `0x80000000`.

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4.6.127 SEL

Select Bytes selects each byte of its result from either its first operand or its second operand, according to the values of the GE flags.

Encodings

T1 `SEL<c> <Rd>,<Rn>,<Rm>`

<table>
<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><td>7</td><td>6</td><td>5</td><td>4</td><td>3</td><td>2</td><td>1</td><td>0</td><td>15</td><td>14</td><td>13</td><td>12</td><td>11</td><td>10</td><td>9</td><td>8</td><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>
<tr><td>1</td><td>1</td><td>1</td><td>1</td><td>1</td><td>0</td><td>1</td><td>0</td><td>1</td><td>0</td><td>1</td><td>0</td><td colspan="4">Rn</td><td>1</td><td>1</td><td>1</td><td>1</td><td colspan="4">Rd</td><td>1</td><td>0</td><td>0</td><td>0</td><td colspan="4">Rm</td></tr>
</table>

```
d = UInt(Rd);  n = UInt(Rn);  m = UInt(Rm);
if BadReg(d) || BadReg(n) || BadReg(m) then UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

```
SEL<c><q>  {<Rd>,} <Rn>, <Rm>
```

where:

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<Rd>` Specifies the destination register. If `<Rd>` is omitted, this register is the same as `<Rn>`.

`<Rn>` Specifies the register that contains the first operand.

`<Rm>` Specifies the register that contains the second operand.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    R[d]<7:0>   = if APSR.GE<0> == '1' then R[n]<7:0>   else R[m]<7:0>;
    R[d]<15:8>  = if APSR.GE<1> == '1' then R[n]<15:8>  else R[m]<15:8>;
    R[d]<23:16> = if APSR.GE<2> == '1' then R[n]<23:16> else R[m]<23:16>;
    R[d]<31:24> = if APSR.GE<3> == '1' then R[n]<31:24> else R[m]<31:24>;
```

Exceptions

None.

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4.6.128 SETEND

`SETEND` modifies the CPSR E bit, without changing any other bits in the CPSR.

Encodings

T1 `SETEND <endian_specifier>` Not allowed in an IT block

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	0	1	1	0	1	1	0	0	1	0	1	E	(0)	(0)	(0)

```
set_bigend = (E == '1');
if InITBlock() then UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set from v6 onwards.

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Assembler syntax

```
SETEND<q>  <endian_specifier>
```

where:

`<q>` See *Standard assembler syntax fields* on page 4-6.

`<endian_specifier>`

Is one of:

`BE` Sets the E bit in the instruction. This sets the CPSR E bit.

`LE` Clears the E bit in the instruction. This clears the CPSR E bit.

Operation

```
EncodingSpecificOperations();
if set_bigend then
    SetEndianness(Endian_Big);
else
    SetEndianness(Endian_Little);
```

Exceptions

None.

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4.6.129 SEV

Send Event is a hint instruction. It causes an event to be signaled to all CPUs within the multiprocessor system.

Encodings

T1 `SEV<c>`

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	0	1	1	1	1	1	1	0	1	0	0	0	0	0	0

```
// Do nothing
```

T2 `SEV<c>.W`

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	1	0	0	1	1	1	0	1	0	(1)	(1)	(1)	(1)	1	0	(0)	0	(0)	0	0	0	0	0	0	0	0	1	0	0

```
// Do nothing
```

Architecture versions

Encodings T1, T2 All versions of the Thumb instruction set from v6K onwards.

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Assembler syntax

```
SEV<c><q>
```

where:

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    Hint_SendEvent();
```

Exceptions

None.

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4.6.130 SHADD16

Signed Halving Add 16 performs two signed 16-bit integer additions, halves the results, and writes the results to the destination register. It does not affect any flags.

Encodings

T1 `SHADD16<c> <Rd>,<Rn>,<Rm>`

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	1	1	0	1	0	1	0	0	1	Rn				1	1	1	1	Rd				0	0	1	0	Rm			

```
d = UInt(Rd);  n = UInt(Rn);  m = UInt(Rm);
if BadReg(d) || BadReg(n) || BadReg(m) then UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

```
SHADD16<c><q>  {<Rd>,} <Rn>, <Rm>
```

where:

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<Rd>` Specifies the destination register. If `<Rd>` is omitted, this register is the same as `<Rn>`.

`<Rn>` Specifies the register that contains the first operand.

`<Rm>` Specifies the register that contains the second operand.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    sum1 = SInt(R[n]<15:0>) + SInt(R[m]<15:0>);
    sum2 = SInt(R[n]<31:16>) + SInt(R[m]<31:16>);
    R[d]<15:0>  = sum1<16:1>;
    R[d]<31:16> = sum2<16:1>;
```

Exceptions

None.

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4.6.131 SHADD8

Signed Halving Add 8 performs four signed 8-bit integer additions, halves the results, and writes the results to the destination register. It does not affect any flags.

Encodings

T1 `SHADD8<c> <Rd>,<Rn>,<Rm>`

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	1	1	0	1	0	1	0	0	0	Rn				1	1	1	1	Rd				0	0	1	0	Rm			

```
d = UInt(Rd);  n = UInt(Rn);  m = UInt(Rm);
if BadReg(d) || BadReg(n) || BadReg(m) then UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

```
SHADD8<c><q>  {<Rd>,} <Rn>, <Rm>
```

where:

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<Rd>` Specifies the destination register. If `<Rd>` is omitted, this register is the same as `<Rn>`.

`<Rn>` Specifies the register that contains the first operand.

`<Rm>` Specifies the register that contains the second operand.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    sum1 = SInt(R[n]<7:0>) + SInt(R[m]<7:0>);
    sum2 = SInt(R[n]<15:8>) + SInt(R[m]<15:8>);
    sum3 = SInt(R[n]<23:16>) + SInt(R[m]<23:16>);
    sum4 = SInt(R[n]<31:24>) + SInt(R[m]<31:24>);
    R[d]<7:0>   = sum1<8:1>;
    R[d]<15:8>  = sum2<8:1>;
    R[d]<23:16> = sum3<8:1>;
    R[d]<31:24> = sum4<8:1>;
```

Exceptions

None.

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4.6.132 SHASX

Signed Halving Add and Subtract with Exchange exchanges the two halfwords of the second operand, performs one signed 16-bit integer addition and one signed 16-bit subtraction, halves the results, and writes the results to the destination register. It does not affect any flags.

Encodings

T1 `SHASX<c> <Rd>,<Rn>,<Rm>`

<table>
<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><td>7</td><td>6</td><td>5</td><td>4</td><td>3</td><td>2</td><td>1</td><td>0</td><td>15</td><td>14</td><td>13</td><td>12</td><td>11</td><td>10</td><td>9</td><td>8</td><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>
<tr><td>1</td><td>1</td><td>1</td><td>1</td><td>1</td><td>0</td><td>1</td><td>0</td><td>1</td><td>0</td><td>1</td><td>0</td><td colspan="4">Rn</td><td>1</td><td>1</td><td>1</td><td>1</td><td colspan="4">Rd</td><td>0</td><td>0</td><td>1</td><td>0</td><td colspan="4">Rm</td></tr>
</table>

```
d = UInt(Rd);  n = UInt(Rn);  m = UInt(Rm);
if BadReg(d) || BadReg(n) || BadReg(m) then UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

```
SHASX<c><q>  {<Rd>,} <Rn>, <Rm>
```

where:

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<Rd>` Specifies the destination register. If `<Rd>` is omitted, this register is the same as `<Rn>`.

`<Rn>` Specifies the register that contains the first operand.

`<Rm>` Specifies the register that contains the second operand.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    diff = SInt(R[n]<15:0>) - SInt(R[m]<31:16>);
    sum  = SInt(R[n]<31:16>) + SInt(R[m]<15:0>);
    R[d]<15:0>  = diff<16:1>;
    R[d]<31:16> = sum<16:1>;
```

Exceptions

None.

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4.6.133 SHSAX

Signed Halving Subtract and Add with Exchange exchanges the two halfwords of the second operand, performs one signed 16-bit integer subtraction and one signed 16-bit addition, halves the results, and writes the results to the destination register. It does not affect any flags.

Encodings

T1 SHSAX<c> <Rd>,<Rn>,<Rm>

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	1	1	0	1	0	1	1	1	0	Rn				1	1	1	1	Rd				0	0	1	0	Rm			

```
d = UInt(Rd);  n = UInt(Rn);  m = UInt(Rm);
if BadReg(d) || BadReg(n) || BadReg(m) then UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

```
SHSAX<c><q>  {<Rd>,} <Rn>, <Rm>
```

where:

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<Rd>` Specifies the destination register. If `<Rd>` is omitted, this register is the same as `<Rn>`.

`<Rn>` Specifies the register that contains the first operand.

`<Rm>` Specifies the register that contains the second operand.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    sum  = SInt(R[n]<15:0>) + SInt(R[m]<31:16>);
    diff = SInt(R[n]<31:16>) - SInt(R[m]<15:0>);
    R[d]<15:0>  = sum<16:1>;
    R[d]<31:16> = diff<16:1>;
```

Exceptions

None.

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4.6.134 SHSUB16

Signed Halving Subtract 16 performs two signed 16-bit integer subtractions, halves the results, and writes the results to the destination register. It does not affect any flags.

Encodings

T1 `SHSUB16<c> <Rd>,<Rn>,<Rm>`

15	14	13	12	11	10	9	8	7	6	5	4	3 2 1 0	15	14	13	12	11 10 9 8	7	6	5	4	3 2 1 0
1	1	1	1	1	0	1	0	1	1	0	1	Rn	1	1	1	1	Rd	0	0	1	0	Rm

```
d = UInt(Rd);  n = UInt(Rn);  m = UInt(Rm);
if BadReg(d) || BadReg(n) || BadReg(m) then UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

```
SHSUB16<c><q>  {<Rd>,} <Rn>, <Rm>
```

where:

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<Rd>` Specifies the destination register. If `<Rd>` is omitted, this register is the same as `<Rn>`.

`<Rn>` Specifies the register that contains the first operand.

`<Rm>` Specifies the register that contains the second operand.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    diff1 = SInt(R[n]<15:0>) - SInt(R[m]<15:0>);
    diff2 = SInt(R[n]<31:16>) - SInt(R[m]<31:16>);
    R[d]<15:0>  = diff1<16:1>;
    R[d]<31:16> = diff2<16:1>;
```

Exceptions

None.

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4.6.135 SHSUB8

Signed Halving Subtract 8 performs four signed 8-bit integer subtractions, halves the results, and writes the results to the destination register. It does not affect any flags.

Encodings

T1 SHSUB8<c> <Rd>,<Rn>,<Rm>

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	1	1	0	1	0	1	1	0	0	Rn				1	1	1	1	Rd				0	0	1	0	Rm			

```
d = UInt(Rd);  n = UInt(Rn);  m = UInt(Rm);
if BadReg(d) || BadReg(n) || BadReg(m) then UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

```
SHSUB8<c><q>  {<Rd>,} <Rn>, <Rm>
```

where:

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<Rd>` Specifies the destination register. If `<Rd>` is omitted, this register is the same as `<Rn>`.

`<Rn>` Specifies the register that contains the first operand.

`<Rm>` Specifies the register that contains the second operand.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    diff1 = SInt(R[n]<7:0>) - SInt(R[m]<7:0>);
    diff2 = SInt(R[n]<15:8>) - SInt(R[m]<15:8>);
    diff3 = SInt(R[n]<23:16>) - SInt(R[m]<23:16>);
    diff4 = SInt(R[n]<31:24>) - SInt(R[m]<31:24>);
    R[d]<7:0>   = diff1<8:1>;
    R[d]<15:8>  = diff2<8:1>;
    R[d]<23:16> = diff3<8:1>;
    R[d]<31:24> = diff4<8:1>;
```

Exceptions

None.

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4.6.136 SMC (formerly SMI)

Secure Monitor Call causes a Secure Monitor exception.

Encodings

T1 SMC<c> #<imm4>

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	1	0	1	1	1	1	1	1	1	imm4				1	0	0	0	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)

```
imm32 = ZeroExtend(imm4, 32);
// imm32 is for assembly/disassembly only and is ignored by hardware
if InITBlock() && !LastInITBlock() then UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set from Thumb-2 onwards, if Security Extensions are implemented.

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Assembler syntax

```
SMC<c><q>  #<imm4>
```

where:

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<imm4>` Is a 4-bit immediate value. This is ignored by the ARM processor. It can be used by the SMI exception handler (secure monitor code) to determine what service is being requested, but this is not recommended.

The pre-UAL syntax `SMI<c>` is equivalent to `SMC<c>`.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    CallSecureMonitor();
```

Exceptions

None.

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4.6.137 SMLABB, SMLABT, SMLATB, SMLATT

Signed Multiply Accumulate (halfwords) performs a signed multiply-accumulate operation. The multiply acts on two signed 16-bit quantities, taken from either the bottom or the top half of their respective source registers. The other halves of these source registers are ignored. The 32-bit product is added to a 32-bit accumulate value and the result is written to the destination register.

If overflow occurs during the addition of the accumulate value, the instruction sets the Q flag in the CPSR. It is not possible for overflow to occur during the multiplication.

Encodings

T1 `SMLA<x><y><c> <Rd>,<Rn>,<Rm>,<Ra>`

15	14	13	12	11	10	9	8	7	6	5	4	3 2 1 0	15 14 13 12	11 10 9 8	7	6	5	4	3 2 1 0
1	1	1	1	1	0	1	1	0	0	0	1	Rn	Ra	Rd	0	0	N	M	Rm

```
d = UInt(Rd);  n = UInt(Rn);  m = UInt(Rm);  a = UInt(Ra);
n_high = (N == '1');  m_high = (M == '1');
if a == 15 then SEE SMULBB, SMULBT, SMULTB, SMULTT on page 4-311;
if BadReg(d) || BadReg(n) || BadReg(m) || a == 13 then UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

```
SMLA<x><y><c><q>  <Rd>, <Rn>, <Rm>, <Ra>
```

where:

`<x>` Specifies which half of the source register `<Rn>` is used as the first multiply operand. If `<x>` is `B`, then the bottom half (bits[15:0]) of `<Rn>` is used. If `<x>` is `T`, then the top half (bits[31:16]) of `<Rn>` is used.

`<y>` Specifies which half of the source register `<Rm>` is used as the second multiply operand. If `<y>` is `B`, then the bottom half (bits[15:0]) of `<Rm>` is used. If `<y>` is `T`, then the top half (bits[31:16]) of `<Rm>` is used.

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<Rd>` Specifies the destination register.

`<Rn>` Specifies the register that contains the first operand.

`<Rm>` Specifies the register that contains the second operand.

`<Ra>` Specifies the register that contains the accumulate value.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    operand1 = if n_high then R[n]<31:16> else R[n]<15:0>;
    operand2 = if m_high then R[m]<31:16> else R[m]<15:0>;
    result = SInt(operand1) * SInt(operand2) + SInt(R[a]);
    R[d] = result<31:0>;
    if result != SInt(result<31:0>) then  // Signed overflow
        APSR.Q = '1';
```

Exceptions

None.

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4.6.138 SMLAD

Signed Multiply Accumulate Dual performs two signed 16 x 16-bit multiplications. It adds the products to a 32-bit accumulate operand.

Optionally, you can exchange the halfwords of the second operand before performing the arithmetic. This produces top x bottom and bottom x top multiplication.

This instruction sets the Q flag if the accumulate operation overflows. Overflow cannot occur during the multiplications.

Encodings

T1 `SMLAD{X}<c> <Rd>,<Rn>,<Rm>,<Ra>`

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	1	1	0	1	1	0	0	1	0	Rn				Ra				Rd				0	0	0	M	Rm			

```
d = UInt(Rd);  n = UInt(Rn);  m = UInt(Rm);  a = UInt(Ra);
m_swap = (M == '1');
if a == 15 then SEE SMUAD on page 4-309;
if BadReg(d) || BadReg(n) || BadReg(m) || a == 13 then UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

```
SMLAD{X}<c><q>  <Rd>, <Rn>, <Rm>, <Ra>
```

where:

`X` If X is present, the multiplications are bottom x top and top x bottom.

If the X is omitted, the multiplications are bottom x bottom and top x top.

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<Rd>` Specifies the destination register.

`<Rn>` Specifies the register that contains the first operand.

`<Rm>` Specifies the register that contains the second operand.

`<Ra>` Specifies the register that contains the accumulate value.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    operand2 = if m_swap then ROR(R[m],16) else R[m];
    product1 = SInt(R[n]<15:0>) * SInt(operand2<15:0>);
    product2 = SInt(R[n]<31:16>) * SInt(operand2<31:16>);
    result = product1 + product2 + SInt(R[a]);
    R[d] = result<31:0>;
    if result != SInt(result<31:0>) then  // Signed overflow
        APSR.Q = '1';
```

Exceptions

None.

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4.6.139 SMLAL

Signed Multiply Accumulate Long multiplies two signed 32-bit values to produce a 64-bit value, and accumulates this with a 64-bit value.

Encodings

T1 `SMLAL<c> <RdLo>,<RdHi>,<Rn>,<Rm>`

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	1	1	0	1	1	1	1	0	0	Rn				RdLo				RdHi				0	0	0	0	Rm			

```
dLo = UInt(RdLo);  dHi = UInt(RdHi);  n = UInt(Rn);  m = UInt(Rm);
if BadReg(dLo) || BadReg(dHi) || BadReg(n) || BadReg(m) then UNPREDICTABLE;
if dHi == dLo then UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

```
SMLAL<c><q>  <RdLo>, <RdHi>, <Rn>, <Rm>
```

where:

`<c><q>`	See *Standard assembler syntax fields* on page 4-6.
`<RdLo>`	Supplies the lower 32 bits of the accumulate value, and is the destination register for the lower 32 bits of the result.
`<RdHi>`	Supplies the upper 32 bits of the accumulate value, and is the destination register for the upper 32 bits of the result.
`<Rn>`	Specifies the register that contains the first operand.
`<Rm>`	Specifies the register that contains the second operand.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    result = SInt(R[n])*Sint(R[m])+SInt(R[dHi]:R[dLo])
    R[dHi] = result<63:32>;
    R[dLo] = result<31:0>;
```

Exceptions

None.

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4.6.140 SMLALBB, SMLALBT, SMLALTB, SMLALTT

Signed Multiply Accumulate Long (halfwords) multiplies two signed 16-bit values to produce a 32-bit value, and accumulates this with a 64-bit value. The multiply acts on two signed 16-bit quantities, taken from either the bottom or the top half of their respective source registers. The other halves of these source registers are ignored. The 32-bit product is sign-extended and accumulated with a 64-bit accumulate value.

Overflow is possible during this instruction, but only as a result of the 64-bit addition. This overflow is not detected if it occurs. Instead, the result wraps around modulo 2^{64}.

Encodings

T1 SMLAL<x><y><c> <RdLo>,<RdHi>,<Rn>,<Rm>

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	1	1	0	1	1	1	1	0	0	Rn				RdLo				RdHi				1	0	N	M	Rm			

```
dLo = UInt(RdLo);  dHi = UInt(RdHi);  n = UInt(Rn);  m = UInt(Rm);
n_high = (N == '1');  m_high = (M == '1');
if BadReg(dLo) || BadReg(dHi) || BadReg(n) || BadReg(m) then UNPREDICTABLE;
if dHi == dLo then UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

```
SMLAL<x><y><c><q>  <RdLo>, <RdHi>, <Rn>, <Rm>
```

where:

`<x>` Specifies which half of the source register `<Rn>` is used as the first multiply operand. If `<x>` is `B`, then the bottom half (bits[15:0]) of `<Rn>` is used. If `<x>` is `T`, then the top half (bits[31:16]) of `<Rn>` is used.

`<y>` Specifies which half of the source register `<Rm>` is used as the second multiply operand. If `<y>` is `B`, then the bottom half (bits[15:0]) of `<Rm>` is used. If `<y>` is `T`, then the top half (bits[31:16]) of `<Rm>` is used.

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<RdLo>` Supplies the lower 32 bits of the accumulate value, and is the destination register for the lower 32 bits of the result.

`<RdHi>` Supplies the upper 32 bits of the accumulate value, and is the destination register for the upper 32 bits of the result.

`<Rn>` Specifies the source register whose bottom or top half (selected by `<x>`) is the first multiply operand.

`<Rm>` Specifies the source register whose bottom or top half (selected by `<y>`) is the second multiply operand.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    operand1 = if n_high then R[n]<31:16> else R[n]<15:0>;
    operand2 = if m_high then R[m]<31:16> else R[m]<15:0>;
    result = SInt(operand1) * SInt(operand2) + SInt(R[dHi]:R[dLo]);
    R[dHi] = result<63:32>;
    R[dLo] = result<31:0>;
```

Exceptions

None.

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4.6.141 SMLALD

Signed Multiply Accumulate Long Dual performs two signed 16 x 16-bit multiplications. It adds the products to a 64-bit accumulate operand.

Optionally, you can exchange the halfwords of the second operand before performing the arithmetic. This produces top x bottom and bottom x top multiplication.

Overflow is possible during this instruction, but only as a result of the 64-bit addition. This overflow is not detected if it occurs. Instead, the result wraps around modulo 2^{64}.

Encodings

T1 `SMLALD{X}<c> <RdLo>,<RdHi>,<Rn>,<Rm>`

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	1	1	0	1	1	1	1	0	0	Rn				RdLo				RdHi				1	1	0	M	Rm			

```
dLo = UInt(RdLo);  dHi = UInt(RdHi);  n = UInt(Rn);  m = UInt(Rm);
m_swap = (M == '1');
if BadReg(dLo) || BadReg(dHi) || BadReg(n) || BadReg(m) then UNPREDICTABLE;
if dHi == dLo then UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

```
SMLALD{X}<c><q>  <RdLo>, <RdHi>, <Rn>, <Rm>
```

where:

X — If X is present, the multiplications are bottom x top and top x bottom.
If the X is omitted, the multiplications are bottom x bottom and top x top.

<c><q> — See *Standard assembler syntax fields* on page 4-6.

<RdLo> — Supplies the lower 32 bits of the accumulate value, and is the destination register for the lower 32 bits of the result.

<RdHi> — Supplies the upper 32 bits of the accumulate value, and is the destination register for the upper 32 bits of the result.

<Rn> — Specifies the register that contains the first operand.

<Rm> — Specifies the register that contains the second operand.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    operand2 = if m_swap then ROR(R[m],16) else R[m];
    product1 = SInt(R[n]<15:0>) * SInt(operand2<15:0>);
    product2 = SInt(R[n]<31:16>) * SInt(operand2<31:16>);
    result = product1 + product2 + SInt(R[dHi]:R[dLo]);
    R[dHi] = result<63:32>;
    R[dLo] = result<31:0>;
```

Exceptions

None.

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4.6.142 SMLAWB, SMLAWT

Signed Multiply Accumulate (word by halfword) performs a signed multiply-accumulate operation. The multiply acts on a signed 32-bit quantity and a signed 16-bit quantity. The signed 16-bit quantity is taken from either the bottom or the top half of its source register. The other half of the second source register is ignored. The top 32 bits of the 48-bit product are added to a 32-bit accumulate value and the result is written to the destination register. The bottom 16 bits of the 48-bit product are ignored.

If overflow occurs during the addition of the accumulate value, the instruction sets the Q flag in the CPSR. No overflow can occur during the multiplication.

Encodings

T1 SMLAW<y><c> <Rd>,<Rn>,<Rm>,<Ra>

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	1	1	0	1	1	0	0	1	1	Rn				Ra				Rd				0	0	0	M	Rm			

```
d = UInt(Rd);  n = UInt(Rn);  m = UInt(Rm);  a = UInt(Ra);
m_high = (M == '1');
if a == 15 then SEE SMULWB, SMULWT on page 4-315;
if BadReg(d) || BadReg(n) || BadReg(m) || a == 13 then UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

`SMLAW<y><c><q>  <Rd>, <Rn>, <Rm>, <Ra>`

where:

`<y>` Specifies which half of the source register `<Rm>` is used as the second multiply operand. If `<y>` is `B`, then the bottom half (bits[15:0]) of `<Rm>` is used. If `<y>` is `T`, then the top half (bits[31:16]) of `<Rm>` is used.

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<Rd>` Specifies the destination register.

`<Rn>` Specifies the register that contains the first operand.

`<Rm>` Specifies the register that contains the second operand.

`<Ra>` Specifies the register that contains the accumulate value.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    operand2 = if m_high then R[m]<31:16> else R[m]<15:0>;
    result = SInt(R[n]) * SInt(operand2) + (SInt(R[a]) << 16);
    R[d] = result<47:16>;
    if (result >> 16) != SInt(R[d]) then  // Signed overflow
        APSR.Q = '1';
```

Exceptions

None.

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4.6.143 SMLSD

Signed Multiply Subtract Dual performs two signed 16 x 16-bit multiplications. It adds the difference of the products to a 32-bit accumulate operand.

Optionally, you can exchange the halfwords of the second operand before performing the arithmetic. This produces top x bottom and bottom x top multiplication.

This instruction sets the Q flag if the accumulate operation overflows. Overflow cannot occur during the multiplications or subtraction.

Encodings

T1 `SMLSD{X}<c> <Rd>,<Rn>,<Rm>,<Ra>`

<table>
<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><td>7</td><td>6</td><td>5</td><td>4</td><td>3</td><td>2</td><td>1</td><td>0</td><td>15</td><td>14</td><td>13</td><td>12</td><td>11</td><td>10</td><td>9</td><td>8</td><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>
<tr><td>1</td><td>1</td><td>1</td><td>1</td><td>1</td><td>0</td><td>1</td><td>1</td><td>0</td><td>1</td><td>0</td><td>0</td><td colspan="4">Rn</td><td colspan="4">Ra</td><td colspan="4">Rd</td><td>0</td><td>0</td><td>0</td><td>M</td><td colspan="4">Rm</td></tr>
</table>

```
d = UInt(Rd);  n = UInt(Rn);  m = UInt(Rm);  a = UInt(Ra);
m_swap = (M == '1');
if a == 15 then SEE SMUSD on page 4-317;
if BadReg(d) || BadReg(n) || BadReg(m) || a == 13 then UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

```
SMLSD{X}<c><q>  <Rd>, <Rn>, <Rm>, <Ra>
```

where:

`X` If X is present, the multiplications are bottom x top and top x bottom.

If the X is omitted, the multiplications are bottom x bottom and top x top.

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<Rd>` Specifies the destination register.

`<Rn>` Specifies the register that contains the first operand.

`<Rm>` Specifies the register that contains the second operand.

`<Ra>` Specifies the register that contains the accumulate value.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    operand2 = if m_swap then ROR(R[m],16) else R[m];
    product1 = SInt(R[n]<15:0>) * SInt(operand2<15:0>);
    product2 = SInt(R[n]<31:16>) * SInt(operand2<31:16>);
    result = product1 - product2 + SInt(R[a]);
    R[d] = result<31:0>;
    if result != SInt(result<31:0>) then  // Signed overflow
        APSR.Q = '1';
```

Exceptions

None.

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4.6.144 SMLSLD

Signed Multiply Subtract Long Dual performs two signed 16 x 16-bit multiplications. It adds the difference of the products to a 64-bit accumulate operand.

Optionally, you can exchange the halfwords of the second operand before performing the arithmetic. This produces top x bottom and bottom x top multiplication.

Overflow is possible during this instruction, but only as a result of the 64-bit addition. This overflow is not detected if it occurs. Instead, the result wraps around modulo 2^{64}.

Encodings

T1 `SMLSLD{X}<c> <RdLo>,<RdHi>,<Rn>,<Rm>`

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	1	1	0	1	1	1	1	0	1	Rn				RdLo				RdHi				1	1	0	M	Rm			

```
dLo = UInt(RdLo);  dHi = UInt(RdHi);  n = UInt(Rn);  m = UInt(Rm);
m_swap = (M == '1');
if BadReg(dLo) || BadReg(dHi) || BadReg(n) || BadReg(m) then UNPREDICTABLE;
if dHi == dLo then UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

```
SMLSLD{X}<c><q>  <RdLo>, <RdHi>, <Rn>, <Rm>
```

where:

`X` If X is present, the multiplications are bottom x top and top x bottom.

If the X is omitted, the multiplications are bottom x bottom and top x top.

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<RdLo>` Supplies the lower 32 bits of the accumulate value, and is the destination register for the lower 32 bits of the result.

`<RdHi>` Supplies the upper 32 bits of the accumulate value, and is the destination register for the upper 32 bits of the result.

`<Rn>` Specifies the register that contains the first operand.

`<Rm>` Specifies the register that contains the second operand.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    operand2 = if m_swap then ROR(R[m],16) else R[m];
    product1 = SInt(R[n]<15:0>) * SInt(operand2<15:0>);
    product2 = SInt(R[n]<31:16>) * SInt(operand2<31:16>);
    result = product1 - product2 + SInt(R[dHi]:R[dLo]);
    R[dHi] = result<63:32>;
    R[dLo] = result<31:0>;
```

Exceptions

None.

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4.6.145 SMMLA

Signed Most Significant Word Multiply Accumulate multiplies two signed 32-bit values, extracts the most significant 32 bits of the result, and adds an accumulate value.

Optionally, you can specify that the result is rounded instead of being truncated. In this case, the constant `0x80000000` is added to the product before the high word is extracted.

Encodings

T1 `SMMLA{R}<c> <Rd>,<Rn>,<Rm>,<Ra>`

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	1	1	0	1	1	0	1	0	1	Rn				Ra				Rd				0	0	0	R	Rm			

```
d = UInt(Rd);  n = UInt(Rn);  m = UInt(Rm);  a = UInt(Ra);
round = (R == '1');
if a == 15 then SEE SMMUL on page 4-307;
if BadReg(d) || BadReg(n) || BadReg(m) || a == 13 then UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

```
SMMLA{R}<c><q>  <Rd>, <Rn>, <Rm>, <Ra>
```

where:

`R` If R is present, the multiplication is rounded.

If the R is omitted, the multiplication is truncated.

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<Rd>` Specifies the destination register.

`<Rn>` Specifies the register that contains the first multiply operand.

`<Rm>` Specifies the register that contains the second multiply operand.

`<Ra>` Specifies the register that contains the accumulate value.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    result = (SInt(R[a]) << 16) + SInt(R[n]) * SInt(R[m]);
    if round then result = result + 0x80000000;
    R[d] = result<63:32>;
```

Exceptions

None.

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4.6.146 SMMLS

Signed Most Significant Word Multiply Subtract multiplies two signed 32-bit values, extracts the most significant 32 bits of the result, and subtracts it from an accumulate value.

Optionally, you can specify that the result is rounded instead of being truncated. In this case, the constant `0x80000000` is added to the product before the high word is extracted.

Encodings

T1 `SMMLS{R}<c> <Rd>,<Rn>,<Rm>,<Ra>`

15	14	13	12	11	10	9	8	7	6	5	4	3 2 1 0	15 14 13 12	11 10 9 8	7	6	5	4	3 2 1 0
1	1	1	1	1	0	1	1	0	1	1	0	Rn	Ra	Rd	0	0	0	R	Rm

```
d = UInt(Rd);  n = UInt(Rn);  m = UInt(Rm);  a = UInt(Ra);
round = (R == '1');
if BadReg(d) || BadReg(n) || BadReg(m) || BadReg(a) then UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

```
SMMLS{R}<c><q>  <Rd>, <Rn>, <Rm>, <Ra>
```

where:

`R` If R is present, the multiplication is rounded.

If the R is omitted, the multiplication is truncated.

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<Rd>` Specifies the destination register.

`<Rn>` Specifies the register that contains the first multiply operand.

`<Rm>` Specifies the register that contains the second multiply operand.

`<Ra>` Specifies the register that contains the accumulate value.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    result = (SInt(R[a]) << 16) - SInt(R[n]) * SInt(R[m]);
    if round then result = result + 0x80000000;
    R[d] = result<63:32>;
```

Exceptions

None.

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4.6.147 SMMUL

Signed Most Significant Word Multiply multiplies two signed 32-bit values, extracts the most significant 32 bits of the result, and writes those bits to the destination register.

Optionally, you can specify that the result is rounded instead of being truncated. In this case, the constant `0x80000000` is added to the product before the high word is extracted.

Encodings

T1 SMMUL{R}<c> <Rd>,<Rn>,<Rm>

15 14 13 12 11	10 9 8 7	6 5 4	3 2 1 0	15 14 13 12	11 10 9 8	7 6 5	4	3 2 1 0
1 1 1 1 1	0 1 1 0	1 0 1	Rn	1 1 1 1	Rd	0 0 0	R	Rm

```
d = UInt(Rd);  n = UInt(Rn);  m = UInt(Rm);
round = (R == '1');
if BadReg(d) || BadReg(n) || BadReg(m) then UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

```
SMMUL{R}<c><q>  {<Rd>,} <Rn>, <Rm>
```

where:

`R`	If R is present, the multiplication is rounded. If the R is omitted, the multiplication is truncated.
`<c><q>`	See *Standard assembler syntax fields* on page 4-6.
`<Rd>`	Specifies the destination register. If `<Rd>` is omitted, this register is the same as `<Rn>`.
`<Rn>`	Specifies the register that contains the first operand.
`<Rm>`	Specifies the register that contains the second operand.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    result = SInt(R[n]) * SInt(R[m]);
    if round then result = result + 0x80000000;
    R[d] = result<63:32>;
```

Exceptions

None.

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4.6.148 SMUAD

Signed Dual Multiply Add performs two signed 16 x 16-bit multiplications. It adds the products together, and writes the result to the destination register.

Optionally, you can exchange the halfwords of the second operand before performing the arithmetic. This produces top x bottom and bottom x top multiplication.

This instruction sets the Q flag if the addition overflows. The multiplications cannot overflow.

Encodings

T1 `SMUAD{X}<c> <Rd>,<Rn>,<Rm>`

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	1	1	0	1	1	0	0	1	0	Rn				1	1	1	1	Rd				0	0	0	M	Rm			

```
d = UInt(Rd);  n = UInt(Rn);  m = UInt(Rm);
m_swap = (M == '1');
if BadReg(d) || BadReg(n) || BadReg(m) then UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

```
SMUAD{x}<c><q>  {<Rd>,} <Rn>, <Rm>
```

where:

`X` — If X is present, the multiplications are bottom x top and top x bottom.
If the X is omitted, the multiplications are bottom x bottom and top x top.

`<c><q>` — See *Standard assembler syntax fields* on page 4-6.

`<Rd>` — Specifies the destination register. If `<Rd>` is omitted, this register is the same as `<Rn>`.

`<Rn>` — Specifies the register that contains the first operand.

`<Rm>` — Specifies the register that contains the second operand.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    operand2 = if m_swap then ROR(R[m],16) else R[m];
    product1 = SInt(R[n]<15:0>) * SInt(operand2<15:0>);
    product2 = SInt(R[n]<31:16>) * SInt(operand2<31:16>);
    result = product1 + product2;
    R[d] = result<31:0>;
    if result != SInt(result<31:0>) then  // Signed overflow
        APSR.Q = '1';
```

Exceptions

None.

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4.6.149 SMULBB, SMULBT, SMULTB, SMULTT

Signed Multiply (halfwords) multiplies two signed 16-bit quantities, taken from either the bottom or the top half of their respective source registers. The other halves of these source registers are ignored. The 32-bit product is written to the destination register. No overflow is possible during this instruction.

Encodings

T1 SMUL<x><y><c> <Rd>,<Rn>,<Rm>

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	1	1	0	1	1	0	0	0	1	Rn				1	1	1	1	Rd				0	0	N	M	Rm			

```
d = UInt(Rd);  n = UInt(Rn);  m = UInt(Rm);
n_high = (N == '1');  m_high = (M == '1');
if BadReg(d) || BadReg(n) || BadReg(m) then UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

```
SMUL<x><y><c><q>  {<Rd>,} <Rn>, <Rm>
```

where:

`<x>` Specifies which half of the source register `<Rn>` is used as the first multiply operand. If `<x>` is `B`, then the bottom half (bits[15:0]) of `<Rn>` is used. If `<x>` is `T`, then the top half (bits[31:16]) of `<Rn>` is used.

`<y>` Specifies which half of the source register `<Rm>` is used as the second multiply operand. If `<y>` is `B`, then the bottom half (bits[15:0]) of `<Rm>` is used. If `<y>` is `T`, then the top half (bits[31:16]) of `<Rm>` is used.

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<Rd>` Specifies the destination register. If `<Rd>` is omitted, this register is the same as `<Rn>`.

`<Rn>` Specifies the register that contains the first operand.

`<Rm>` Specifies the register that contains the second operand.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    operand1 = if n_high then R[n]<31:16> else R[n]<15:0>;
    operand2 = if m_high then R[m]<31:16> else R[m]<15:0>;
    result = SInt(operand1) * SInt(operand2);
    R[d] = result<31:0>;
    // Signed overflow cannot occur
```

Exceptions

None.

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4.6.150 SMULL

Signed Multiply Long multiplies two 32-bit signed values to produce a 64-bit result.

Encodings

T1

```
SMULL<c> <RdLo>,<RdHi>,<Rn>,<Rm>
```

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	1	1	0	1	1	1	0	0	0	Rn				RdLo				RdHi				0	0	0	0	Rm			

```
dLo = UInt(RdLo);  dHi = UInt(RdHi);  n = UInt(Rn);  m = UInt(Rm);
if BadReg(dLo) || BadReg(dHi) || BadReg(n) || BadReg(m) then UNPREDICTABLE;
if dHi == dLo then UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

```
SMULL<c><q>  <RdLo>, <RdHi>, <Rn>, <Rm>
```

where:

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<RdLo>` Stores the lower 32 bits of the result.

`<RdHi>` Stores the upper 32 bits of the result.

`<Rn>` Specifies the register that contains the first operand.

`<Rm>` Specifies the register that contains the second operand.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    result = SInt(R[n]) * SInt(R[m]);
    R[dHi] = result<63:32>;
    R[dLo] = result<31:0>;
```

Exceptions

None.

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4.6.151 SMULWB, SMULWT

Signed Multiply (word by halfword) multiplies a signed 32-bit quantity and a signed 16-bit quantity. The signed 16-bit quantity is taken from either the bottom or the top half of its source register. The other half of the second source register is ignored. The top 32 bits of the 48-bit product are written to the destination register. The bottom 16 bits of the 48-bit product are ignored. No overflow is possible during this instruction.

Encodings

T1 `SMULW<y><c> <Rd>,<Rn>,<Rm>`

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	1	1	0	1	1	0	0	1	1	Rn				1	1	1	1	Rd				0	0	0	M	Rm			

```
d = UInt(Rd);  n = UInt(Rn);  m = UInt(Rm);  m_high = (M == '1');
if BadReg(d) || BadReg(n) || BadReg(m) then UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

```
SMULW<y><c><q>  {<Rd>,} <Rn>, <Rm>
```

where:

`<y>` Specifies which half of the source register `<Rm>` is used as the second multiply operand. If `<y>` is `B`, then the bottom half (bits[15:0]) of `<Rm>` is used. If `<y>` is `T`, then the top half (bits[31:16]) of `<Rm>` is used.

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<Rd>` Specifies the destination register. If `<Rd>` is omitted, this register is the same as `<Rn>`

`<Rn>` Specifies the register that contains the first operand.

`<Rm>` Specifies the register that contains the second operand.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    operand2 = if m_high then R[m]<31:16> else R[m]<15:0>;
    product = SInt(R[n]) * SInt(operand2);
    R[d] = product<47:16>;
    // Signed overflow cannot occur
```

Exceptions

None.

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4.6.152 SMUSD

Signed Dual Multiply Subtract performs two signed 16 x 16-bit multiplications. It subtracts one of the products from the other, and writes the result to the destination register.

Optionally, you can exchange the halfwords of the second operand before performing the arithmetic. This produces top x bottom and bottom x top multiplication.

Overflow cannot occur.

Encodings

T1 `SMUSD{X}<c> <Rd>,<Rn>,<Rm>`

<table>
<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><td>7</td><td>6</td><td>5</td><td>4</td><td>3</td><td>2</td><td>1</td><td>0</td><td>15</td><td>14</td><td>13</td><td>12</td><td>11</td><td>10</td><td>9</td><td>8</td><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>
<tr><td>1</td><td>1</td><td>1</td><td>1</td><td>1</td><td>0</td><td>1</td><td>1</td><td>0</td><td>1</td><td>0</td><td>0</td><td colspan="4">Rn</td><td>1</td><td>1</td><td>1</td><td>1</td><td colspan="4">Rd</td><td>0</td><td>0</td><td>0</td><td>M</td><td colspan="4">Rm</td></tr>
</table>

```
d = UInt(Rd);  n = UInt(Rn);  m = UInt(Rm);
m_swap = (M == '1');
if BadReg(d) || BadReg(n) || BadReg(m) then UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

```
SMUSD{X}<c><q>  {<Rd>,} <Rn>, <Rm>
```

where:

`X` If X is present, the multiplications are bottom x top and top x bottom.

If the X is omitted, the multiplications are bottom x bottom and top x top.

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<Rd>` Specifies the destination register. If `<Rd>` is omitted, this register is the same as `<Rn>`.

`<Rn>` Specifies the register that contains the first operand.

`<Rm>` Specifies the register that contains the second operand.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    operand2 = if m_swap then ROR(R[m],16) else R[m];
    product1 = SInt(R[n]<15:0>) * SInt(operand2<15:0>);
    product2 = SInt(R[n]<31:16>) * SInt(operand2<31:16>);
    result = product1 - product2;
    R[d] = result<31:0>;
    // Signed overflow cannot occur
```

Exceptions

None.

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4.6.153 SRS

Store Return State stores the R14 and SPSR of the current mode to the word at the specified address and the following word respectively. The address is determined from the banked version of R13 belonging to a specified mode. See *Memory accesses* on page 4-13 for information about memory accesses.

Encodings

T1 SRSDB<c> #<R13_mode>{!}

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	0	1	0	0	0	0	0	W	0	(1)	(1)	(0)	(1)	(1)	(1)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	mode				

```
mode_no = UInt(mode);  wback = (W == '1');  increment = FALSE;
```

T2 SRS{IA}<c> #<R13_mode>{!}

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	0	1	0	0	1	1	0	W	0	(1)	(1)	(0)	(1)	(1)	(1)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	mode				

```
mode_no = UInt(mode);  wback = (W == '1');  increment = TRUE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

```
SRS{IA|DB}<c><q>  #<R13_mode>{!}
```

where:

`<c><q>`	See *Standard assembler syntax fields* on page 4-6.
`IA`	Means Increment After. The memory address is incremented after each load operation. This is the default. For this instruction, `EA`, meaning Empty Ascending, is equivalent to `IA`.
`DB`	Means Decrement Before. The memory address is decremented before each load operation. For this instruction, `FD`, meaning Full Descending, is equivalent to DB.
`<R13_mode>`	Specifies the number of the mode whose banked register is used as the base register. The mode number is the 5-bit encoding of the chosen mode in a PSR, as described in the *ARM Architecture Reference Manual*.
`!`	Causes the instruction to write a modified value back to the base register. If `!` is omitted, the instruction does not change the base register.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    if !CurrentModeHasSPSR() then
        UNPREDICTABLE;
    else
        base = Rmode[13,mode_no];
        address = if increment then base else base-8;
        wbvalue = if increment then base+8 else base-8;
        if wback then Rmode[13,mode_no] = wbvalue;
        MemA[address,4]   = LR;
        MemA[address+4,4] = SPSR;
```

Exceptions

Data Abort.

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4.6.154 SSAT

Signed Saturate saturates an optionally-shifted signed value to a selectable signed range.

The Q flag is set if the operation saturates.

Encodings

T1 `SSAT<c> <Rd>,#<imm>,<Rn>{,<shift>}`

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	1	0	(0)	1	1	0	0	sh	0	Rn				0	imm3			Rd				imm2		(0)	sat_imm				

```
d = UInt(Rd);  n = UInt(Rn);  saturate_to = UInt(sat_imm)+1;
if sh == 1 && imm3:imm2 == '00000' then SEE SSAT16 on page 4-323;
(shift_t, shift_n) = DecodeImmShift(sh:'0', imm3:imm2);
if BadReg(d) || BadReg(n) then UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

```
SSAT<c><q>  <Rd>, #<imm>, <Rn> {,<shift>}
```

where:

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<Rd>` Specifies the destination register.

`<imm>` Specifies the bit position for saturation, in the range 1 to 32.

`<Rn>` Specifies the register that contains the value to be saturated.

`<shift>` Specifies the optional shift. If present, it must be one of:

`LSL #N`	*N* must be in the range 0 to 31.
`ASR #N`	*N* must be in the range 1 to 31.

If `<shift>` is omitted, `LSL #0` is used.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    operand = Shift(R[n], shift_t, shift_n, APSR.C);  // APSR.C ignored
    (result, sat) = SignedSatQ(SInt(operand), saturate_to);
    R[d] = SignExtend(result, 32);
    if sat then
        APSR.Q = '1';
```

Exceptions

None.

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4.6.155 SSAT16

Signed Saturate 16 saturates two signed 16-bit values to a selected signed range.

The Q flag is set if the operation saturates.

Encodings

T1 `SSAT16<c> <Rd>,#<imm>,<Rn>`

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	1	0	(0)	1	1	0	0	1	0	Rn				0	0	0	0	Rd				0	0	(0)	(0)	sat_imm			

```
d = UInt(Rd);  n = UInt(Rn);  saturate_to = UInt(sat_imm)+1;
if BadReg(d) || BadReg(n) then UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

```
SSAT16<c><q>  <Rd>, #<imm>, <Rn>
```

where:

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<Rd>` Specifies the destination register.

`<imm>` Specifies the bit position for saturation, in the range 1 to 16.

`<Rn>` Specifies the register that contains the values to be saturated.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    (result1, sat1) = SignedSatQ(SInt(R[n]<15:0>), saturate_to);
    (result2, sat2) = SignedSatQ(SInt(R[n]<31:16>), saturate_to);
    R[d]<15:0> = SignExtend(result1, 16);
    R[d]<31:16> = SignExtend(result2, 16);
    if sat1 || sat2 then
        APSR.Q = '1';
```

Exceptions

None.

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4.6.156 SSAX

Signed Subtract and Add with Exchange exchanges the two halfwords of the second operand, performs one 16-bit integer subtraction and one 16-bit addition, and writes the results to the destination register. It sets the GE bits in the APSR according to the results.

Encodings

T1 `SSAX<c> <Rd>,<Rn>,<Rm>`

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	1	1	0	1	0	1	1	1	0	Rn				1	1	1	1	Rd				0	0	0	0	Rm			

```
d = UInt(Rd);  n = UInt(Rn);  m = UInt(Rm);
if BadReg(d) || BadReg(n) || BadReg(m) then UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

```
SSAX<c><q>  {<Rd>,} <Rn>, <Rm>
```

where:

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<Rd>` Specifies the destination register. If `<Rd>` is omitted, this register is the same as `<Rn>`.

`<Rn>` Specifies the register that contains the first operand.

`<Rm>` Specifies the register that contains the second operand.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    sum  = SInt(R[n]<15:0>) + SInt(R[m]<31:16>);
    diff = SInt(R[n]<31:16>) - SInt(R[m]<15:0>);
    R[d]<15:0>  = sum<15:0>;
    R[d]<31:16> = diff<15:0>;
    APSR.GE<1:0> = if sum  >= 0 then '11' else '00';
    APSR.GE<3:2> = if diff >= 0 then '11' else '00';
```

Exceptions

None.

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4.6.157 SSUB16

Signed Subtract 16 performs two 16-bit signed integer subtractions, and writes the results to the destination register. It sets the GE bits in the APSR according to the results of the subtractions.

Encodings

T1 `SSUB16<c> <Rd>,<Rn>,<Rm>`

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	1	1	0	1	0	1	1	0	1	Rn				1	1	1	1	Rd				0	0	0	0	Rm			

```
d = UInt(Rd);  n = UInt(Rn);  m = UInt(Rm);
if BadReg(d) || BadReg(n) || BadReg(m) then UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

```
SSUB16<c><q>  {<Rd>,} <Rn>, <Rm>
```

where:

<c><q> See *Standard assembler syntax fields* on page 4-6.

<Rd> Specifies the destination register. If <Rd> is omitted, this register is the same as <Rn>.

<Rn> Specifies the register that contains the first operand.

<Rm> Specifies the register that contains the second operand.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    diff1 = SInt(R[n]<15:0>) - SInt(R[m]<15:0>);
    diff2 = SInt(R[n]<31:16>) - SInt(R[m]<31:16>);
    R[d]<15:0>  = diff1<15:0>;
    R[d]<31:16> = diff2<15:0>;
    APSR.GE<1:0> = if diff1 >= 0 then '11' else '00';
    APSR.GE<3:2> = if diff2 >= 0 then '11' else '00';
```

Exceptions

None.

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4.6.158 SSUB8

Signed Subtract 8 performs four 8-bit signed integer subtractions, and writes the results to the destination register. It sets the GE bits in the APSR according to the results of the subtractions.

Encodings

T1 `SSUB8<c> <Rd>,<Rn>,<Rm>`

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	1	1	0	1	0	1	1	0	0	Rn				1	1	1	1	Rd				0	0	0	0	Rm			

```
d = UInt(Rd);  n = UInt(Rn);  m = UInt(Rm);
if BadReg(d) || BadReg(n) || BadReg(m) then UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

```
SSUB8<c><q>  {<Rd>,} <Rn>, <Rm>
```

where:

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<Rd>` Specifies the destination register. If `<Rd>` is omitted, this register is the same as `<Rn>`.

`<Rn>` Specifies the register that contains the first operand.

`<Rm>` Specifies the register that contains the second operand.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    diff1 = SInt(R[n]<7:0>) - SInt(R[m]<7:0>);
    diff2 = SInt(R[n]<15:8>) - SInt(R[m]<15:8>);
    diff3 = SInt(R[n]<23:16>) - SInt(R[m]<23:16>);
    diff4 = SInt(R[n]<31:24>) - SInt(R[m]<31:24>);
    R[d]<7:0>   = diff1<7:0>;
    R[d]<15:8>  = diff2<7:0>;
    R[d]<23:16> = diff3<7:0>;
    R[d]<31:24> = diff4<7:0>;
    APSR.GE<0>  = if diff1 >= 0 then '1' else '0';
    APSR.GE<1>  = if diff2 >= 0 then '1' else '0';
    APSR.GE<2>  = if diff3 >= 0 then '1' else '0';
    APSR.GE<3>  = if diff4 >= 0 then '1' else '0';
```

Exceptions

None.

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4.6.159 STC, STC2

Store Coprocessor stores data from a coprocessor to a sequence of consecutive memory addresses.

If no coprocessor can execute the instruction, an Undefined Instruction exception is generated.

Encoding

T1

```
STC{2}{L}<c> <coproc>,<CRd>,[<Rn>,#+/-<imm8>]
STC{2}{L}<c> <coproc>,<CRd>,[<Rn>],#+/-<imm8>
STC{2}{L}<c> <coproc>,<CRd>,[<Rn>,#+/-<imm8>]!
```

15 14 13	12	11 10 9	8	7	6	5	4	3 2 1 0	15 14 13 12	11 10 9 8	7 6 5 4 3 2 1 0
1 1 1	C	1 1 0	P	U	N	W	0	Rn	CRd	coproc	imm8

```
n = UInt(Rn);  cp = UInt(coproc);  imm32 = ZeroExtend(imm8:'00', 32);
opc1 = N;  opc0 = C;  // STC if C == '0', STC2 if C == '1'
index = (P == '1');  add = (U == '1');  wback = (W == '1');
if P == '0' && U == '0' && N == '0' && W == '0' then UNDEFINED;
if P == '0' && U == '0' && N == '1' && W == '0' then
    SEE MCRR, MCRR2 on page 4-160;
if n == 15 && wback then UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

`STC{2}{L}<c><q>`	`<coproc>,<CRd>,[<Rn>{,#+/-<imm>}]`	`index==TRUE`, `wback==FALSE`
`STC{2}{L}<c><q>`	`<coproc>,<CRd>,[<Rn>,#+/-<imm>]!`	`index==TRUE`, `wback==TRUE`
`STC{2}{L}<c><q>`	`<coproc>,<CRd>,[<Rn>],#+/-<imm>`	`index==FALSE`, `wback==TRUE`

where:

`2` If specified, selects the C == 1 form of the encoding. If omitted, selects the C == 0 form.

`L` If specified, selects the N == 1 form of the encoding. If omitted, selects the N == 0 form.

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<coproc>` Specifies the name of the coprocessor. The standard generic coprocessor names are p0, p1, ..., p15.

`<CRd>` Specifies the coprocessor source register.

`<Rn>` Specifies the base register. This register is allowed to be the SP.

`+/-` Is + or omitted to indicate that the immediate offset is added to the base register value (`add == TRUE`), or – to indicate that the offset is to be subtracted (`add == FALSE`). Different instructions are generated for `#0` and `#-0`.

`<imm>` Specifies the immediate offset added to or subtracted from the value of `<Rn>` to form the address. For the offset addressing syntax, `<imm>` can be omitted, meaning an offset of 0.

The pre-UAL syntax `STC<c>L` is equivalent to `STCL<c>`.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    if !Coproc_Accepted(cp, ThisInstr()) then
        RaiseCoprocessorException();
    else
        offset_addr = if add then (R[n] + imm32) else (R[n] - imm32);
        address = if index then offset_addr else R[n];
        if wback then R[n] = offset_addr;
        repeat
            value = Coproc_GetWordToStore(cp, ThisInstr());
            MemA[address,4] = value;
            address = address + 4;
        until Coproc_DoneStoring(cp, ThisInstr());
```

Exceptions

Undefined Instruction, Data Abort.

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4.6.160 STMDB / STMFD

Store Multiple Decrement Before (Store Multiple Full Descending) stores multiple registers to sequential memory locations using an address from a base register. The sequential memory locations end just below this address, and the address of the first of those locations can optionally be written back to the base register.

Encoding

T1 STMDB<c> <Rn>{!},<registers>

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	0	1	0	0	1	0	0	W	0	Rn				(0)	M	(0)	register_list												

```
n = UInt(Rn);  registers = '0':M:'0':register_list;  wback = (W == '1');
if n == 13 && wback then SEE PUSH on page 4-211;
if n == 15 || BitCount(registers) < 2 then UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

```
STMDB<c><q>  <Rn>{!}, <registers>
```

where:

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<Rn>` Specifies the base register. This register is allowed to be the SP. If it is the SP and ! is specified, it is treated as described in *PUSH* on page 4-211.

`!` Sets the W bit to 1, causing the instruction to write a modified value back to `<Rn>`. If `!` is omitted, the instruction does not change `<Rn>`.

`<registers>`

Is a list of one or more registers, separated by commas and surrounded by `{` and `}`. It specifies the set of registers to be stored. The registers are stored with the lowest-numbered register to the lowest memory address, through to the highest-numbered register to the highest memory address.

Encoding T1 does not support a list containing only one register. If an `STMDB` instruction with just one register `<Rt>` in the list is assembled to Thumb, it is assembled to the equivalent `STR<c><q> <Rt>,[<Rn>,#-4]{!}` instruction.

The SP and PC cannot be in the list.

`STMFD` is s synonym for `STMDB`, referring to its use for pushing data onto Full Descending stacks.

The pre-UAL syntaxes `STM<c>DB` and `STM<c>FD` are equivalent to `STMDB<c>`.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    originalRn = R[n];
    address = R[n] - 4*BitCount(registers);
    if wback then R[n] = R[n] + 4*BitCount(registers);
    for i = 0 to 14
        if registers<i> == '1' then
            if i == n && wback then
                if i == LowestSetBit(registers) then
                    MemA[address,4] = originalRn;
                else
                    MemA[address,4] = bits(32) UNKNOWN;
            else
                MemA[address,4] = R[i];
            address = address + 4;
    assert address == originalRn;
```

Exceptions

Data Abort.

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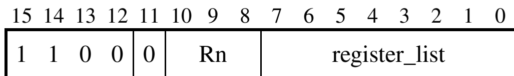
4.6.161 STMIA / STMEA

Store Multiple Increment After (Store Multiple Empty Ascending) stores multiple registers to consecutive memory locations using an address from a base register. The sequential memory locations start at this address, and the address just above the last of those locations can optionally be written back to the base register.

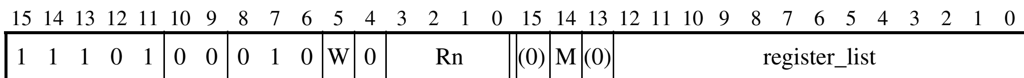
Encoding

T1 `STMIA<c> <Rn>!,<registers>`




```
n = UInt(Rn);  registers = '00000000':register_list;  wback = TRUE;
if BitCount(registers) < 1 then UNPREDICTABLE;
```

T2 `STMIA<c>.W <Rn>{!},<registers>`




```
n = UInt(Rn);  registers = '0':M:'0':register_list;  wback = (W == '1');
if n == 15 || BitCount(registers) < 2 then UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set.

Encoding T2 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

```
STMIA<c><q>  <Rn>{!}, <registers>
```

where:

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<Rn>` Specifies the base register. This register is allowed to be the SP.

`!` Causes the instruction to write a modified value back to `<Rn>`. If `!` is omitted, the instruction does not change `<Rn>`.

`<registers>`

Is a list of one or more registers, separated by commas and surrounded by `{` and `}`. It specifies the set of registers to be stored. The registers are stored with the lowest-numbered register to the lowest memory address, through to the highest-numbered register to the highest memory address.

Encoding T2 does not support a list containing only one register. If an `STMIA` instruction with just one register `<Rt>` in the list is assembled to Thumb and encoding T1 is not available, it is assembled to the equivalent `STR<c><q> <Rt>,[<Rn>]{,#-4}` instruction.

The SP and PC cannot be in the list.

`STMEA` is a synonym for `STMIA`, referring to its use for pushing data onto Empty Ascending stacks.

The pre-UAL syntaxes `STM<c>IA` and `STM<c>EA` are equivalent to `STMIA<c>`.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    originalRn = R[n];
    address = R[n];
    if wback then R[n] = R[n] + 4*BitCount(registers);
    for i = 0 to 14
        if registers<i> == '1' then
            if i == n && wback then
                if i == LowestSetBit(registers) then
                    MemA[address,4] = originalRn;
                else
                    MemA[address,4] = bits(32) UNKNOWN;
            else
                MemA[address,4] = R[i];
            address = address + 4;
    assert address == originalRn + 4*BitCount(registers);
```

Exceptions

Data Abort.

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4.6.162 STR (immediate)

Store Register (immediate) calculates an address from a base register value and an immediate offset, and stores a word from a register to memory. It can use offset, post-indexed, or pre-indexed addressing. See *Memory accesses* on page 4-13 for information about memory accesses.

Encoding

T1

```
STR<c> <Rt>,[<Rn>,#<imm>]
```

<table>
<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><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>
<tr><td>0</td><td>1</td><td>1</td><td>0</td><td>0</td><td colspan="5">imm5</td><td colspan="3">Rn</td><td colspan="3">Rt</td></tr>
</table>

```
t = UInt(Rt);  n = UInt(Rn);  imm32 = ZeroExtend(imm5:'00', 32);
index = TRUE;  add = TRUE;  wback = FALSE;
```

T2

```
STR<c> <Rt>,[SP,#<imm>]
```

<table>
<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><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>
<tr><td>1</td><td>0</td><td>0</td><td>1</td><td>0</td><td colspan="3">Rt</td><td colspan="8">imm8</td></tr>
</table>

```
t = UInt(Rt);  n = 13;  imm32 = ZeroExtend(imm8:'00', 32);
index = TRUE;  add = TRUE;  wback = FALSE;
```

T3

```
STR<c>.W <Rt>,[<Rn>,#<imm12>]
```

<table>
<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><td>7</td><td>6</td><td>5</td><td>4</td><td>3</td><td>2</td><td>1</td><td>0</td><td>15</td><td>14</td><td>13</td><td>12</td><td>11</td><td>10</td><td>9</td><td>8</td><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>
<tr><td>1</td><td>1</td><td>1</td><td>1</td><td>1</td><td>0</td><td>0</td><td>0</td><td>1</td><td>1</td><td>0</td><td>0</td><td colspan="4">Rn</td><td colspan="4">Rt</td><td colspan="12">imm12</td></tr>
</table>

```
t = UInt(Rt);  n = UInt(Rn);  imm32 = ZeroExtend(imm12, 32);
index = TRUE;  add = TRUE;  wback = FALSE;
if n == 15 then UNDEFINED;
if t == 15 then UNPREDICTABLE;
```

T4

```
STR<c> <Rt>,[<Rn>,#-<imm8>]
STR<c> <Rt>,[<Rn>],#+/-<imm8>
STR<c> <Rt>,[<Rn>,#+/-<imm8>]!
```

<table>
<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><td>7</td><td>6</td><td>5</td><td>4</td><td>3</td><td>2</td><td>1</td><td>0</td><td>15</td><td>14</td><td>13</td><td>12</td><td>11</td><td>10</td><td>9</td><td>8</td><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>
<tr><td>1</td><td>1</td><td>1</td><td>1</td><td>1</td><td>0</td><td>0</td><td>0</td><td>0</td><td>1</td><td>0</td><td>0</td><td colspan="4">Rn</td><td colspan="4">Rt</td><td>1</td><td>P</td><td>U</td><td>W</td><td colspan="8">imm8</td></tr>
</table>

```
t = UInt(Rt);  n = UInt(Rn);  imm32 = ZeroExtend(imm8, 32);
index = (P == '1');  add = (U == '1');  wback = (W == '1');
if P == '1' && U == '1' && W == '0' then SEE STRT on page 4-363;
if n == 15 || (P == '0' && W == '0') then UNDEFINED;
if t == 15 || (wback && n == t) then UNPREDICTABLE;
```


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Architecture versions

Encodings T1, T2 All versions of the Thumb instruction set.

Encodings T3, T4 All versions of the Thumb instruction set from Thumb-2 onwards.

Assembler syntax

`STR<c><q>  <Rt>, [<Rn> {, #+/-<imm>}]`	Offset: `index==TRUE`, `wback==FALSE`
`STR<c><q>  <Rt>, [<Rn>, #+/-<imm>]!`	Pre-indexed: `index==TRUE`, `wback==TRUE`
`STR<c><q>  <Rt>, [<Rn>], #+/-<imm>`	Post-indexed: `index==FALSE`, `wback==TRUE`

where:

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<Rt>` Specifies the source register. This register is allowed to be the SP.

`<Rn>` Specifies the base register. This register is allowed to be the SP.

`+/-` Is + or omitted to indicate that the immediate offset is added to the base register value (`add == TRUE`), or – to indicate that the offset is to be subtracted (`add == FALSE`). Different instructions are generated for `#0` and `#-0`.

`<imm>` Specifies the immediate offset added to or subtracted from the value of `<Rn>` to form the address. For the offset addressing syntax, `<imm>` can be omitted, meaning an offset of 0.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    offset_addr = if add then (R[n] + imm32) else (R[n] - imm32);
    address = if index then offset_addr else R[n];
    if wback then R[n] = offset_addr;
    MemU[address,4] = R[t];
```

Exceptions

Data Abort.

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4.6.163 STR (register)

Store Register (register) calculates an address from a base register value and an offset register value, stores a word from a register to memory. The offset register value can be shifted left by 0, 1, 2, or 3 bits. See *Memory accesses* on page 4-13 for information about memory accesses.

Encoding

T1 STR<c> <Rt>,[<Rn>,<Rm>]

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0	1	0	1	0	0	0	Rm			Rn			Rt		

```
t = UInt(Rt);  n = UInt(Rn);  m = UInt(Rm);
(shift_t, shift_n) = (SRType_None, 0);
```

T2 STR<c>.W <Rt>,[<Rn>,<Rm>{,LSL #<shift>}]

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	1	1	0	0	0	0	1	0	0	Rn			

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Rt				0	0	0	0	0	0	shift		Rm			

```
t = UInt(Rt);  n = UInt(Rn);  m = UInt(Rm);
(shift_t, shift_n) = (SRType_LSL, UInt(shift));
if n == 15 then UNDEFINED;
if t == 15 || BadReg(m) then UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set.

Encoding T2 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

```
STR<c><q>  <Rt>, [<Rn>, <Rm> {, LSL #<shift>}]
```

where:

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<Rt>` Specifies the source register. This register is allowed to be the SP.

`<Rn>` Specifies the register that contains the base value. This register is allowed to be the SP.

`<Rm>` Contains the offset that is shifted left and added to the value of `<Rn>` to form the address.

`<shift>` Specifies the number of bits the value from `<Rm>` is shifted left, in the range 0-3. If this option is omitted, a shift by 0 is assumed and both encodings are permitted. If this option is specified, only encoding T2 is permitted.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    address = R[n] + LSL(R[m], shift_n);
    MemU[address,4] = R[t];
```

Exceptions

Data Abort.

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4.6.164 STRB (immediate)

Store Register Byte (immediate) calculates an address from a base register value and an immediate offset, and stores a byte from a register to memory. It can use offset, post-indexed, or pre-indexed addressing. See *Memory accesses* on page 4-13 for information about memory accesses.

Encoding

T1
```
STRB<c> <Rt>,[<Rn>,#<imm>]
```

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0	1	1	1	0	imm5					Rn			Rt		

```
t = UInt(Rt);  n = UInt(Rn);  imm32 = ZeroExtend(imm5, 32);
index = TRUE;  add = TRUE;  wback = FALSE;
```

T2
```
STRB<c>.W <Rt,[<Rn>,#<imm12>]
```

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	1	1	0	0	0	1	0	0	0	Rn				Rt				imm12											

```
t = UInt(Rt);  n = UInt(Rn);  imm32 = ZeroExtend(imm12, 32);
index = TRUE;  add = TRUE;  wback = FALSE;
if n == 15 then UNDEFINED;
if BadReg(t) then UNPREDICTABLE;
```

T3
```
STRB<c> <Rt>,[<Rn>,#-<imm8>]
STRB<c> <Rt>,[<Rn>],#+/-<imm8>
STRB<c> <Rt>,[<Rn>,#+/-<imm8>]!
```

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	1	1	0	0	0	0	0	0	0	Rn				Rt				1	P	U	W	imm8							

```
t = UInt(Rt);  n = UInt(Rn);  imm32 = ZeroExtend(imm8, 32);
index = (P == '1');  add = (U == '1');  wback = (W == '1');
if P == '1' && U == '1' && W == '0' then SEE STRBT on page 4-345;
if n == 15 || (P == '0' && W == '0') then UNDEFINED;
if BadReg(t) || (wback && n == t) then UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set.

Encodings T2, T3 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

`STRB<c><q> <Rt>, [<Rn> {, #+/-<imm>}]`	Offset: `index==TRUE`, `wback==FALSE`
`STRB<c><q> <Rt>, [<Rn>, #+/-<imm>]!`	Pre-indexed: `index==TRUE`, `wback==TRUE`
`STRB<c><q> <Rt>, [<Rn>], #+/-<imm>`	Post-indexed: `index==FALSE`, `wback==TRUE`

where:

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<Rt>` Specifies the source register.

`<Rn>` Specifies the base register. This register is allowed to be the SP.

`+/-` Is + or omitted to indicate that the immediate offset is added to the base register value (`add == TRUE`), or – to indicate that the offset is to be subtracted (`add == FALSE`). Different instructions are generated for `#0` and `#-0`.

`<imm>` Specifies the immediate offset added to or subtracted from the value of `<Rn>` to form the address. For the offset addressing syntax, `<imm>` can be omitted, meaning an offset of 0.

The pre-UAL syntax `STR<c>B` is equivalent to `STRB<c>`.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    offset_addr = if add then (R[n] + imm32) else (R[n] - imm32);
    address = if index then offset_addr else R[n];
    if wback then R[n] = offset_addr;
    MemU[address,1] = R[t]<7:0>;
```

Exceptions

Data Abort.

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4.6.165 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 register to memory. The offset register value can be shifted left by 0, 1, 2, or 3 bits. See *Memory accesses* on page 4-13 for information about memory accesses.

Encoding

T1 STRB<c> <Rt>,[<Rn>,<Rm>]

15 14 13 12	11 10 9	8 7 6	5 4 3	2 1 0
0 1 0 1	0 1 0	Rm	Rn	Rt

```
t = UInt(Rt);  n = UInt(Rn);  m = UInt(Rm);
(shift_t, shift_n) = (SRType_None, 0);
```

T2 STRB<c>.W <Rt>,[<Rn>,<Rm>{,LSL #<shift>}]

15 14 13 12 11	10 9	8	7	6 5	4	3 2 1 0	15 14 13 12	11	10 9 8 7 6	5 4	3 2 1 0
1 1 1 1 1	0 0	0	0	0 0	0	Rn	Rt	0	0 0 0 0 0	shift	Rm

```
t = UInt(Rt);  n = UInt(Rn);  m = UInt(Rm);
(shift_t, shift_n) = (SRType_LSL, UInt(shift));
if n == 15 then UNDEFINED;
if BadReg(t) || BadReg(m) then UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set.

Encoding T2 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

```
STRB<c><q>  <Rt>, [<Rn>, <Rm> {, LSL #<shift>}]
```

where:

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<Rn>` Specifies the register that contains the base value. This register is allowed to be the SP.

`<Rm>` Contains the offset that is shifted left and added to the value of `<Rn>` to form the address.

`<shift>` Specifies the number of bits the value from `<Rm>` is shifted left, in the range 0-3. If this option is omitted, a shift by 0 is assumed and both encodings are permitted. If this option is specified, only encoding T2 is permitted.

The pre-UAL syntax `STR<c>B` is equivalent to `STRB<c>`.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    address = R[n] + LSL(R[m], shift_n);
    MemU[address,1] = R[t]<7:0>;
```

Exceptions

Data Abort.

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4.6.166 STRBT

Store Register Byte Unprivileged calculates an address from a base register value and an immediate offset, and stores a byte from a register to memory. See *Memory accesses* on page 4-13 for information about memory accesses.

The memory access is restricted as if the processor were running in User mode. (This makes no difference if the processor is actually running in User mode.)

Encoding

T1

```
STRBT<c> <Rt>,[<Rn>,#<imm8>]
```

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	1	1	0	0	0	0	0	0	0	Rn				Rt				1	1	1	0	imm8							

```
t = UInt(Rt);  n = UInt(Rn);  imm32 = ZeroExtend(imm8, 32);
if n == 15 then UNDEFINED;
if BadReg(t) then UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

```
STRBT<c><q>  <Rt>, [<Rn> {, #<imm>}]
```

where:

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<Rt>` Specifies the source register.

`<Rn>` Specifies the base register. This register is allowed to be the SP.

`<imm>` Specifies the immediate offset added to the value of `<Rn>` to form the address. `<imm>` can be omitted, meaning an offset of 0.

The pre-UAL syntax `STR<c>BT` is equivalent to `STRBT<c>`.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    address = R[n] + imm32;
    MemU_unpriv[address,1] = R[t]<7:0>;
```

Exceptions

Data Abort.

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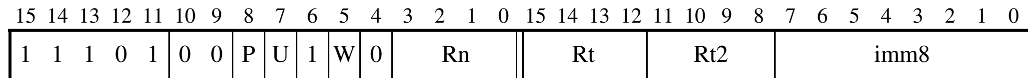
4.6.167 STRD (immediate)

Store Register Double (immediate) calculates an address from a base register value and an immediate offset, and stores two words from two registers to memory. It can use offset, post-indexed, or pre-indexed addressing. See *Memory accesses* on page 4-13 for information about memory accesses.

Encoding

T1 `STRD<c> <Rt>,<Rt2>,[<Rn>,#+/-<imm>]{!}`

`STRD<c> <Rt>,<Rt2>,[<Rn>],#+/-<imm>`




```
t = UInt(Rt);  t2 = UInt(Rt2);  n = UInt(Rn);  imm32 = ZeroExtend(imm8:'00');
index = (P == '1');  add = (U == '1');  wback = (W == '1');
if P == '0' && W == '0' then
    SEE Load/store double and exclusive, and table branch on page 3-28;
if wback && t == n then UNPREDICTABLE;
if wback && t2 == n then UNPREDICTABLE;
if n == 15 || BadReg(t) || BadReg(t2) then UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

`STRD<c><q> <Rt>,<Rt2>,[<Rn>{,#+/-<imm>}]`	Offset: `index==TRUE`, `wback==FALSE`
`STRD<c><q> <Rt>,<Rt2>,[<Rn>,#+/-<imm>]!`	Pre-indexed: `index==TRUE`, `wback==TRUE`
`STRD<c><q> <Rt>,<Rt2>,[<Rn>],#+/-<imm>`	Post-indexed: `index==FALSE`, `wback==TRUE`

where:

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<Rt>` Specifies the first source register.

`<Rt2>` Specifies the second source register.

`<Rn>` Specifies the base register. This register is allowed to be the SP.

`+/-` Is + or omitted to indicate that the immediate offset is added to the base register value (`add == TRUE`), or – to indicate that the offset is to be subtracted (`add == FALSE`). Different instructions are generated for `#0` and `#-0`.

`<imm>` Specifies the immediate offset added to or subtracted from the value of `<Rn>` to form the address. For the offset addressing syntax, `<imm>` can be omitted, meaning an offset of 0.

The pre-UAL syntax `STR<c>D` is equivalent to `STRD<c>`.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    offset_addr = if add then (R[n] + imm32) else (R[n] - imm32);
    address = if index then offset_addr else R[n];
    if wback then R[n] = offset_addr;
    MemA[address,4] = R[t];
    MemA[address+4,4] = R[t2];
```

Exceptions

Data Abort.

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4.6.168 STREX

Store Register Exclusive calculates an address from a base register value and an immediate offset, and stores a word from a register to memory if the executing processor has exclusive access to the memory addressed.

See *Memory accesses* on page 4-13 for information about memory accesses.

Encoding

T1 `STREX<c> <Rd>,<Rt>,[<Rn>{,#<imm>}]`

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	0	1	0	0	0	0	1	0	0	Rn				Rt				Rd				imm8							

```
d = UInt(Rd);  t = UInt(Rt);  n = UInt(Rn);
imm32 = ZeroExtend(imm8:'00', 32);
if BadReg(d) || BadReg(t) || n == 15 then UNPREDICTABLE;
if d == n || d == t then UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

```
STREX<c><q>  <Rd>, <Rt>, [<Rn> {,#<imm>}]
```

where:

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<Rd>` Specifies the destination register for the returned status value. The value returned is:

- `0` if the operation updates memory
- `1` if the operation fails to update memory.

`<Rt>` Specifies the source register.

`<Rn>` Specifies the base register. This register is allowed to be the SP.

`<imm>` Specifies the immediate offset added to or subtracted from the value of `<Rn>` to form the address. `<imm>` can be omitted, meaning an offset of 0.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    address = R[n] + imm32;
    if ExclusiveMonitorsPass(address,4) then
        MemAA[address,4] = R[t];
        R[d] = 0;
    else
        R[d] = 1;
```

Exceptions

Data Abort.

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4.6.169 STREXB

Store Register Exclusive Byte derives an address from a base register value, and stores a byte from a register to memory if the executing processor has exclusive access to the memory addressed.

See *Memory accesses* on page 4-13 for information about memory accesses.

Encoding

T1 `STREXB<c> <Rd>,<Rt>,[<Rn>]`

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	0	1	0	0	0	1	1	0	0	Rn			

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Rt				(1)	(1)	(1)	(1)	0	1	0	0	Rd			

```
d = UInt(Rd);  t = UInt(Rt);  n = UInt(Rn);
if BadReg(d) || BadReg(t) || n == 15 then UNPREDICTABLE;
if d == n || d == t then UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set from v6K onwards.

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Assembler syntax

```
STREXB<c><q>  <Rd>, <Rt>, [<Rn>]
```

where:

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<Rd>` Specifies the destination register for the returned status value. The value returned is:

- `0` if the operation updates memory
- `1` if the operation fails to update memory.

`<Rt>` Specifies the source register.

`<Rn>` Specifies the base register. This register is allowed to be the SP.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    address = R[n];
    if ExclusiveMonitorsPass(address,1) then
        MemAA[address,1] = R[t];
        R[d] = 0;
    else
        R[d] = 1;
```

Exceptions

Data Abort.

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4.6.170 STREXD

Store Register Exclusive Doubleword derives an address from a base register value, and stores a 64-bit doubleword from two registers to memory if the executing processor has exclusive access to the memory addressed.

See *Memory accesses* on page 4-13 for information about memory accesses.

Encoding

T1 `STREXD<c> <Rd>,<Rt>,<Rt2>,[<Rn>]`

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	0	1	0	0	0	1	1	0	0	Rn				Rt				Rt2				0	1	1	1	Rd			

```
d = UInt(Rd);  t = UInt(Rt);  t2 = UInt(Rt2);  n = UInt(Rn);
if BadReg(d) || BadReg(t) || BadReg(t2) || n == 15 then UNPREDICTABLE;
if d == n || d == t || d == t2 then UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set from v6K onwards.

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Assembler syntax

```
STREXD<c><q>  <Rd>, <Rt>, <Rt2>, [<Rn>]
```

where:

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<Rd>` Specifies the destination register for the returned status value. The value returned is:

- `0` if the operation updates memory
- `1` if the operation fails to update memory.

`<Rt>` Specifies the first source register.

`<Rt2>` Specifies the second source register.

`<Rn>` Specifies the base register. This register is allowed to be the SP.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    address = R[n];
    // Create 64-bit value to store such that R[t] will be
    // stored at address and R[t2] at address+4.
    value = if BigEndian() then R[t]:R[t2] else R[t2]:R[t];
    if ExclusiveMonitorsPass(address,8) then
        MemAA[address,8] = value;
        R[d] = 0;
    else
        R[d] = 1;
```

Exceptions

Data Abort.

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4.6.171 STREXH

Store Register Exclusive Halfword derives an address from a base register value, and stores a halfword from a register to memory if the executing processor has exclusive access to the memory addressed.

See *Memory accesses* on page 4-13 for information about memory accesses.

Encoding

T1 `STREXH<c> <Rd>,<Rt>,[<Rn>]`

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	0	1	0	0	0	1	1	0	0	Rn				Rt				(1)	(1)	(1)	(1)	0	1	0	1	Rd			

```
d = UInt(Rd);  t = UInt(Rt);  n = UInt(Rn);
if BadReg(d) || BadReg(t) || n == 15 then UNPREDICTABLE;
if d == n || d == t then UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set from v6K onwards.

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Assembler syntax

```
STREXH<c><q>  <Rd>, <Rt>, [<Rn>]
```

where:

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<Rd>` Specifies the destination register for the returned status value. The value returned is:

- `0` if the operation updates memory
- `1` if the operation fails to update memory.

`<Rt>` Specifies the source register.

`<Rn>` Specifies the base register. This register is allowed to be the SP.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    address = R[n];
    if ExclusiveMonitorsPass(address,2) then
        MemAA[address,2] = R[t];
        R[d] = 0;
    else
        R[d] = 1;
```

Exceptions

Data Abort.

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4.6.172 STRH (immediate)

Store Register Halfword (immediate) calculates an address from a base register value and an immediate offset, and stores a halfword from a register to memory. It can use offset, post-indexed, or pre-indexed addressing. See *Memory accesses* on page 4-13 for information about memory accesses.

Encoding

T1

```
STRH<c> <Rt>,[<Rn>,#<imm>]
```

15 14 13 12	11	10 9 8 7 6	5 4 3	2 1 0
1 0 0 0	0	imm5	Rn	Rt

```
t = UInt(Rt);  n = UInt(Rn);  imm32 = ZeroExtend(imm5:'0', 32);
index = TRUE;  add = TRUE;  wback = FALSE;
```

T2

```
STRH<c>.W <Rt,[<Rn>,#<imm12>]
```

15 14 13 12 11	10 9	8	7	6 5	4	3 2 1 0	15 14 13 12	11 10 9 8 7 6 5 4 3 2 1 0
1 1 1 1 1	0 0	0	1	0 1	0	Rn	Rt	imm12

```
t = UInt(Rt);  n = UInt(Rn);  imm32 = ZeroExtend(imm12, 32);
index = TRUE;  add = TRUE;  wback = FALSE;
if n == 15 then UNDEFINED;
if BadReg(t) then UNPREDICTABLE;
```

T3

```
STRH<c> <Rt>,[<Rn>,#-<imm8>]
STRH<c> <Rt>,[<Rn>],#+/-<imm8>
STRH<c> <Rt>,[<Rn>,#+/-<imm8>]!
```

15 14 13 12 11	10 9	8	7	6 5	4	3 2 1 0	15 14 13 12	11	10 9 8	7 6 5 4 3 2 1 0
1 1 1 1 1	0 0	0	0	0 1	0	Rn	Rt	1	P U W	imm8

```
t = UInt(Rt);  n = UInt(Rn);  imm32 = ZeroExtend(imm8, 32);
index = (P == '1');  add = (U == '1');  wback = (W == '1');
if P == '1' && U == '1' && W == '0' then SEE STRHT on page 4-361;
if n == 15 || (P == '0' && W == '0') then UNDEFINED;
if BadReg(t) || (wback && n == t) then UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set.

Encodings T2, T3 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

STRH<c><q> <Rt>, [<Rn> {, #+/-<imm>}]	Offset: index==TRUE, wback==FALSE
STRH<c><q> <Rt>, [<Rn>, #+/-<imm>]!	Pre-indexed: index==TRUE, wback==TRUE
STRH<c><q> <Rt>, [<Rn>], #+/-<imm>	Post-indexed: index==FALSE, wback==TRUE

where:

<c><q> See *Standard assembler syntax fields* on page 4-6.

<Rt> Specifies the source register.

<Rn> Specifies the base register. This register is allowed to be the SP.

+/- Is + or omitted to indicate that the immediate offset is added to the base register value (add == TRUE), or – to indicate that the offset is to be subtracted (add == FALSE). Different instructions are generated for #0 and #-0.

<imm> Specifies the immediate offset added to or subtracted from the value of <Rn> to form the address. For the offset addressing syntax, <imm> can be omitted, meaning an offset of 0.

The pre-UAL syntax STR<c>H is equivalent to STRH<c>.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    offset_addr = if add then (R[n] + imm32) else (R[n] - imm32);
    address = if index then offset_addr else R[n];
    if wback then R[n] = offset_addr;
    MemU[address,2] = R[t]<15:0>;
```

Exceptions

Data Abort.

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4.6.173 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 register to memory. The offset register value can be shifted left by 0, 1, 2, or 3 bits. See *Memory accesses* on page 4-13 for information about memory accesses.

Encoding

T1 STRH<c> <Rt>,[<Rn>,<Rm>]

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0	1	0	1	0	0	1	Rm			Rn			Rt		

```
t = UInt(Rt);  n = UInt(Rn);  m = UInt(Rm);
(shift_t, shift_n) = (SRType_None, 0);
```

T2 STRH<c>.W <Rt>,[<Rn>,<Rm>{,LSL #<shift>}]

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	1	1	0	0	0	0	0	1	0	Rn				Rt				0	0	0	0	0	0	shift		Rm			

```
t = UInt(Rt);  n = UInt(Rn);  m = UInt(Rm);
(shift_t, shift_n) = (SRType_LSL, UInt(shift));
if n == 15 then UNDEFINED;
if BadReg(t) || BadReg(m) then UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set.

Encoding T2 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

```
STRH<c><q>  <Rt>, [<Rn>, <Rm> {, LSL #<shift>}]
```

where:

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<Rn>` Specifies the register that contains the base value. This register is allowed to be the SP.

`<Rm>` Contains the offset that is shifted left and added to the value of `<Rn>` to form the address.

`<shift>` Specifies the number of bits the value from `<Rm>` is shifted left, in the range 0-3. If this option is omitted, a shift by 0 is assumed and both encodings are permitted. If this option is specified, only encoding T2 is permitted.

The pre-UAL syntax `STR<c>H` is equivalent to `STRH<c>`.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    address = R[n] + LSL(R[m], shift_n);
    MemU[address,2] = R[t]<15:0>;
```

Exceptions

Data Abort.

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4.6.174 STRHT

Store Register Halfword Unprivileged calculates an address from a base register value and an immediate offset, and stores a halfword from a register to memory. See *Memory accesses* on page 4-13 for information about memory accesses.

The memory access is restricted as if the processor were running in User mode. (This makes no difference if the processor is actually running in User mode.)

Encoding

T1 `STRHT<c> <Rt>,[<Rn>,#<imm8>]`

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	1	1	0	0	0	0	0	1	0	Rn				Rt				1	1	1	0	imm8							

```
t = UInt(Rt);  n = UInt(Rn);  imm32 = ZeroExtend(imm8, 32);
if n == 15 then UNDEFINED;
if BadReg(t) then UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

```
STRHT<c><q>  <Rt>, [<Rn> {, #<imm>}]
```

where:

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<Rt>` Specifies the source register.

`<Rn>` Specifies the base register. This register is allowed to be the SP.

`<imm>` Specifies the immediate offset added to the value of `<Rn>` to form the address. `<imm>` can be omitted, meaning an offset of 0.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    address = R[n] + offset;
    MemU_unpriv[address,2] = R[t]<15:0>;
```

Exceptions

Data Abort.

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4.6.175 STRT

Store Register Unprivileged calculates an address from a base register value and an immediate offset, and stores a word from a register to memory. See *Memory accesses* on page 4-13 for information about memory accesses.

The memory access is restricted as if the processor were running in User mode. (This makes no difference if the processor is actually running in User mode.)

Encoding

T1

```
STRT<c> <Rt>,[<Rn>,#<imm8>]
```

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	1	1	0	0	0	0	1	0	0	Rn				Rt				1	1	1	0	imm8							

```
t = UInt(Rt);  n = UInt(Rn);  imm32 = ZeroExtend(imm8, 32);
if n == 15 then UNDEFINED;
if BadReg(t) then UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

```
STRT<c><q>  <Rt>, [<Rn> {, #<imm>}]
```

where:

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<Rt>` Specifies the source register.

`<Rn>` Specifies the base register. This register is allowed to be the SP.

`<imm>` Specifies the immediate offset added to the value of `<Rn>` to form the address. `<imm>` can be omitted, meaning an offset of 0.

The pre-UAL syntax `STR<c>T` is equivalent to `STRT<c>`.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    address = R[n] + imm32;
    MemU_unpriv[address,4] = R[t];
```

Exceptions

Data Abort.

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4.6.176 SUB (immediate)

This instruction subtracts an immediate value from a register value, and writes the result to the destination register. It can optionally update the condition flags based on the result.

Encodings

T1 SUBS <Rd>,<Rn>,#<imm3> — Outside IT block.

SUB<c> <Rd>,<Rn>,#<imm3> — Inside IT block.

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0	0	0	1	1	1	1	imm3			Rn			Rd		

```
d = UInt(Rd);  n = UInt(Rn);  setflags = !InITBlock();
imm32 = ZeroExtend(imm3, 32);
```

T2 SUBS <Rdn>,#<imm8> — Outside IT block.

SUB<c> <Rdn>,#<imm8> — Inside IT block.

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0	0	1	1	1	Rdn			imm8							

```
d = UInt(Rdn);  n = UInt(Rdn);  setflags = !InITBlock();
imm32 = ZeroExtend(imm8, 32);
```

T3 SUB{S}<c>.W <Rd>,<Rn>,#<const>

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	1	0	i	0	1	1	0	1	S	Rn				0	imm3			Rd				imm8							

```
d = UInt(Rd);  n = UInt(Rn);  setflags = (S == '1');
imm32 = ThumbExpandImm(i:imm3:imm8);
if d == 15 && setflags then SEE CMP (immediate) on page 4-72;
if n == 13 then SEE SUB (SP minus immediate) on page 4-369;
if BadReg(d) || n == 15 then UNPREDICTABLE;
```

T4 SUBW<c> <Rd>,<Rn>,#<imm12>

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	1	0	i	1	0	1	0	1	0	Rn				0	imm3			Rd				imm8							

```
d = UInt(Rd);  n = UInt(Rn);  setflags = FALSE;
imm32 = ZeroExtend(i:imm3:imm8, 32);
if n == 15 then SEE ADR on page 4-28;
if n == 13 then SEE SUB (SP minus immediate) on page 4-369;
if BadReg(d) then UNPREDICTABLE;
```


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Architecture versions

Encodings T1, T2 All versions of the Thumb instruction set.

Encodings T3, T4 All versions of the Thumb instruction set from Thumb-2 onwards.

Assembler syntax

`SUB{S}<c><q> {<Rd>,} <Rn>, #<const>`	All encodings permitted
`SUBW<c><q> {<Rd>,} <Rn>, #<const>`	Only encoding T4 permitted

where:

`S` If present, specifies that the instruction updates the flags. Otherwise, the instruction does not update the flags.

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<Rd>` Specifies the destination register. If `<Rd>` is omitted, this register is the same as `<Rn>`.

`<Rn>` Specifies the register that contains the first operand. If the SP is specified for `<Rn>`, see *SUB (SP minus immediate)* on page 4-369. If the PC is specified for `<Rn>`, see *ADR* on page 4-28.

`<const>` Specifies the immediate value to be subtracted from the value obtained from `<Rn>`. The range of allowed values is 0-7 for encoding T1, 0-255 for encoding T2 and 0-4095 for encoding T4. See *Immediate constants* on page 4-8 for the range of allowed values for encoding T3.

When multiple encodings of the same length are available for an instruction, encoding T3 is preferred to encoding T4 (if encoding T4 is required, use the `SUBW` syntax). Encoding T1 is preferred to encoding T2 if `<Rd>` is specified and encoding T2 is preferred to encoding T1 if `<Rd>` is omitted.

The pre-UAL syntax `SUB<c>S` is equivalent to `SUBS<c>`.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    (result, carry, overflow) = AddWithCarry(R[n], NOT(imm32), '1');
    R[d] = result;
    if setflags then
        APSR.N = result<31>; APSR.Z = IsZeroBit(result);
        APSR.C = carry;      APSR.V = overflow;
```

Exceptions

None.

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4.6.177 SUB (register)

This instruction subtracts an optionally-shifted register value from a register value, and writes the result to the destination register. It can optionally update the condition flags based on the result.

Encodings

T1 `SUBS <Rd>,<Rn>,<Rm>` Outside IT block.

`SUB<c> <Rd>,<Rn>,<Rm>` Inside IT block.

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0	0	0	1	1	0	1	Rm			Rn			Rd		

```
d = UInt(Rd);  n = UInt(Rn);  m = UInt(Rm);  setflags = !InITBlock();
(shift_t, shift_n) = (SRType_None, 0);
```

T2 `SUB{S}<c>.W <Rd>,<Rn>,<Rm>{,<shift>}`

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	0	1	0	1	1	1	0	1	S	Rn			

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
(0)	imm3			Rd				imm2		type		Rm			

```
d = UInt(Rd);  n = UInt(Rn);  m = UInt(Rm);  setflags = (S == '1');
(shift_t, shift_n) = DecodeImmShift(type, imm3:imm2);
if d == 15 && setflags then SEE CMP (register) on page 4-74;
if n == 13 then SEE SUB (SP minus register) on page 4-371;
if BadReg(d) || n == 15 || BadReg(m) then UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set.

Encoding T2 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

```
SUB{S}<c><q>  {<Rd>,} <Rn>, <Rm> {,<shift>}
```

where:

`S` If present, specifies that the instruction updates the flags. Otherwise, the instruction does not update the flags.

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<Rd>` Specifies the destination register. If `<Rd>` is omitted, this register is the same as `<Rn>`.

`<Rn>` Specifies the register that contains the first operand. If the SP is specified for `<Rn>`, see *SUB (SP minus register)* on page 4-371.

`<Rm>` Specifies the register that is optionally shifted and used as the second operand.

`<shift>` Specifies the shift to apply to the value read from `<Rm>`. If `<shift>` is omitted, no shift is applied and both encodings are permitted. If `<shift>` is specified, only encoding T2 is permitted. The possible shifts and how they are encoded are described in *Constant shifts applied to a register* on page 4-10.

The pre-UAL syntax `SUB<c>S` is equivalent to `SUBS<c>`.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    shifted = Shift(R[m], shift_t, shift_n, APSR.C);
    (result, carry, overflow) = AddWithCarry(R[n], NOT(shifted), '1');
    R[d] = result;
    if setflags then
        APSR.N = result<31>;
        APSR.Z = IsZeroBit(result);
        APSR.C = carry;
        APSR.V = overflow;
```

Exceptions

None.

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4.6.178 SUB (SP minus immediate)

This instruction subtracts an immediate value from the SP value, and writes the result to the destination register.

Encodings

T1 SUB<c> SP,SP,#<imm>

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	0	1	1	0	0	0	0	1	imm7						

```
d = 13;  setflags = FALSE;  imm32 = ZeroExtend(imm7:'00', 32);
```

T2 SUB{S}<c>.W <Rd>,SP,#<const>

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	1	0	i	0	1	1	0	1	S	1	1	0	1	0	imm3			Rd				imm8							

```
d = UInt(Rd);  setflags = (S == '1');
imm32 = ThumbExpandImm(i:imm3:imm8);
if d == 15 && setflags then SEE CMP (immediate) on page 4-72;
if d == 15 then UNPREDICTABLE;
```

T3 SUBW<c> <Rd>,SP,#<imm12>

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	1	0	i	1	0	1	0	1	0	1	1	0	1	0	imm3			Rd				imm8							

```
d = UInt(Rd);  setflags = FALSE;  imm32 = ZeroExtend(i:imm3:imm8, 32);
if d == 15 then UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set.

Encodings T2, T3 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

`SUB{S}<c><q>  {<Rd>,} SP, #<const>`	All encodings permitted
`SUBW<c><q>  {<Rd>,} SP, #<const>`	Only encoding T4 permitted

where:

`S` If present, specifies that the instruction updates the flags. Otherwise, the instruction does not update the flags.

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<Rd>` Specifies the destination register. If `<Rd>` is omitted, this register is SP.

`<const>` Specifies the immediate value to be added to the value obtained from `<Rn>`. Allowed values are multiples of 4 in the range 0-508 for encoding T1 and any value in the range 0-4095 for encoding T3. See *Immediate constants* on page 4-8 for the range of allowed values for encoding T2.

When both 32-bit encodings are available for an instruction, encoding T2 is preferred to encoding T3 (if encoding T3 is required, use the `SUBW` syntax).

The pre-UAL syntax `SUB<c>S` is equivalent to `SUBS<c>`.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    (result, carry, overflow) = AddWithCarry(SP, NOT(imm32), '1');
    R[d] = result;
    if setflags then
        APSR.N = result<31>;
        APSR.Z = IsZeroBit(result);
        APSR.C = carry;
        APSR.V = overflow;
```

Exceptions

None.

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4.6.179 SUB (SP minus register)

This instruction subtracts an optionally-shifted register value from the SP value, and writes the result to the destination register.

Encodings

T1 `SUB<c> <Rd>,SP,<Rm>{,<shift>}`

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	15	14 13 12	11 10 9 8	7 6	5 4	3 2 1 0
1	1	1	0	1	0	1	1	1	0	1	S	1	1	0	1	(0)	imm3	Rd	imm2	type	Rm

```
d = UInt(Rd);  m = UInt(Rm);  setflags = (S == '1');
(shift_t, shift_n) = DecodeImmShift(type, imm3:imm2);
if d == 15 || BadReg(m) then UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

```
SUB{S}<c><q>  {<Rd>,} SP, <Rm> {,<shift>}
```

where:

`S` If present, specifies that the instruction updates the flags. Otherwise, the instruction does not update the flags.

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<Rd>` Specifies the destination register. If `<Rd>` is omitted, this register is SP.

`<Rm>` Specifies the register that is optionally shifted and used as the second operand.

`<shift>` Specifies the shift to apply to the value read from `<Rm>`. If `<shift>` is omitted, no shift is applied. The possible shifts and how they are encoded are described in *Constant shifts applied to a register* on page 4-10.

The pre-UAL syntax `SUB<c>S` is equivalent to `SUBS<c>`.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    shifted = Shift(R[m], shift_t, shift_n, APSR.C);
    (result, carry, overflow) = AddWithCarry(SP, NOT(shifted), '1');
    R[d] = result;
    if setflags then
        APSR.N = result<31>;
        APSR.Z = IsZeroBit(result);
        APSR.C = carry;
        APSR.V = overflow;
```

Exceptions

None.

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4.6.180 SUBS PC, LR

This instruction provides an exception return without the use of the stack.

Encodings

T1 `SUBS<c> PC,LR,#<imm8>` Outside or last in IT block

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	1	0	0	1	1	1	1	0	1	(1)	(1)	(1)	(0)	1	0	(0)	0	(1)	(1)	(1)	(1)	imm8							

```
imm32 = ZeroExtend(imm8, 32);
if InITBlock() && !LastInITBlock() then UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

```
SUBS<c><q>  PC, LR, #<imm>
```

where:

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<imm>` Specifies an 8-bit immediate constant.

The pre-UAL syntax `SUB<c>S` is equivalent to `SUBS<c>`.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    BranchWritePC(LR - imm32);
    CPSR = SPSR;
```

Exceptions

None.

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4.6.181 SVC (formerly SWI)

Generates a supervisor call, formerly called a Software Interrupt. See *Exceptions* in the *ARM Architecture Reference Manual*.

Use it as a call to an operating system to provide a service.

Encodings

T1 `SVC<c> #<imm8>`

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	0	1	1	1	1	1	imm8							

```
imm32 = ZeroExtend(imm24, 32);
// imm32 is for assembly/disassembly only and is ignored by hardware
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

```
SVC<c><q>  #<imm>
```

where:

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<imm>` Specifies an 8-bit immediate constant.

The pre-UAL syntax `SWI<c>` is equivalent to `SVC<c>`.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    CallSupervisor();
```

Exceptions

None.

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4.6.182 SXTAB

Signed Extend and Add Byte extracts an 8-bit value from a register, sign extends it to 32 bits, adds the result to the value in another register, and writes the final result to the destination register. You can specify a rotation by 0, 8, 16, or 24 bits before extracting the 8-bit value.

Encodings

T1 `SXTAB<c> <Rd>,<Rn>,<Rm>{,<rotation>}`

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	1	1	0	1	0	0	1	0	0	Rn				1	1	1	1	Rd				1	(0)	rotate		Rm			

```
d = UInt(Rd);  n = UInt(Rn);  m = UInt(Rm);  rotation = UInt(rotate:'000');
if n == 15 then SEE SXTB on page 4-383;
if BadReg(d) || n == 13 || BadReg(m) then UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

```
SXTAB<c><q>  {<Rd>,} <Rn>, <Rm> {, <rotation>}
```

where:

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<Rd>` Specifies the destination register. If `<Rd>` is omitted, this register is the same as `<Rn>`.

`<Rn>` Specifies the register that contains the first operand.

`<Rm>` Specifies the register that contains the second operand.

`<rotation>`

This can be any one of:

- `ROR #8`.
- `ROR #16`.
- `ROR #24`.
- Omitted.

Note

If your assembler accepts shifts by `#0` and treats them as equivalent to no shift or `LSL #0`, then it must accept `ROR #0` here. It is equivalent to omitting `<rotation>`.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    rotated = ROR(R[m], rotation);
    R[d] = R[n] + SignExtend(rotated<7:0>, 32);
```

Exceptions

None.

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4.6.183 SXTAB16

Signed Extend and Add Byte 16 extracts two 8-bit values from a register, sign extends them to 16 bits each, adds the results to two 16-bit values from another register, and writes the final results to the destination register. You can specify a rotation by 0, 8, 16, or 24 bits before extracting the 8-bit values.

Encodings

T1

```
SXTAB16<c> <Rd>,<Rn>,<Rm>{,<rotation>}
```

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	1	1	0	1	0	0	0	1	0	Rn				1	1	1	1	Rd				1	(0)	rotate		Rm			

```
d = UInt(Rd);  n = UInt(Rn);  m = UInt(Rm);  rotation = UInt(rotate:'000');
if n == 15 then SEE SXTB16 on page 4-385;
if BadReg(d) || n == 13 || BadReg(m) then UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

```
SXTAB16<c><q>  {<Rd>,} <Rn>, <Rm> {, <rotation>}
```

where:

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<Rd>` Specifies the destination register. If `<Rd>` is omitted, this register is the same as `<Rn>`.

`<Rn>` Specifies the register that contains the first operand.

`<Rm>` Specifies the register that contains the second operand.

`<rotation>`

This can be any one of:

- `ROR #8`.
- `ROR #16`.
- `ROR #24`.
- Omitted.

Note

If your assembler accepts shifts by `#0` and treats them as equivalent to no shift or `LSL #0`, then it must accept `ROR #0` here. It is equivalent to omitting `<rotation>`.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    rotated = ROR(R[m], rotation);
    R[d]<15:0>  = R[n]<15:0> + SignExtend(rotated<7:0>, 16);
    R[d]<31:16> = R[n]<31:16> + SignExtend(rotated<23:16>, 16);
```

Exceptions

None.

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4.6.184 SXTAH

Signed Extend and Add Halfword extracts a 16-bit value from a register, sign extends it to 32 bits, adds the result to a value from another register, and writes the final result to the destination register. You can specify a rotation by 0, 8, 16, or 24 bits before extracting the 16-bit value.

Encodings

T1 `SXTAH<c> <Rd>,<Rn>,<Rm>{,<rotation>}`

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	1	1	0	1	0	0	0	0	0	Rn				1	1	1	1	Rd				1	(0)	rotate		Rm			

```
d = UInt(Rd);  n = UInt(Rn);  m = UInt(Rm);  rotation = UInt(rotate:'000');
if n == 15 then SEE SXTH on page 4-387;
if BadReg(d) || n == 13 || BadReg(m) then UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

```
SXTAH<c><q>  {<Rd>,} <Rn>, <Rm> {, <rotation>}
```

where:

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<Rd>` Specifies the destination register. If `<Rd>` is omitted, this register is the same as `<Rn>`.

`<Rn>` Specifies the register that contains the first operand.

`<Rm>` Specifies the register that contains the second operand.

`<rotation>`

This can be any one of:

- `ROR #8`.
- `ROR #16`.
- `ROR #24`.
- Omitted.

Note

If your assembler accepts shifts by `#0` and treats them as equivalent to no shift or `LSL #0`, then it must accept `ROR #0` here. It is equivalent to omitting `<rotation>`.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    rotated = ROR(R[m], rotation);
    R[d] = R[n] + SignExtend(rotated<15:0>, 32);
```

Exceptions

None.

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4.6.185 SXTB

Signed Extend Byte extracts an 8-bit value from a register, sign extends it to 32 bits, and writes the result to the destination register. You can specify a rotation by 0, 8, 16, or 24 bits before extracting the 8-bit value.

Encodings

T1 `SXTB<c> <Rd>,<Rm>`

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	0	1	1	0	0	1	0	0	1	Rm			Rd		

```
d = UInt(Rd);  m = UInt(Rm);  rotation = 0;
```

T2 `SXTB<c> <Rd>,<Rm>{,<rotation>}`

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	1	1	0	1	0	0	1	0	0	1	1	1	1	1	1	1	1	Rd				1	(0)	rotate		Rm			

```
d = UInt(Rd);  m = UInt(Rm);  rotation = UInt(rotate:'000');
if BadReg(d) || BadReg(m) then UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set from ARMv6 onwards.

Encoding T2 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

```
SXTB<c><q>  <Rd>, <Rm> {, <rotation>}
```

where:

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<Rd>` Specifies the destination register.

`<Rm>` Specifies the register that contains the operand.

`<rotation>`

This can be any one of:

- `ROR #8`.
- `ROR #16`.
- `ROR #24`.
- Omitted.

Note

If your assembler accepts shifts by `#0` and treats them as equivalent to no shift or `LSL #0`, then it must accept `ROR #0` here. It is equivalent to omitting `<rotation>`.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    rotated = ROR(R[m], rotation);
    R[d] = SignExtend(rotated<7:0>, 32);
```

Exceptions

None.

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4.6.186 SXTB16

Signed Extend Byte 16 extracts two 8-bit values from a register, sign extends them to 16 bits each, and writes the results to the destination register. You can specify a rotation by 0, 8, 16, or 24 bits before extracting the 8-bit values.

Encodings

T1 `SXTB16<c> <Rd>,<Rm>{,<rotation>}`

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	1	1	0	1	0	0	0	1	0	1	1	1	1	1	1	1	1	Rd				1	(0)	rotate		Rm			

```
d = UInt(Rd);  m = UInt(Rm);  rotation = UInt(rotate:'000');
if BadReg(d) || BadReg(m) then UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

```
SXTB16<c><q>  <Rd>, <Rm> {, <rotation>}
```

where:

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<Rd>` Specifies the destination register.

`<Rm>` Specifies the register that contains the operand.

`<rotation>`

This can be any one of:

- `ROR #8`.
- `ROR #16`.
- `ROR #24`.
- Omitted.

Note

If your assembler accepts shifts by `#0` and treats them as equivalent to no shift or `LSL #0`, then it must accept `ROR #0` here. It is equivalent to omitting `<rotation>`.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    rotated = ROR(R[m], rotation);
    R[d]<15:0>  = SignExtend(rotated<7:0>, 16);
    R[d]<31:16> = SignExtend(rotated<23:16>, 16);
```

Exceptions

None.

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4.6.187 SXTH

Signed Extend Halfword extracts a 16-bit value from a register, sign extends it to 32 bits, and writes the result to the destination register. You can specify a rotation by 0, 8, 16, or 24 bits before extracting the 16-bit value.

Encodings

T1 `SXTH<c> <Rd>,<Rm>`

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	0	1	1	0	0	1	0	0	0	Rm			Rd		

```
d = UInt(Rd);  m = UInt(Rm);  rotation = 0;
```

T2 `SXTH<c> <Rd>,<Rm>{,<rotation>}`

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	1	1	0	1	0	0	0	0	0	1	1	1	1	1	1	1	1	Rd				1	(0)	rotate		Rm			

```
d = UInt(Rd);  m = UInt(Rm);  rotation = UInt(rotate:'000');
if BadReg(d) || BadReg(m) then UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set from ARMv6 onwards.

Encoding T2 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

```
SXTH<c><q>  <Rd>, <Rm> {, <rotation>}
```

where:

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<Rd>` Specifies the destination register.

`<Rm>` Specifies the register that contains the operand.

`<rotation>`

This can be any one of:

- `ROR #8`.
- `ROR #16`.
- `ROR #24`.
- Omitted.

Note

If your assembler accepts shifts by `#0` and treats them as equivalent to no shift or `LSL #0`, then it must accept `ROR #0` here. It is equivalent to omitting `<rotation>`.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    rotated = ROR(R[m], rotation);
    R[d] = SignExtend(rotated<15:0>, 32);
```

Exceptions

None.

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4.6.188 TBB

Table Branch Byte causes a PC-relative forward branch using a table of single byte offsets. A base register provides a pointer to the table, and a second register supplies an index into the table. The branch length is twice the value of the byte returned from the table.

Encodings

T1 `TBB [<Rn>,<Rm>]` Outside or last in IT block

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	0	1	0	0	0	1	1	0	1	Rn				(1)	(1)	(1)	(1)	(0)	(0)	(0)	(0)	0	0	0	0	Rm			

```
n = UInt(Rn);  m = UInt(Rm);
if n == 13 || BadReg(m) then UNPREDICTABLE;
if InITBlock() && !LastInITBlock() then UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

```
TBB<q>  [<Rn>, <Rm>]
```

where:

`<q>` See *Standard assembler syntax fields* on page 4-6.

`<Rn>` Specifies the base register. This contains the address of the table of branch lengths. This register is allowed to be the PC. If it is, the table immediately follows this instruction.

`<Rm>` Specifies the index register. This contains an integer pointing to a single byte within the table. The offset within the table is the value of the index.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    halfwords = MemA[R[n]+R[m], 1];
    BranchWritePC(PC + ZeroExtend(halfwords:'0', 32));
```

Exceptions

Data abort.

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4.6.189 TBH

Table Branch Halfword causes a PC-relative forward branch using a table of single halfword offsets. A base register provides a pointer to the table, and a second register supplies an index into the table. The branch length is twice the value of the halfword returned from the table.

Encodings

T1 TBH [<Rn>,<Rm>,LSL #1]   Outside or last in IT block

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	0	1	0	0	0	1	1	0	1	Rn				(1)	(1)	(1)	(1)	(0)	(0)	(0)	(0)	0	0	0	1	Rm			

```
n = UInt(Rn);  m = UInt(Rm);
if n == 13 || BadReg(m) then UNPREDICTABLE;
if InITBlock() && !LastInITBlock() then UNPREDICTABLE;
```

Architecture versions

Encoding T1   All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

```
TBH<q>  [<Rn>, <Rm>, LSL #1]
```

where:

`<q>` See *Standard assembler syntax fields* on page 4-6.

`<Rn>` Specifies the base register. This contains the address of the table of branch lengths. This register is allowed to be the PC. If it is, the table immediately follows this instruction.

`<Rm>` Specifies the index register. This contains an integer pointing to a halfword within the table. The offset within the table is twice the value of the index.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    halfwords = MemA[R[n]+LSL(R[m],1), 2];
    BranchWritePC(PC + ZeroExtend(halfwords:'0', 32));
```

Exceptions

Data abort.

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4.6.190 TEQ (immediate)

Test Equivalence (immediate) performs an exclusive OR operation on a register value and an immediate value. It updates the condition flags based on the result, and discards the result.

Encodings

T1 `TEQ<c> <Rn>,#<const>`

<table>
<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><td>7</td><td>6</td><td>5</td><td>4</td><td>3</td><td>2</td><td>1</td><td>0</td><td>15</td><td>14</td><td>13</td><td>12</td><td>11</td><td>10</td><td>9</td><td>8</td><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>
<tr><td>1</td><td>1</td><td>1</td><td>1</td><td>0</td><td>i</td><td>0</td><td>0</td><td>1</td><td>0</td><td>0</td><td>1</td><td colspan="4">Rn</td><td>0</td><td colspan="3">imm3</td><td>1</td><td>1</td><td>1</td><td>1</td><td colspan="8">imm8</td></tr>
</table>

```
n = UInt(Rn);
(imm32, carry) = ThumbExpandImmWithC(i:imm3:imm8, APSR.C);
if BadReg(n) then UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

```
TEQ<c><q>  <Rn>, #<const>
```

where:

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<Rn>` Specifies the register that contains the operand.

`<const>` Specifies the immediate value to be added to the value obtained from `<Rn>`. See *Immediate constants* on page 4-8 for the range of allowed values.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    result = R[n] EOR imm32;
    APSR.N = result<31>;
    APSR.Z = IsZeroBit(result);
    APSR.C = carry;
    // APSR.V unchanged
```

Exceptions

None.

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4.6.191 TEQ (register)

Test Equivalence (register) performs an exclusive OR operation on a register value and an optionally-shifted register value. It updates the condition flags based on the result, and discards the result.

Encodings

T1 `TEQ<c> <Rn>, <Rm> {,<shift>}`

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	0	1	0	1	0	1	0	0	1	Rn				(0)	imm3			1	1	1	1	imm2		type		Rm			

```
n = UInt(Rn);  m = UInt(Rm);
(shift_t, shift_n) = DecodeImmShift(type, imm3:imm2);
if BadReg(n) || BadReg(m) THEN UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

```
TEQ<c><q>  <Rn>, <Rm> {,<shift>}
```

where:

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<Rn>` Specifies the register that contains the first operand.

`<Rm>` Specifies the register that is optionally shifted and used as the second operand.

`<shift>` Specifies the shift to apply to the value read from `<Rm>`. If `<shift>` is omitted, no shift is applied. The possible shifts and how they are encoded are described in *Constant shifts applied to a register* on page 4-10.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    (shifted, carry) = Shift_C(R[m], shift_t, shift_n, APSR.C);
    result = R[n] EOR shifted;
    APSR.N = result<31>;
    APSR.Z = IsZeroBit(result);
    APSR.C = carry;
    // APSR.V unchanged
```

Exceptions

None.

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4.6.192 TST (immediate)

Test (immediate) performs a logical AND operation on a register value and an immediate value. It updates the condition flags based on the result, and discards the result.

Encodings

T1 TST<c> <Rn>,#<const>

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	1	0	i	0	0	0	0	0	1	Rn				0	imm3			1	1	1	1	imm8							

```
n = UInt(Rn);
(imm32, carry) = ThumbExpandImmWithC(i:imm3:imm8, APSR.C);
if BadReg(n) then UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

```
TST<c><q>  <Rn>, #<const>
```

where:

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<Rn>` Specifies the register that contains the operand.

`<const>` Specifies the immediate value to be added to the value obtained from `<Rn>`. See *Immediate constants* on page 4-8 for the range of allowed values.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    result = R[n] AND imm32;
    APSR.N = result<31>;
    APSR.Z = IsZeroBit(result);
    APSR.C = carry;
    // APSR.V unchanged
```

Exceptions

None.

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4.6.193 TST (register)

Test (register) performs a logical AND operation on a register value and an optionally-shifted register value. It updates the condition flags based on the result, and discards the result.

Encodings

T1

```
TST<c> <Rn>,<Rm>
```

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0	1	0	0	0	0	1	0	0	0	Rm			Rn		

```
n = UInt(Rdn);  m = UInt(Rm);
(shift_t, shift_n) = (SRType_None, 0);
```

T2

```
TST<c>.W  <Rn>,<Rm>{,<shift>}
```

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	0	1	0	1	0	0	0	0	1	Rn			

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
(0)	imm3			1	1	1	1	imm2		type		Rm			

```
n = UInt(Rn);  m = UInt(Rm);
(shift_t, shift_n) = DecodeImmShift(type, imm3:imm2);
if BadReg(n) || BadReg(m) THEN UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set.

Encoding T2 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

```
TST<c><q>  <Rn>, <Rm> {,<shift>}
```

where:

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<Rn>` Specifies the register that contains the first operand.

`<Rm>` Specifies the register that is optionally shifted and used as the second operand.

`<shift>` Specifies the shift to apply to the value read from `<Rm>`. If `<shift>` is omitted, no shift is applied and both encodings are permitted. If `<shift>` is specified, only encoding T2 is permitted. The possible shifts and how they are encoded are described in *Constant shifts applied to a register* on page 4-10.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    (shifted, carry) = Shift_C(R[m], shift_t, shift_n, APSR.C);
    result = R[n] AND shifted;
    APSR.N = result<31>;
    APSR.Z = IsZeroBit(result);
    APSR.C = carry;
    // APSR.V unchanged
```

Exceptions

None.

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4.6.194 UADD16

Unsigned Add 16 performs two 16-bit unsigned integer additions, and writes the results to the destination register. It sets the GE bits in the APSR according to the results of the additions.

Encodings

T1 UADD16<c> <Rd>,<Rn>,<Rm>

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	1	1	0	1	0	1	0	0	1	Rn				1	1	1	1	Rd				0	1	0	0	Rm			

```
d = UInt(Rd);  n = UInt(Rn);  m = UInt(Rm);
if BadReg(d) || BadReg(n) || BadReg(m) then UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

```
UADD16<c><q>  {<Rd>,} <Rn>, <Rm>
```

where:

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<Rd>` Specifies the destination register. If `<Rd>` is omitted, this register is the same as `<Rn>`.

`<Rn>` Specifies the register that contains the first operand.

`<Rm>` Specifies the register that contains the second operand.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    sum1 = UInt(R[n]<15:0>) + UInt(R[m]<15:0>);
    sum2 = UInt(R[n]<31:16>) + UInt(R[m]<31:16>);
    R[d]<15:0>  = sum1<15:0>;
    R[d]<31:16> = sum2<15:0>;
    APSR.GE<1:0> = if sum1 >= 0x10000 then '11' else '00';
    APSR.GE<3:2> = if sum2 >= 0x10000 then '11' else '00';
```

Exceptions

None.

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4.6.195 UADD8

Unsigned Add 8 performs four unsigned 8-bit integer additions, and writes the results to the destination register. It sets the GE bits in the APSR according to the results of the additions.

Encodings

T1 `UADD8<c> <Rd>,<Rn>,<Rm>`

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	1	1	0	1	0	1	0	0	0	Rn				1	1	1	1	Rd				0	1	0	0	Rm			

```
d = UInt(Rd);  n = UInt(Rn);  m = UInt(Rm);
if BadReg(d) || BadReg(n) || BadReg(m) then UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

```
UADD8<c><q>  {<Rd>,} <Rn>, <Rm>
```

where:

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<Rd>` Specifies the destination register. If `<Rd>` is omitted, this register is the same as `<Rn>`.

`<Rn>` Specifies the register that contains the first operand.

`<Rm>` Specifies the register that contains the second operand.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    sum1 = UInt(R[n]<7:0>) + UInt(R[m]<7:0>);
    sum2 = UInt(R[n]<15:8>) + UInt(R[m]<15:8>);
    sum3 = UInt(R[n]<23:16>) + UInt(R[m]<23:16>);
    sum4 = UInt(R[n]<31:24>) + UInt(R[m]<31:24>);
    R[d]<7:0>   = sum1<7:0>;
    R[d]<15:8>  = sum2<7:0>;
    R[d]<23:16> = sum3<7:0>;
    R[d]<31:24> = sum4<7:0>;
    APSR.GE<0>  = if sum1 >= 0x100 then '1' else '0';
    APSR.GE<1>  = if sum2 >= 0x100 then '1' else '0';
    APSR.GE<2>  = if sum3 >= 0x100 then '1' else '0';
    APSR.GE<3>  = if sum4 >= 0x100 then '1' else '0';
```

Exceptions

None.

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4.6.196 UASX

Unsigned Add and Subtract with Exchange exchanges the two halfwords of the second operand, performs one unsigned 16-bit integer addition and one unsigned 16-bit subtraction, and writes the results to the destination register. It sets the GE bits in the APSR according to the results.

Encodings

T1 `UASX<c> <Rd>,<Rn>,<Rm>`

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	1	1	0	1	0	1	0	1	0	Rn				1	1	1	1	Rd				0	1	0	0	Rm			

```
d = UInt(Rd);  n = UInt(Rn);  m = UInt(Rm);
if BadReg(d) || BadReg(n) || BadReg(m) then UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

```
UASX<c><q>  {<Rd>,} <Rn>, <Rm>
```

where:

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<Rd>` Specifies the destination register. If `<Rd>` is omitted, this register is the same as `<Rn>`.

`<Rn>` Specifies the register that contains the first operand.

`<Rm>` Specifies the register that contains the second operand.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    diff = UInt(R[n]<15:0>) - UInt(R[m]<31:16>);
    sum  = UInt(R[n]<31:16>) + UInt(R[m]<15:0>);
    R[d]<15:0>  = diff<15:0>;
    R[d]<31:16> = sum<15:0>;
    APSR.GE<1:0> = if diff >= 0 then '11' else '00';
    APSR.GE<3:2> = if sum  >= 0x10000 then '11' else '00';
```

Exceptions

None.

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4.6.197 UBFX

Unsigned Bit Field Extract extracts any number of adjacent bits at any position from one register, zero extends them to 32 bits, and writes the result to the destination register.

Encodings

T1 `UBFX<c> <Rd>,<Rn>,#<lsb>,#<width>`

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	1	0	(0)	1	1	1	1	0	0	Rn				0	imm3			Rd				imm2		(0)	widthm1				

```
d = UInt(Rd);  n = UInt(Rn);
lsbit = UInt(imm3:imm2);  widthminus1 = UInt(widthm1);
if BadReg(d) || BadReg(n) then UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

```
UBFX<c><q>  <Rd>, <Rn>, #<lsb>, #<width>
```

where:

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<Rd>` Specifies the destination register.

`<Rn>` Specifies the register that contains the first operand.

`<lsb>` is the bit number of the least significant bit in the bitfield, in the range 0-31. This determines the required value of `lsbit`.

`<width>` is the width of the bitfield, in the range 1 to 32-`<lsb>`). The required value of `widthminus1` is `<width>-1`.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    msbit = lsbit + widthminus1;
    if msbit <= 31 then
        R[d] = ZeroExtend(R[n]<msbit:lsbit>, 32);
    else
        UNPREDICTABLE;
```

Exceptions

None.

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4.6.198 UDIV

Unsigned Divide divides a 32-bit unsigned integer register value by a 32-bit unsigned integer register value, and writes the result to the destination register. The condition code flags are not affected.

Encodings

T1 UDIV<c> <Rd>,<Rn>,<Rm>

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	1	1	0	1	1	1	0	1	1	Rn				(1)	(1)	(1)	(1)	Rd				1	1	1	1	Rm			

```
d = UInt(Rd);  n = UInt(Rn);  m = UInt(Rm);
if BadReg(d) || BadReg(n) || BadReg(m) then UNPREDICTABLE;
```

Architecture versions

Encoding T1 Profile R versions of the Thumb instruction set from ARMv7 onwards.

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Assembler syntax

```
UDIV<c><q>  {<Rd>,} <Rn>, <Rm>
```

where:

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<Rd>` Specifies the destination register. If `<Rd>` is omitted, this register is the same as `<Rn>`.

`<Rn>` Specifies the register that contains the dividend.

`<Rm>` Specifies the register that contains the divisor.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    if UInt(R[m]) == 0 then
        if IntegerZeroDivideTrappingEnabled() then
            RaiseIntegerZeroDivide();
        else
            result = 0;
    else
        result = RoundTowardsZero(UInt(R[n]) / UInt(R[m]));
    R[d] = result<31:0>;
```

Exceptions

Undefined Instruction.

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4.6.199 UHADD16

Unsigned Halving Add 16 performs two unsigned 16-bit integer additions, halves the results, and writes the results to the destination register. It does not affect any flags.

Encodings

T1 `UHADD16<c> <Rd>,<Rn>,<Rm>`

15	14	13	12	11	10	9	8	7	6	5	4	3 2 1 0	15	14	13	12	11 10 9 8	7	6	5	4	3 2 1 0
1	1	1	1	1	0	1	0	1	0	0	1	Rn	1	1	1	1	Rd	0	1	1	0	Rm

```
d = UInt(Rd);  n = UInt(Rn);  m = UInt(Rm);
if BadReg(d) || BadReg(n) || BadReg(m) then UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

```
UHADD16<c><q>  {<Rd>,} <Rn>, <Rm>
```

where:

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<Rd>` Specifies the destination register. If `<Rd>` is omitted, this register is the same as `<Rn>`.

`<Rn>` Specifies the register that contains the first operand.

`<Rm>` Specifies the register that contains the second operand.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    sum1 = UInt(R[n]<15:0>) + UInt(R[m]<15:0>);
    sum2 = UInt(R[n]<31:16>) + UInt(R[m]<31:16>);
    R[d]<15:0>  = sum1<16:1>;
    R[d]<31:16> = sum2<16:1>;
```

Exceptions

None.

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4.6.200 UHADD8

Unsigned Halving Add 8 performs four unsigned 8-bit integer additions, halves the results, and writes the results to the destination register. It does not affect any flags.

Encodings

T1 `UHADD8<c> <Rd>,<Rn>,<Rm>`

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	1	1	0	1	0	1	0	0	0	Rn				1	1	1	1	Rd				0	1	1	0	Rm			

```
d = UInt(Rd);  n = UInt(Rn);  m = UInt(Rm);
if BadReg(d) || BadReg(n) || BadReg(m) then UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

```
UHADD8<c><q>  {<Rd>,} <Rn>, <Rm>
```

where:

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<Rd>` Specifies the destination register. If `<Rd>` is omitted, this register is the same as `<Rn>`.

`<Rn>` Specifies the register that contains the first operand.

`<Rm>` Specifies the register that contains the second operand.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    sum1 = UInt(R[n]<7:0>) + UInt(R[m]<7:0>);
    sum2 = UInt(R[n]<15:8>) + UInt(R[m]<15:8>);
    sum3 = UInt(R[n]<23:16>) + UInt(R[m]<23:16>);
    sum4 = UInt(R[n]<31:24>) + UInt(R[m]<31:24>);
    R[d]<7:0>   = sum1<8:1>;
    R[d]<15:8>  = sum2<8:1>;
    R[d]<23:16> = sum3<8:1>;
    R[d]<31:24> = sum4<8:1>;
```

Exceptions

None.

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4.6.201 UHASX

Unsigned Halving Add and Subtract with Exchange exchanges the two halfwords of the second operand, performs one unsigned 16-bit integer addition and one unsigned 16-bit subtraction, halves the results, and writes the results to the destination register. It does not affect any flags.

Encodings

T1 `UHASX<c> <Rd>,<Rn>,<Rm>`

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	1	1	0	1	0	1	0	1	0	Rn				1	1	1	1	Rd				0	1	1	0	Rm			

```
d = UInt(Rd);  n = UInt(Rn);  m = UInt(Rm);
if BadReg(d) || BadReg(n) || BadReg(m) then UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

```
UHASX<c><q>  {<Rd>,} <Rn>, <Rm>
```

where:

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<Rd>` Specifies the destination register. If `<Rd>` is omitted, this register is the same as `<Rn>`.

`<Rn>` Specifies the register that contains the first operand.

`<Rm>` Specifies the register that contains the second operand.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    diff = UInt(R[n]<15:0>) - UInt(R[m]<31:16>);
    sum  = UInt(R[n]<31:16>) + UInt(R[m]<15:0>);
    R[d]<15:0>  = diff<16:1>;
    R[d]<31:16> = sum<16:1>;
```

Exceptions

None.

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4.6.202 UHSAX

Unsigned Halving Subtract and Add with Exchange exchanges the two halfwords of the second operand, performs one unsigned 16-bit integer subtraction and one unsigned 16-bit addition, halves the results, and writes the results to the destination register. It does not affect any flags.

Encodings

T1 `UHSAX<c> <Rd>,<Rn>,<Rm>`

15 14 13 12 11	10 9 8	7	6 5 4	3 2 1 0	15 14 13 12	11 10 9 8	7	6 5 4	3 2 1 0
1 1 1 1 1	0 1 0	1	1 1 0	Rn	1 1 1 1	Rd	0	1 1 0	Rm

```
d = UInt(Rd);  n = UInt(Rn);  m = UInt(Rm);
if BadReg(d) || BadReg(n) || BadReg(m) then UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

```
UHSAX<c><q>  {<Rd>,} <Rn>, <Rm>
```

where:

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<Rd>` Specifies the destination register. If `<Rd>` is omitted, this register is the same as `<Rn>`.

`<Rn>` Specifies the register that contains the first operand.

`<Rm>` Specifies the register that contains the second operand.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    sum  = UInt(R[n]<15:0>) + UInt(R[m]<31:16>);
    diff = UInt(R[n]<31:16>) - UInt(R[m]<15:0>);
    R[d]<15:0>  = sum<16:1>;
    R[d]<31:16> = diff<16:1>;
```

Exceptions

None.

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4.6.203 UHSUB16

Unsigned Halving Subtract 16 performs two unsigned 16-bit integer subtractions, halves the results, and writes the results to the destination register. It does not affect any flags.

Encodings

T1 UHSUB16<c> <Rd>,<Rn>,<Rm>

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	1	1	0	1	0	1	1	0	1	Rn				1	1	1	1	Rd				0	1	1	0	Rm			

```
d = UInt(Rd);  n = UInt(Rn);  m = UInt(Rm);
if BadReg(d) || BadReg(n) || BadReg(m) then UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

```
UHSUB16<c><q>  {<Rd>,} <Rn>, <Rm>
```

where:

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<Rd>` Specifies the destination register. If `<Rd>` is omitted, this register is the same as `<Rn>`.

`<Rn>` Specifies the register that contains the first operand.

`<Rm>` Specifies the register that contains the second operand.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    diff1 = UInt(R[n]<15:0>) - UInt(R[m]<15:0>);
    diff2 = UInt(R[n]<31:16>) - UInt(R[m]<31:16>);
    R[d]<15:0>  = diff1<16:1>;
    R[d]<31:16> = diff2<16:1>;
```

Exceptions

None.

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4.6.204 UHSUB8

Unsigned Halving Subtract 8 performs four unsigned 8-bit integer subtractions, halves the results, and writes the results to the destination register. It does not affect any flags.

Encodings

T1 `UHSUB8<c> <Rd>,<Rn>,<Rm>`

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	1	1	0	1	0	1	1	0	0	Rn				1	1	1	1	Rd				0	1	1	0	Rm			

```
d = UInt(Rd);  n = UInt(Rn);  m = UInt(Rm);
if BadReg(d) || BadReg(n) || BadReg(m) then UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

```
UHSUB8<c><q>  {<Rd>,} <Rn>, <Rm>
```

where:

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<Rd>` Specifies the destination register. If `<Rd>` is omitted, this register is the same as `<Rn>`.

`<Rn>` Specifies the register that contains the first operand.

`<Rm>` Specifies the register that contains the second operand.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    diff1 = UInt(R[n]<7:0>) - UInt(R[m]<7:0>);
    diff2 = UInt(R[n]<15:8>) - UInt(R[m]<15:8>);
    diff3 = UInt(R[n]<23:16>) - UInt(R[m]<23:16>);
    diff4 = UInt(R[n]<31:24>) - UInt(R[m]<31:24>);
    R[d]<7:0>   = diff1<8:1>;
    R[d]<15:8>  = diff2<8:1>;
    R[d]<23:16> = diff3<8:1>;
    R[d]<31:24> = diff4<8:1>;
```

Exceptions

None.

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4.6.205 UMAAL

Unsigned Multiply Accumulate Accumulate Long multiplies two unsigned 32-bit values to produce a 64-bit value, adds two unsigned 32-bit values, and writes the 64-bit result to two registers.

Encodings

T1 `UMAAL<c> <RdLo>,<RdHi>,<Rn>,<Rm>`

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	1	1	0	1	1	1	1	1	0	Rn				RdLo				RdHi				0	1	1	0	Rm			

```
dLo = UInt(RdLo);  dHi = UInt(RdHi);  n = UInt(Rn);  m = UInt(Rm);
if BadReg(dLo) || BadReg(dHi) || BadReg(n) || BadReg(m) then UNPREDICTABLE;
if dHi == dLo then UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

```
UMAAL<c><q>  <RdLo>, <RdHi>, <Rn>, <Rm>
```

where:

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<RdLo>` Supplies one of the 32 bit values to be added, and is the destination register for the lower 32 bits of the result.

`<RdHi>` Supplies the other of the 32 bit values to be added, and is the destination register for the upper 32 bits of the result.

`<Rn>` Specifies the register that contains the first multiply operand.

`<Rm>` Specifies the register that contains the second multiply operand.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    result = UInt(R[n]) * UInt(R[m]) + UInt(R[dHi]) + UInt(R[dLo]);
    R[dHi] = result<63:32>;
    R[dLo] = result<31:0>;
```

Exceptions

None.

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4.6.206 UMLAL

Unsigned Multiply Accumulate Long multiplies two unsigned 32-bit values to produce a 64-bit value, and accumulates this with a 64-bit value.

Encodings

T1 `UMLAL<c> <RdLo>,<RdHi>,<Rn>,<Rm>`

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	1	1	0	1	1	1	1	1	0	Rn				RdLo				RdHi				0	0	0	0	Rm			

```
dLo = UInt(RdLo);  dHi = UInt(RdHi);  n = UInt(Rn);  m = UInt(Rm);
if BadReg(dLo) || BadReg(dHi) || BadReg(n) || BadReg(m) then UNPREDICTABLE;
if dHi == dLo then UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

```
UMLAL<c><q>  <RdLo>, <RdHi>, <Rn>, <Rm>
```

where:

`<c><q>`	See *Standard assembler syntax fields* on page 4-6.
`<RdLo>`	Supplies the lower 32 bits of the accumulate value, and is the destination register for the lower 32 bits of the result.
`<RdHi>`	Supplies the upper 32 bits of the accumulate value, and is the destination register for the upper 32 bits of the result.
`<Rn>`	Specifies the register that contains the first operand.
`<Rm>`	Specifies the register that contains the second operand.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    result = UInt(R[n]) * UInt(R[m]) + UInt(R[dHi]:R[dLo]);
    R[dHi] = result<63:32>;
    R[dLo] = result<31:0>;
```

Exceptions

None.

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4.6.207 UMULL

Unsigned Multiply Long multiplies two 32-bit unsigned values to produce a 64-bit result.

Encodings

T1 UMULL<c> <RdLo>,<RdHi>,<Rn>,<Rm>

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	1	1	0	1	1	1	0	1	0	Rn				RdLo				RdHi				0	0	0	0	Rm			

```
dLo = UInt(RdLo);  dHi = UInt(RdHi);  n = UInt(Rn);  m = UInt(Rm);
if BadReg(dLo) || BadReg(dHi) || BadReg(n) || BadReg(m) then UNPREDICTABLE;
if dHi == dLo then UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

```
UMULL<c><q>  <RdLo>, <RdHi>, <Rn>, <Rm>
```

where:

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<RdLo>` Stores the lower 32 bits of the result.

`<RdHi>` Stores the upper 32 bits of the result.

`<Rn>` Specifies the register that contains the first operand.

`<Rm>` Specifies the register that contains the second operand.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    result = UInt(R[n])*Uint(R[m]);
    R[dHi] = result<63:32>;
    R[dLo] = result<31:0>;
```

Exceptions

None.

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4.6.208 UQADD16

Unsigned Saturating Add 16 performs two unsigned 16-bit integer additions, saturates the results to the 16-bit unsigned integer range $0 \leq x \leq 2^{16} - 1$, and writes the results to the destination register. It does not affect any flags.

Encodings

T1 `UQADD16<c> <Rd>,<Rn>,<Rm>`

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	1	1	0	1	0	1	0	0	1	Rn				1	1	1	1	Rd				0	1	0	1	Rm			

```
d = UInt(Rd);  n = UInt(Rn);  m = UInt(Rm);
if BadReg(d) || BadReg(n) || BadReg(m) then UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

```
UQADD16<c><q>  {<Rd>,} <Rn>, <Rm>
```

where:

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<Rd>` Specifies the destination register. If `<Rd>` is omitted, this register is the same as `<Rn>`.

`<Rn>` Specifies the register that contains the first operand.

`<Rm>` Specifies the register that contains the second operand.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    sum1 = UInt(R[n]<15:0>) + UInt(R[m]<15:0>);
    sum2 = UInt(R[n]<31:16>) + UInt(R[m]<31:16>);
    R[d]<15:0>  = UnsignedSat(sum1, 16);
    R[d]<31:16> = UnsignedSat(sum2, 16);
```

Exceptions

None.

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4.6.209 UQADD8

Unsigned Saturating Add 8 performs four unsigned 8-bit integer additions, saturates the results to the 8-bit unsigned integer range $0 \le x \le 2^8 - 1$, and writes the results to the destination register. It does not affect any flags.

Encodings

T1 `UQADD8<c> <Rd>,<Rn>,<Rm>`

15	14	13	12	11	10	9	8	7	6	5	4	3 2 1 0	15	14	13	12	11 10 9 8	7	6	5	4	3 2 1 0
1	1	1	1	1	0	1	0	1	0	0	0	Rn	1	1	1	1	Rd	0	1	0	1	Rm

```
d = UInt(Rd);  n = UInt(Rn);  m = UInt(Rm);
if BadReg(d) || BadReg(n) || BadReg(m) then UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

```
UQADD8<c><q>  {<Rd>,} <Rn>, <Rm>
```

where:

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<Rd>` Specifies the destination register. If `<Rd>` is omitted, this register is the same as `<Rn>`.

`<Rn>` Specifies the register that contains the first operand.

`<Rm>` Specifies the register that contains the second operand.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    sum1 = UInt(R[n]<7:0>) + UInt(R[m]<7:0>);
    sum2 = UInt(R[n]<15:8>) + UInt(R[m]<15:8>);
    sum3 = UInt(R[n]<23:16>) + UInt(R[m]<23:16>);
    sum4 = UInt(R[n]<31:24>) + UInt(R[m]<31:24>);
    R[d]<7:0>   = UnsignedSat(sum1, 8);
    R[d]<15:8>  = UnsignedSat(sum2, 8);
    R[d]<23:16> = UnsignedSat(sum3, 8);
    R[d]<31:24> = UnsignedSat(sum4, 8);
```

Exceptions

None.

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4.6.210 UQASX

Unsigned Saturating Add and Subtract with Exchange exchanges the two halfwords of the second operand, performs one unsigned 16-bit integer addition and one unsigned 16-bit subtraction, saturates the results to the 16-bit unsigned integer range $0 \leq x \leq 2^{16} - 1$, and writes the results to the destination register. It does not affect any flags.

Encodings

T1 `UQASX<c> <Rd>,<Rn>,<Rm>`

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	1	1	0	1	0	1	0	1	0	Rn				1	1	1	1	Rd				0	1	0	1	Rm			

```
d = UInt(Rd);  n = UInt(Rn);  m = UInt(Rm);
if BadReg(d) || BadReg(n) || BadReg(m) then UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

```
UQASX<c><q>  {<Rd>,} <Rn>, <Rm>
```

where:

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<Rd>` Specifies the destination register. If `<Rd>` is omitted, this register is the same as `<Rn>`.

`<Rn>` Specifies the register that contains the first operand.

`<Rm>` Specifies the register that contains the second operand.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    diff = UInt(R[n]<15:0>) - UInt(R[m]<31:16>);
    sum  = UInt(R[n]<31:16>) + UInt(R[m]<15:0>);
    R[d]<15:0>  = UnsignedSat(diff, 16);
    R[d]<31:16> = UnsignedSat(sum, 16);
```

Exceptions

None.

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4.6.211 UQSAX

Unsigned Saturating Subtract and Add with Exchange exchanges the two halfwords of the second operand, performs one unsigned 16-bit integer subtraction and one unsigned 16-bit addition, saturates the results to the 16-bit unsigned integer range $0 \leq x \leq 2^{16} - 1$, and writes the results to the destination register. It does not affect any flags.

Encodings

T1 `UQSAX<c> <Rd>,<Rn>,<Rm>`

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	1	1	0	1	0	1	1	1	0	Rn				1	1	1	1	Rd				0	1	0	1	Rm			

```
d = UInt(Rd);  n = UInt(Rn);  m = UInt(Rm);
if BadReg(d) || BadReg(n) || BadReg(m) then UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

```
UQSAX<c><q>  {<Rd>,} <Rn>, <Rm>
```

where:

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<Rd>` Specifies the destination register. If `<Rd>` is omitted, this register is the same as `<Rn>`.

`<Rn>` Specifies the register that contains the first operand.

`<Rm>` Specifies the register that contains the second operand.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    sum  = UInt(R[n]<15:0>) + UInt(R[m]<31:16>);
    diff = UInt(R[n]<31:16>) - UInt(R[m]<15:0>);
    R[d]<15:0>  = UnsignedSat(sum, 16);
    R[d]<31:16> = UnsignedSat(diff, 16);
```

Exceptions

None.

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4.6.212 UQSUB16

Unsigned Saturating Subtract 16 performs two unsigned 16-bit integer subtractions, saturates the results to the 16-bit unsigned integer range $0 \leq x \leq 2^{16} - 1$, and writes the results to the destination register. It does not affect any flags.

Encodings

T1 `UQSUB16<c> <Rd>,<Rn>,<Rm>`

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	1	1	0	1	0	1	1	0	1	Rn				1	1	1	1	Rd				0	1	0	1	Rm			

```
d = UInt(Rd);  n = UInt(Rn);  m = UInt(Rm);
if BadReg(d) || BadReg(n) || BadReg(m) then UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

```
UQSUB16<c><q>  {<Rd>,} <Rn>, <Rm>
```

where:

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<Rd>` Specifies the destination register. If `<Rd>` is omitted, this register is the same as `<Rn>`.

`<Rn>` Specifies the register that contains the first operand.

`<Rm>` Specifies the register that contains the second operand.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    diff1 = UInt(R[n]<15:0>) - UInt(R[m]<15:0>);
    diff2 = UInt(R[n]<31:16>) - UInt(R[m]<31:16>);
    R[d]<15:0>  = UnsignedSat(diff1, 16);
    R[d]<31:16> = UnsignedSat(diff2, 16);
```

Exceptions

None.

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4.6.213 UQSUB8

Unsigned Saturating Subtract 8 performs four unsigned 8-bit integer subtractions, saturates the results to the 8-bit unsigned integer range $0 \leq x \leq 2^8 - 1$, and writes the results to the destination register. It does not affect any flags.

Encodings

T1 `UQSUB8<c> <Rd>,<Rn>,<Rm>`

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	1	1	0	1	0	1	1	0	0	Rn				1	1	1	1	Rd				0	1	0	1	Rm			

```
d = UInt(Rd);  n = UInt(Rn);  m = UInt(Rm);
if BadReg(d) || BadReg(n) || BadReg(m) then UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

```
UQSUB8<c><q>  {<Rd>,} <Rn>, <Rm>
```

where:

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<Rd>` Specifies the destination register. If `<Rd>` is omitted, this register is the same as `<Rn>`.

`<Rn>` Specifies the register that contains the first operand.

`<Rm>` Specifies the register that contains the second operand.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    diff1 = UInt(R[n]<7:0>) - UInt(R[m]<7:0>);
    diff2 = UInt(R[n]<15:8>) - UInt(R[m]<15:8>);
    diff3 = UInt(R[n]<23:16>) - UInt(R[m]<23:16>);
    diff4 = UInt(R[n]<31:24>) - UInt(R[m]<31:24>);
    R[d]<7:0>   = UnsignedSat(diff1, 8);
    R[d]<15:8>  = UnsignedSat(diff2, 8);
    R[d]<23:16> = UnsignedSat(diff3, 8);
    R[d]<31:24> = UnsignedSat(diff4, 8);
```

Exceptions

None.

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4.6.214 USAD8

Unsigned Sum of Absolute Differences performs four unsigned 8-bit subtractions, and adds the absolute values of the differences together.

Encodings

T1 `USAD8<c> <Rd>,<Rn>,<Rm>`

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	1	1	0	1	1	0	1	1	1	Rn				1	1	1	1	Rd				0	0	0	0	Rm			

```
d = UInt(Rd);  n = UInt(Rn);  m = UInt(Rm);
if BadReg(d) || BadReg(n) || BadReg(m) then UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

```
USAD8<c><q>  {<Rd>,} <Rn>, <Rm>
```

where:

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<Rd>` Specifies the destination register. If `<Rd>` is omitted, this register is the same as `<Rn>`.

`<Rn>` Specifies the register that contains the first operand.

`<Rm>` Specifies the register that contains the second operand.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    absdiff1 = ABS(UInt(R[n]<7:0>)   - UInt(R[m]<7:0>));
    absdiff2 = ABS(UInt(R[n]<15:8>)  - UInt(R[m]<15:8>));
    absdiff3 = ABS(UInt(R[n]<23:16>) - UInt(R[m]<23:16>));
    absdiff4 = ABS(UInt(R[n]<31:24>) - UInt(R[m]<31:24>));
    result = absdiff1 + absdiff2 + absdiff3 + absdiff4;
    R[d] = result<31:0>;
```

Exceptions

None.

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4.6.215 USADA8

Unsigned Sum of Absolute Differences and Accumulate performs four unsigned 8-bit subtractions, and adds the absolute values of the differences to a 32-bit accumulate operand.

Encodings

T1 `USADA8<c> <Rd>,<Rn>,<Rm>,<Ra>`

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	1	1	0	1	1	0	1	1	1	Rn				Ra				Rd				0	0	0	0	Rm			

```
d = UInt(Rd);  n = UInt(Rn);  m = UInt(Rm);  a == UInt(Ra);
if a == 15 then SEE USAD8 on page 4-441;
if BadReg(d) || BadReg(n) || BadReg(m) || BadReg(a) then UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

```
USADA8<c><q>  <Rd>, <Rn>, <Rm>, <Ra>
```

where:

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<Rd>` Specifies the destination register.

`<Rn>` Specifies the register that contains the first operand.

`<Rm>` Specifies the register that contains the second operand.

`<Ra>` Specifies the register that contains the accumulation value.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    absdiff1 = ABS(UInt(R[n]<7:0>)   - UInt(R[m]<7:0>));
    absdiff2 = ABS(UInt(R[n]<15:8>)  - UInt(R[m]<15:8>));
    absdiff3 = ABS(UInt(R[n]<23:16>) - UInt(R[m]<23:16>));
    absdiff4 = ABS(UInt(R[n]<31:24>) - UInt(R[m]<31:24>));
    result = UInt(R[a]) + absdiff1 + absdiff2 + absdiff3 + absdiff4;
    R[d] = result<31:0>;
```

Exceptions

None.

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4.6.216 USAT

Unsigned Saturate saturates an optionally-shifted signed value to a selected unsigned range.

The Q flag is set if the operation saturates.

Encodings

T1 `USAT<c> <Rd>,#<imm>,<Rn>{,<shift>}`

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	1	0	(0)	1	1	1	0	sh	0	Rn				0	imm3			Rd				imm2		(0)	sat_imm				

```
d = UInt(Rd);  n = UInt(Rn);  saturate_to = UInt(sat_imm);
if sh == 1 && imm3:imm2 == '00000' then SEE USAT16 on page 4-447;
(shift_t, shift_n) = DecodeImmShift(sh:'0', imm3:imm2);
if BadReg(d) || BadReg(n) then UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

```
USAT<c><q>  <Rd>, #<imm>, <Rn> {,<shift>}
```

where:

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<Rd>` Specifies the destination register.

`<imm>` Specifies the bit position for saturation, in the range 0 to 31.

`<Rn>` Specifies the register that contains the value to be saturated.

`<shift>` Specifies the optional shift. If present, it must be one of:

`LSL #N`	*N* must be in the range 0 to 31.
`ASR #N`	*N* must be in the range 1 to 31.

If `<shift>` is omitted, `LSL #0` is used.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    operand = Shift(R[n], shift_t, shift_n, APSR.C);  // APSR.C ignored
    (result, sat) = UnsignedSatQ(SInt(operand), saturate_to);
    R[d] = ZeroExtend(result, 32);
    if sat then
        APSR.Q = '1';
```

Exceptions

None.

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4.6.217 USAT16

Unsigned Saturate 16 saturates two signed 16-bit values to a selected unsigned range.

The Q flag is set if the operation saturates.

Encodings

T1 `USAT16<c> <Rd>,#<imm>,<Rn>`

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	1	0	(0)	1	1	1	0	1	0	Rn				0	0	0	0	Rd				0	0	(0)	(0)	sat_imm			

```
d = UInt(Rd);  n = UInt(Rn);  saturate_to = UInt(sat_imm);
if BadReg(d) || BadReg(n) then UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

```
USAT16<c><q>  <Rd>, #<imm>, <Rn>
```

where:

`<c><q>`	See *Standard assembler syntax fields* on page 4-6.
`<Rd>`	Specifies the destination register.
`<imm>`	Specifies the bit position for saturation, in the range 0 to 15.
`<Rn>`	Specifies the register that contains the values to be saturated.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    (result1, sat1) = UnsignedSatQ(SInt(R[n]<15:0>), saturate_to);
    (result2, sat2) = UnsignedSatQ(SInt(R[n]<31:16>), saturate_to);
    R[d]<15:0> = ZeroExtend(result1, 16);
    R[d]<31:16> = ZeroExtend(result2, 16);
    if sat1 || sat2 then
        APSR.Q = '1';
```

Exceptions

None.

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4.6.218 USAX

Unsigned Subtract and Add with Exchange exchanges the two halfwords of the second operand, performs one unsigned 16-bit integer subtraction and one unsigned 16-bit addition, and writes the results to the destination register. It sets the GE bits in the APSR according to the results.

Encodings

T1

```
USAX<c> <Rd>,<Rn>,<Rm>
```

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	1	1	0	1	0	1	1	1	0	Rn				1	1	1	1	Rd				0	1	0	0	Rm			

```
d = UInt(Rd);  n = UInt(Rn);  m = UInt(Rm);
if BadReg(d) || BadReg(n) || BadReg(m) then UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

```
USAX<c><q>  {<Rd>,} <Rn>, <Rm>
```

where:

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<Rd>` Specifies the destination register. If `<Rd>` is omitted, this register is the same as `<Rn>`.

`<Rn>` Specifies the register that contains the first operand.

`<Rm>` Specifies the register that contains the second operand.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    sum  = UInt(R[n]<15:0>) + UInt(R[m]<31:16>);
    diff = UInt(R[n]<31:16>) - UInt(R[m]<15:0>);
    R[d]<15:0>  = sum<15:0>;
    R[d]<31:16> = diff<15:0>;
    APSR.GE<1:0> = if sum  >= 0x10000 then '11' else '00';
    APSR.GE<3:2> = if diff >= 0 then '11' else '00';
```

Exceptions

None.

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4.6.219 USUB16

Unsigned Subtract 16 performs two 16-bit unsigned integer subtractions, and writes the results to the destination register. It sets the GE bits in the APSR according to the results of the subtractions.

Encodings

T1 USUB16<c> <Rd>,<Rn>,<Rm>

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	1	1	0	1	0	1	1	0	1	Rn				1	1	1	1	Rd				0	1	0	0	Rm			

```
d = UInt(Rd);  n = UInt(Rn);  m = UInt(Rm);
if BadReg(d) || BadReg(n) || BadReg(m) then UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

```
USUB16<c><q>  {<Rd>,} <Rn>, <Rm>
```

where:

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<Rd>` Specifies the destination register. If `<Rd>` is omitted, this register is the same as `<Rn>`.

`<Rn>` Specifies the register that contains the first operand.

`<Rm>` Specifies the register that contains the second operand.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    diff1 = UInt(R[n]<15:0>) - UInt(R[m]<15:0>);
    diff2 = UInt(R[n]<31:16>) - UInt(R[m]<31:16>);
    R[d]<15:0>  = diff1<15:0>;
    R[d]<31:16> = diff2<15:0>;
    APSR.GE<1:0> = if diff1 >= 0 then '11' else '00';
    APSR.GE<3:2> = if diff2 >= 0 then '11' else '00';
```

Exceptions

None.

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4.6.220 USUB8

Unsigned Subtract 8 performs four 8-bit unsigned integer subtractions, and writes the results to the destination register. It sets the GE bits in the APSR according to the results of the subtractions.

Encodings

T1 `USUB8<c> <Rd>,<Rn>,<Rm>`

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	1	1	0	1	0	1	1	0	0	Rn				1	1	1	1	Rd				0	1	0	0	Rm			

```
d = UInt(Rd);  n = UInt(Rn);  m = UInt(Rm);
if BadReg(d) || BadReg(n) || BadReg(m) then UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

```
USUB8<c><q>  {<Rd>,} <Rn>, <Rm>
```

where:

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<Rd>` Specifies the destination register. If `<Rd>` is omitted, this register is the same as `<Rn>`.

`<Rn>` Specifies the register that contains the first operand.

`<Rm>` Specifies the register that contains the second operand.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    diff1 = UInt(R[n]<7:0>) - UInt(R[m]<7:0>);
    diff2 = UInt(R[n]<15:8>) - UInt(R[m]<15:8>);
    diff3 = UInt(R[n]<23:16>) - UInt(R[m]<23:16>);
    diff4 = UInt(R[n]<31:24>) - UInt(R[m]<31:24>);
    R[d]<7:0>   = diff1<7:0>;
    R[d]<15:8>  = diff2<7:0>;
    R[d]<23:16> = diff3<7:0>;
    R[d]<31:24> = diff4<7:0>;
    APSR.GE<0>  = if diff1 >= 0 then '1' else '0';
    APSR.GE<1>  = if diff2 >= 0 then '1' else '0';
    APSR.GE<2>  = if diff3 >= 0 then '1' else '0';
    APSR.GE<3>  = if diff4 >= 0 then '1' else '0';
```

Exceptions

None.

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4.6.221 UXTAB

Unsigned Extend and Add Byte extracts an 8-bit value from a register, zero extends it to 32 bits, adds the result to the value in another register, and writes the final result to the destination register. You can specify a rotation by 0, 8, 16, or 24 bits before extracting the 8-bit value.

Encodings

T1 `UXTAB<c> <Rd>,<Rn>,<Rm>{,<rotation>}`

<table>
<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><td>7</td><td>6</td><td>5</td><td>4</td><td>3</td><td>2</td><td>1</td><td>0</td><td>15</td><td>14</td><td>13</td><td>12</td><td>11</td><td>10</td><td>9</td><td>8</td><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>
<tr><td>1</td><td>1</td><td>1</td><td>1</td><td>1</td><td>0</td><td>1</td><td>0</td><td>0</td><td>1</td><td>0</td><td>1</td><td colspan="4">Rn</td><td>1</td><td>1</td><td>1</td><td>1</td><td colspan="4">Rd</td><td>1</td><td>(0)</td><td colspan="2">rotate</td><td colspan="4">Rm</td></tr>
</table>

```
d = UInt(Rd);  n = UInt(Rn);  m = UInt(Rm);  rotation = UInt(rotate:'000');
if n == 15 then SEE UXTB on page 4-461;
if BadReg(d) || n == 13 || BadReg(m) then UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

```
UXTAB<c><q>  {<Rd>,} <Rn>, <Rm> {, <rotation>}
```

where:

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<Rd>` Specifies the destination register. If `<Rd>` is omitted, this register is the same as `<Rn>`.

`<Rn>` Specifies the register that contains the first operand.

`<Rm>` Specifies the register that contains the second operand.

`<rotation>`

This can be any one of:

- `ROR #8`.
- `ROR #16`.
- `ROR #24`.
- Omitted.

Note

If your assembler accepts shifts by `#0` and treats them as equivalent to no shift or `LSL #0`, then it must accept `ROR #0` here. It is equivalent to omitting `<rotation>`.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    rotated = ROR(R[m], rotation);
    R[d] = R[n] + ZeroExtend(rotated<7:0>, 32);
```

Exceptions

None.

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4.6.222 UXTAB16

Unsigned Extend and Add Byte 16 extracts two 8-bit values from a register, zero extends them to 16 bits each, adds the results to two 16-bit values from another register, and writes the final results to the destination register. You can specify a rotation by 0, 8, 16, or 24 bits before extracting the 8-bit values.

Encodings

T1 UXTAB16<c> <Rd>,<Rn>,<Rm>{,<rotation>}

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	1	1	0	1	0	0	0	1	1	Rn				1	1	1	1	Rd				1	(0)	rotate		Rm			

```
d = UInt(Rd);  n = UInt(Rn);  m = UInt(Rm);  rotation = UInt(rotate:'000');
if n == 15 then SEE UXTB16 on page 4-463;
if BadReg(d) || n == 13 || BadReg(m) then UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

```
UXTAB16<c><q>  {<Rd>,} <Rn>, <Rm> {, <rotation>}
```

where:

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<Rd>` Specifies the destination register. If `<Rd>` is omitted, this register is the same as `<Rn>`.

`<Rn>` Specifies the register that contains the first operand.

`<Rm>` Specifies the register that contains the second operand.

`<rotation>`

This can be any one of:

- `ROR #8`.
- `ROR #16`.
- `ROR #24`.
- Omitted.

Note

If your assembler accepts shifts by `#0` and treats them as equivalent to no shift or `LSL #0`, then it must accept `ROR #0` here. It is equivalent to omitting `<rotation>`.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    rotated = ROR(R[m], rotation);
    R[d]<15:0>  = R[n]<15:0> + ZeroExtend(rotated<7:0>, 16);
    R[d]<31:16> = R[n]<31:16> + ZeroExtend(rotated<23:16>, 16);
```

Exceptions

None.

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4.6.223 UXTAH

Unsigned Extend and Add Halfword extracts a 16-bit value from a register, zero extends it to 32 bits, adds the result to a value from another register, and writes the final result to the destination register. You can specify a rotation by 0, 8, 16, or 24 bits before extracting the 16-bit value.

Encodings

T1 `UXTAH<c> <Rd>,<Rn>,<Rm>{,<rotation>}`

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	1	1	0	1	0	0	0	0	1	Rn				1	1	1	1	Rd				1	(0)	rotate		Rm			

```
d = UInt(Rd);  n = UInt(Rn);  m = UInt(Rm);  rotation = UInt(rotate:'000');
if n == 15 then SEE UXTH on page 4-465;
if BadReg(d) || n == 13 || BadReg(m) then UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

```
UXTAH<c><q>  {<Rd>,} <Rn>, <Rm> {, <rotation>}
```

where:

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<Rd>` Specifies the destination register. If `<Rd>` is omitted, this register is the same as `<Rn>`.

`<Rn>` Specifies the register that contains the first operand.

`<Rm>` Specifies the register that contains the second operand.

`<rotation>`

This can be any one of:

- `ROR #8`.
- `ROR #16`.
- `ROR #24`.
- Omitted.

Note

If your assembler accepts shifts by `#0` and treats them as equivalent to no shift or `LSL #0`, then it must accept `ROR #0` here. It is equivalent to omitting `<rotation>`.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    rotated = ROR(R[m], rotation);
    R[d] = R[n] + ZeroExtend(rotated<15:0>, 32);
```

Exceptions

None.

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4.6.224 UXTB

Unsigned Extend Byte extracts an 8-bit value from a register, zero extends it to 32 bits, and writes the result to the destination register. You can specify a rotation by 0, 8, 16, or 24 bits before extracting the 8-bit value.

Encodings

T1 `UXTB<c> <Rd>,<Rm>`

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	0	1	1	0	0	1	0	1	1	Rm			Rd		

```
d = UInt(Rd);  m = UInt(Rm);  rotation = 0;
```

T2 `UXTB<c> <Rd>,<Rm>{,<rotation>}`

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	1	1	0	1	0	0	1	0	1	1	1	1	1	1	1	1	1	Rd				1	(0)	rotate		Rm			

```
d = UInt(Rd);  m = UInt(Rm);  rotation = UInt(rotate:'000');
if BadReg(d) || BadReg(m) then UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set from ARMv6 onwards.

Encoding T2 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

```
UXTB<c><q>  <Rd>, <Rm> {, <rotation>}
```

where:

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<Rd>` Specifies the destination register.

`<Rm>` Specifies the register that contains the second operand.

`<rotation>`

This can be any one of:

- `ROR #8`.
- `ROR #16`.
- `ROR #24`.
- Omitted.

Note

If your assembler accepts shifts by `#0` and treats them as equivalent to no shift or `LSL #0`, then it must accept `ROR #0` here. It is equivalent to omitting `<rotation>`.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    rotated = ROR(R[m], rotation);
    R[d] = ZeroExtend(rotated<7:0>, 32);
```

Exceptions

None.

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4.6.225 UXTB16

Unsigned Extend Byte 16 extracts two 8-bit values from a register, zero extends them to 16 bits each, and writes the results to the destination register. You can specify a rotation by 0, 8, 16, or 24 bits before extracting the 8-bit values.

Encodings

T1

```
UXTB16<c> <Rd>,<Rm>{,<rotation>}
```

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	1	1	0	1	0	0	0	1	1	1	1	1	1	1	1	1	1	Rd				1	(0)	rotate		Rm			

```
d = UInt(Rd);  m = UInt(Rm);  rotation = UInt(rotate:'000');
if BadReg(d) || BadReg(m) then UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

```
UXTB16<c><q>  <Rd>, <Rm> {, <rotation>}
```

where:

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<Rd>` Specifies the destination register.

`<Rm>` Specifies the register that contains the second operand.

`<rotation>`

This can be any one of:

- `ROR #8`.
- `ROR #16`.
- `ROR #24`.
- Omitted.

Note

If your assembler accepts shifts by `#0` and treats them as equivalent to no shift or `LSL #0`, then it must accept `ROR #0` here. It is equivalent to omitting `<rotation>`.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    rotated = ROR(R[m], rotation);
    R[d]<15:0>  = ZeroExtend(rotated<7:0>, 16);
    R[d]<31:16> = ZeroExtend(rotated<23:16>, 16);
```

Exceptions

None.

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4.6.226 UXTH

Unsigned Extend Halfword extracts a 16-bit value from a register, zero extends it to 32 bits, and writes the result to the destination register. You can specify a rotation by 0, 8, 16, or 24 bits before extracting the 16-bit value.

Encodings

T1 `UXTH<c> <Rd>,<Rm>`

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	0	1	1	0	0	1	0	1	0	Rm			Rd		

```
d = UInt(Rd);  m = UInt(Rm);  rotation = 0;
```

T2 `UXTH<c> <Rd>,<Rm>{,<rotation>}`

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	1	1	0	1	0	0	0	0	1	1	1	1	1	1	1	1	1	Rd				1	(0)	rotate		Rm			

```
d = UInt(Rd);  m = UInt(Rm);  rotation = UInt(rotate:'000');
if BadReg(d) || BadReg(m) then UNPREDICTABLE;
```

Architecture versions

Encoding T1 All versions of the Thumb instruction set from ARMv6 onwards.

Encoding T2 All versions of the Thumb instruction set from Thumb-2 onwards.

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Assembler syntax

```
UXTH<c><q>  <Rd>, <Rm> {, <rotation>}
```

where:

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<Rd>` Specifies the destination register.

`<Rm>` Specifies the register that contains the second operand.

`<rotation>`

This can be any one of:

- `ROR #8`.
- `ROR #16`.
- `ROR #24`.
- Omitted.

Note

If your assembler accepts shifts by `#0` and treats them as equivalent to no shift or `LSL #0`, then it must accept `ROR #0` here. It is equivalent to omitting `<rotation>`.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    rotated = ROR(R[m], rotation);
    R[d] = ZeroExtend(rotated<15:0>, 32);
```

Exceptions

None.

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4.6.227 WFE

Wait For Event is a hint instruction. If the Event Register is clear, it suspends execution in the lowest power state available consistent with a fast wakeup without the need for software restoration, until one of the following events occurs:

- an IRQ interrupt, unless masked by the CPSR I-bit
- an FIQ interrupt, unless masked by the CPSR F-bit
- an Imprecise Data abort, unless masked by the CPSR A-bit
- a Debug Entry request, if Debug is enabled
- an Event signaled by another processor using the `SEV` (Send Event) instruction
- Reset.

If the Event Register is set, Wait For Event clears it and returns immediately.

Encodings

T1 `WFE<c>`

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	0	1	1	1	1	1	1	0	0	1	0	0	0	0	0

```
// Do nothing
```

T2 `WFE<c>.W`

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	1	0	0	1	1	1	0	1	0	(1)	(1)	(1)	(1)	1	0	(0)	0	(0)	0	0	0	0	0	0	0	0	0	1	0

```
// Do nothing
```

Architecture versions

Encodings T1, T2 All versions of the Thumb instruction set from v6K onwards.

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Assembler syntax

`WFE<c><q>`

where:

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    if EventRegistered() then
        ClearEventRegister();
    else
        WaitForEvent();
```

Exceptions

None.

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4.6.228 WFI

Wait For Interrupt is a hint instruction. It suspends execution, in the lowest power state available consistent with a fast wakeup without the need for software restoration, until one of the following events occurs:

- an IRQ interrupt, regardless of the CPSR I-bit
- an FIQ interrupt, regardless of the CPSR F-bit
- an Imprecise Data abort, regardless of the CPSR A-bit
- a Debug Entry request, if Debug is enabled
- Reset.

Encodings

T1 `WFI<c>`

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	0	1	1	1	1	1	1	0	0	1	1	0	0	0	0

```
// Do nothing
```

T2 `WFI<c>.W`

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	1	0	0	1	1	1	0	1	0	(1)	(1)	(1)	(1)	1	0	(0)	0	(0)	0	0	0	0	0	0	0	0	0	1	1

```
// Do nothing
```

Architecture versions

Encodings T1, T2 All versions of the Thumb instruction set from v6K onwards.

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Assembler syntax

```
WFI<c><q>
```

where:

<c><q> See *Standard assembler syntax fields* on page 4-6.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    WaitForInterrupt();
```

Exceptions

None.

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4.6.229 YIELD

`YIELD` is a hint instruction. It allows software with a multithreading capability to indicate to the hardware that it is performing a task, for example a spinlock, that could be swapped out to improve overall system performance. Hardware can use this hint to suspend and resume multiple code threads if it supports the capability.

Encodings

T1 `YIELD<c>`

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	0	1	1	1	1	1	1	0	0	0	1	0	0	0	0

```
// Do nothing
```

T2 `YIELD<c>.W`

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	1	0	0	1	1	1	0	1	0	(1)	(1)	(1)	(1)	1	0	(0)	0	(0)	0	0	0	0	0	0	0	0	0	0	1

```
// Do nothing
```

Architecture versions

Encodings T1, T2 All versions of the Thumb instruction set from v6K onwards.

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Assembler syntax

```
YIELD<c><q>
```

where:

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    Hint_Yield();
```

Exceptions

None.

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Chapter 5
New ARM instructions

This chapter describes the new ARM® instructions introduced with Thumb®-2. It contains the following section:

- *Alphabetical list of new ARM instructions* on page 5-2.

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5.1 Alphabetical list of new ARM instructions

Every new ARM instruction introduced with Thumb-2 is listed in this chapter. See *Format of instruction descriptions* on page 4-2 for details of the format used.

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5.1.1 BFC

BFC (Bit Field Clear) clears any number of adjacent bits at any position in a register, without affecting the other bits in the register.

Encodings

A1 BFC<c> <Rd>,#<lsb>,#<width>

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

```
d = UInt(Rd);  msbit = UInt(msb);  lsbit = UInt(lsb);
if d == 15 then UNPREDICTABLE;
```

Architecture versions

Encoding A1 All versions of the ARM instruction set from ARMv6T2 onwards.

Assembler Syntax

BFC<c><q> <Rd>, #<lsb>, #<width>

where:

<c><q> See *Standard assembler syntax fields* on page 4-6.

<Rd> Specifies the destination register.

<lsb> Specifies the least significant bit that is to be cleared.

<width> Specifies the number of bits to be cleared.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    if msbit >= lsbit then
        R[d]<msbit:lsbit> = Replicate('0', msbit-lsbit+1);
        // Other bits of R[d] are unchanged
    else
        UNPREDICTABLE;
```

Exceptions

None.

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5.1.2 BFI

Bit Field Insert copies any number of low order bits from a register into the same number of adjacent bits at any position in the destination register.

Encodings

A1 `BFI<c> <Rd>,<Rn>,#<lsb>,#<width>`

31–28	27	26	25	24	23	22	21	20–16	15–12	11–7	6	5	4	3–0
cond	0	1	1	1	1	1	0	msb	Rd	lsb	0	0	1	Rm

```
d = UInt(Rd);  n = UInt(Rn);  msbit = UInt(msb);  lsbit = UInt(lsb);
if n == 15 then SEE BFC on page 5-3;
if d == 15 then UNPREDICTABLE;
```

Architecture versions

Encoding A1 All versions of the ARM instruction set from ARMv6T2 onwards.

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Assembler syntax

```
BFI<c><q>  <Rd>, <Rn>, #<lsb>, #<width>
```

where:

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<Rd>` Specifies the destination register.

`<Rn>` Specifies the source register.

`<lsb>` Specifies the least significant destination bit.

`<width>` Specifies the number of bits to be copied.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    if msbit >= lsbit then
        R[d]<msbit:lsbit> = R[n]<(msbit-lsbit):0>;
        // Other bits of R[d] are unchanged
    else
        UNPREDICTABLE;
```

Exceptions

None.

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5.1.3 CLREX

Clear Exclusive clears the local record of the executing processor that an address has had a request for an exclusive access.

Encodings

A1 `CLREX`

31	30	29	28	27	26	25	24	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	0	1	0	1	1	1	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(0)	(0)	(0)	(0)	0	0	0	1	(1)	(1)	(1)	(1)

```
// Do nothing
```

Architecture versions

Encoding A1 All versions of the ARM instruction set from v6K onwards.

Assembler syntax

```
CLREX<c><q>
```

where:

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

Encoding A1 only supports unconditional execution, so `<c>` must be omitted or `AL` if the instruction is to be assembled to ARM. The `<c>` qualifier is only useful when assembling to Thumb.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    ClearExclusiveMonitors();
```

Exceptions

None.

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5.1.4 DBG

Debug Hint provides a hint to debug and related systems. See their documentation for what use (if any) they make of this instruction.

Encodings

A1 `DBG<c> #<option>`

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

```
// Do nothing
```

Architecture versions

Encoding A1 All versions of the ARM instruction set from v7 onwards.

Assembler syntax

```
DBG<c><q>  #<option>
```

where:

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

Encoding A1 only supports unconditional execution, so `<c>` must be omitted or `AL` if the instruction is to be assembled to ARM. The `<c>` qualifier is only useful when assembling to Thumb.

`<option>` Provides extra information about the hint, and is in the range 0 to 15.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    Hint_Debug(option);
```

Exceptions

None.

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5.1.5 DMB

Data Memory Barrier acts as a memory barrier. It ensures that all explicit memory accesses that appear in program order before the DMB instruction are observed before any explicitly memory accesses that appear in program order after the DMB instruction. It does not affect the ordering of any other instructions executing on the processor.

Encodings

A1 DMB

31	30	29	28	27	26	25	24	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	0	1	0	1	1	1	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(0)	(0)	(0)	(0)	0	1	0	1	option			

```
// Do nothing
```

Architecture versions

Encoding A1 All versions of the ARM instruction set from v7 onwards.

Assembler syntax

```
DMB<c><q>  {<opt>}
```

where:

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

Encoding A1 only supports unconditional execution, so `<c>` must be omitted or `AL` if the instruction is to be assembled to ARM. The `<c>` qualifier is only useful when assembling to Thumb.

`<opt>` Specifies an optional limitation on the DMB operation. Allowed values are:

`SY` Full system DMB operation, encoded as option == '1111'. Can be omitted.

All other encodings of option are RESERVED. The corresponding instructions execute as full system DMB operations, but should not be relied upon by software.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    DataMemoryBarrier(option);
```

Exceptions

None.

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5.1.6 DSB

Data Synchronization Barrier acts as a special kind of memory barrier. No instruction in program order after this instruction can execute until this instruction completes. This instruction completes when:

- All explicit memory accesses before this instruction complete.
- All Cache, Branch predictor and TLB maintenance operations before this instruction complete.

Encodings

A1 `DSB`

31	30	29	28	27	26	25	24	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	0	1	0	1	1	1	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(0)	(0)	(0)	(0)	0	1	0	0	option			

```
// Do nothing
```

Architecture versions

Encoding A1 All versions of the ARM instruction set from ARMv6T2 onwards.

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Assembler syntax

```
DSB<c><q>  {<opt>}
```

where:

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

Encoding A1 only supports unconditional execution, so `<c>` must be omitted or `AL` if the instruction is to be assembled to ARM. The `<c>` qualifier is only useful when assembling to Thumb.

`<opt>` Specifies an optional limitation on the DSB operation. Allowed values are:

- `SY` Full system DSB operation, encoded as option == '1111'. Can be omitted.
- `UN` DSB operation only out to the point of unification, encoded as option == '0111'.
- `ST` DSB operation that waits only for stores to complete, encoded as option == '1110'.
- `UNST` DSB operation that waits only for stores to complete and only out to the point of unification, encoded as option == '0110'.

All other encodings of option are RESERVED. The corresponding instructions execute as full system DSB operations, but should not be relied upon by software.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    DataSynchronizationBarrier(option);
```

Exceptions

None.

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5.1.7 ISB

Instruction Synchronization Barrier flushes the pipeline in the processor, so that all instructions following the ISB are fetched from cache or memory, after the instruction has been completed. It ensures that the effects of context altering operations, such as changing the ASID, or completed TLB maintenance operations, or branch predictor maintenance operations, as well as all changes to the CP15 registers, executed before the ISB instruction are visible to the instructions fetched after the ISB.

In addition, the ISB instruction ensures that any branches that appear in program order after it are always written into the branch prediction logic with the context that is visible after the ISB instruction. This is required to ensure correct execution of the instruction stream.

Encodings

A1 ISB

31	30	29	28	27	26	25	24	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	0	1	0	1	1	1	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(0)	(0)	(0)	(0)	0	1	1	0	option			

```
// Do nothing
```

Architecture versions

Encoding A1 All versions of the ARM instruction set from ARMv6T2 onwards.

Assembler syntax

```
ISB<c><q>  {<opt>}
```

where:

<c><q> See *Standard assembler syntax fields* on page 4-6.

Encoding A1 only supports unconditional execution, so <c> must be omitted or AL if the instruction is to be assembled to ARM. The <c> qualifier is only useful when assembling to Thumb.

<opt> Specifies an optional limitation on the ISB operation. Allowed values are:

SY Full system ISB operation, encoded as option == '1111'. Can be omitted.

All other encodings of option are RESERVED. The corresponding instructions execute as full system ISB operations, but should not be relied upon by software.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    InstructionSynchronizationBarrier(option);
```

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Exceptions

None.

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5.1.8 LDREXB

Load Register Exclusive Byte derives an address from a base register value, loads a byte from memory, zero-extends it to form a 32-bit word, writes it to a register and:

- if the address has the Shared Memory attribute, marks the physical address as exclusive access for the executing processor in a shared monitor
- causes the executing processor to indicate an active exclusive access in the local monitor.

See *Memory accesses* on page 4-13 for information about memory accesses.

Encodings

A1 LDREXB<c> <Rt>, [<Rn>]

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

```
t = UInt(Rt);  n = UInt(Rn);
if t == 15 || n == 15 then UNPREDICTABLE;
```

Architecture versions

Encoding A1 All versions of the ARM instruction set from v6K onwards.

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Assembler syntax

```
LDREXB<c><q>  <Rt>, [<Rn>]
```

where:

`<c><q>`	See *Standard assembler syntax fields* on page 4-6.
`<Rt>`	Specifies the destination register.
`<Rn>`	Specifies the base register.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    address = R[n];
    SetExclusiveMonitors(address,1);
    R[t] = MemAA[address,1];
```

Exceptions

Data Abort.

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5.1.9 LDREXD

Load Register Exclusive Doubleword derives an address from a base register value, loads a 64-bit doubleword from memory, writes it to two registers and:

- if the address has the Shared Memory attribute, marks the physical address as exclusive access for the executing processor in a shared monitor
- causes the executing processor to indicate an active exclusive access in the local monitor.

See *Memory accesses* on page 4-13 for information about memory accesses.

Encodings

A1 `LDREXD<c> <Rt>,{<Rt2>,}[<Rn>]`

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

```
t = UInt(Rt);  t2 = t+1;  n = UInt(Rn);
if Rt<0> = '1' || Rt == '1110' || n == 15 then UNPREDICTABLE;
```

Architecture versions

Encoding A1 All versions of the ARM instruction set from v6K onwards.

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Assembler syntax

```
LDREXD<c><q>  <Rt>, {<Rt2>,} [<Rn>]
```

where:

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<Rt>` Specifies the first destination register.

`<Rt2>` Optionally specifies the second destination register.

`<Rn>` Specifies the base register.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    address = R[n];
    SetExclusiveMonitors(address,8);
    value = MemAA[address,8];
    // Extract words from 64-bit loaded value such that R[t] is
    // loaded from address and R[t2] from address+4.
    if BigEndian() then
        R[t]  = value<63:32>;  // = contents of word at address
        R[t2] = value<31:0>;   // = contents of word at address+4
    else
        R[t]  = value<31:0>;   // = contents of word at address
        R[t2] = value<63:32>;  // = contents of word at address+4
```

Exceptions

Data Abort.

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5.1.10 LDREXH

Load Register Exclusive Halfword derives an address from a base register value, loads a halfword from memory, zero-extends it to form a 32-bit word, writes it to a register and:

- if the address has the Shared Memory attribute, marks the physical address as exclusive access for the executing processor in a shared monitor
- causes the executing processor to indicate an active exclusive access in the local monitor.

See *Memory accesses* on page 4-13 for information about memory accesses.

Encodings

A1 LDREXH<c> <Rt>, [<Rn>]

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

```
t = UInt(Rt);  n = UInt(Rn);
if t == 15 || n == 15 then UNPREDICTABLE;
```

Architecture versions

Encoding A1 All versions of the ARM instruction set from v6K onwards.

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Assembler syntax

```
LDREXH<c><q>  <Rt>, [<Rn>]
```

where:

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<Rt>` Specifies the destination register.

`<Rn>` Specifies the base register.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    address = R[n];
    SetExclusiveMonitors(address,2);
    R[t] = MemAA[address,2];
```

Exceptions

Data Abort.

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5.1.11 LDRHT

Load Register Halfword Unprivileged calculates an address from a base register value and an immediate offset, loads a halfword from memory, zero-extends it to form a 32-bit word, and writes it to a register. See *Memory accesses* on page 4-13 for information about memory accesses.

The memory access is restricted as if the processor were running in User mode. (This makes no difference if the processor is actually running in User mode.)

Encodings

A1 LDRHT<c> <Rt>, [<Rn>] {, #+/-<offset_8>}

31 30 29 28	27	26	25	24	23	22	21	20	19 18 17 16	15 14 13 12	11 10 9 8	7	6	5	4	3 2 1 0
cond	0	0	0	0	U	1	1	1	Rn	Rt	imm4H	1	0	1	1	imm4L

```
t == UInt(Rt);  n = UInt(Rn);  postindex = TRUE;  add = (U == '1');
offset = ZeroExtend(imm4H:imm4L, 32);
if t == 15 || n == 15 || n == t then UNPREDICTABLE;
```

A2 LDRHT<c> <Rt>, [<Rn>], #+/-<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
cond	0	0	0	0	U	0	1	1	Rn	Rt	(0)	(0)	(0)	(0)	1	0	1	1	Rm

```
t = UInt(Rt);  n = UInt(Rn);  m = UInt(Rm);
postindex = TRUE;  add = (U == '1');
offset = R[m];
if t == 15 || n == 15 || n == t || m == 15 then UNPREDICTABLE;
```

Architecture versions

Encodings A1, A2 All versions of the ARM instruction set from ARMv6T2 onwards.

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Assembler syntax

```
LDRHT<c><q>  <Rt>, [<Rn>] {, #<imm>}
LDRHT<c><q>  <Rt>, [<Rn>], +/-<Rm>
```

where:

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<Rt>` Specifies the destination register.

`<Rn>` Specifies the base register.

`<imm>` Specifies the immediate offset added to the value of `<Rn>` to form the address. `<imm>` can be omitted, meaning an offset of 0.

`<Rm>` Specifies the register containing the offset.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    offset_addr = if add then (R[n] + offset) else (R[n] - offset);
    address = if postindex then R[n] else offset_addr;
    if postindex then R[n] = offset_addr;
    R[t] = ZeroExtend(MemU_unpriv[address,2], 32);
```

Exceptions

Data Abort.

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5.1.12 LDRSBT

Load Register Signed Byte Unprivileged calculates an address from a base register value and an immediate offset, loads a byte from memory, sign-extends it to form a 32-bit word, and writes it to a register. See *Memory accesses* on page 4-13 for information about memory accesses.

The memory access is restricted as if the processor were running in User mode. (This makes no difference if the processor is actually running in User mode.)

Encodings

A1 `LDRSBT<c> <Rt>, [<Rn>] {, #+/-<offset_8>}`

31 30 29 28	27 26 25 24	23	22	21	20	19 18 17 16	15 14 13 12	11 10 9 8	7 6 5 4	3 2 1 0
cond	0 0 0 0	U	1	1	1	Rn	Rt	imm4H	1 1 0 1	imm4L

```
t == UInt(Rt);  n = UInt(Rn);  postindex = TRUE;  add = (U == '1');
offset = ZeroExtend(imm4H:imm4L, 32);
if t == 15 || n == 15 || n == t then UNPREDICTABLE;
```

A2 `LDRSBT<c> <Rt>, [<Rn>], #+/-<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
cond	0 0 0 0	U	0	1	1	Rn	Rt	(0) (0) (0) (0)	1 1 0 1	Rm

```
t = UInt(Rt);  n = UInt(Rn);  m = UInt(Rm);
postindex = TRUE;  add = (U == '1');
offset = R[m];
if t == 15 || n == 15 || n == t || m == 15 then UNPREDICTABLE;
```

Architecture versions

Encodings A1, A2 All versions of the ARM instruction set from ARMv6T2 onwards.

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Assembler syntax

```
LDRSBT<c><q>  <Rt>, [<Rn>] {, #<imm>}
LDRSBT<c><q>  <Rt>, [<Rn>], +/-<Rm>
```

where:

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<Rt>` Specifies the destination register.

`<Rn>` Specifies the base register.

`<imm>` Specifies the immediate offset added to the value of `<Rn>` to form the address. `<imm>` can be omitted, meaning an offset of 0.

`<Rm>` Specifies the register containing the offset.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    offset_addr = if add then (R[n] + offset) else (R[n] - offset);
    address = if postindex then R[n] else offset_addr;
    if postindex then R[n] = offset_addr;
    R[t] = SignExtend(MemU_unpriv[address,1], 32);
```

Exceptions

Data Abort.

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5.1.13 LDRSHT

Load Register Signed Halfword Unprivileged calculates an address from a base register value and an immediate offset, loads a halfword from memory, sign-extends it to form a 32-bit word, and writes it to a register. See *Memory accesses* on page 4-13 for information about memory accesses.

The memory access is restricted as if the processor were running in User mode. (This makes no difference if the processor is actually running in User mode.)

Encodings

A1 `LDRHT<c> <Rt>, [<Rn>] {, #+/-<offset_8>}`

31–28	27	26	25	24	23	22	21	20	19–16	15–12	11–8	7	6	5	4	3–0
cond	0	0	0	0	U	1	1	1	Rn	Rt	imm4H	1	1	1	1	imm4L

```
t == UInt(Rt);  n = UInt(Rn);  postindex = TRUE;  add = (U == '1');
offset = ZeroExtend(imm4H:imm4L, 32);
if t == 15 || n == 15 || n == t then UNPREDICTABLE;
```

A2 `LDRHT<c> <Rt>, [<Rn>], #+/-<Rm>`

31–28	27	26	25	24	23	22	21	20	19–16	15–12	11	10	9	8	7	6	5	4	3–0
cond	0	0	0	0	U	0	1	1	Rn	Rt	(0)	(0)	(0)	(0)	1	1	1	1	Rm

```
t = UInt(Rt);  n = UInt(Rn);  m = UInt(Rm);
postindex = TRUE;  add = (U == '1');
offset = R[m];
if t == 15 || n == 15 || n == t || m == 15 then UNPREDICTABLE;
```

Architecture versions

Encodings A1, A2 All versions of the ARM instruction set from ARMv6T2 onwards.

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Assembler syntax

```
LDRSHT<c><q>  <Rt>, [<Rn>] {, #<imm>}
LDRSHT<c><q>  <Rt>, [<Rn>], +/-<Rm>
```

where:

`<c><q>`	See *Standard assembler syntax fields* on page 4-6.
`<Rt>`	Specifies the destination register.
`<Rn>`	Specifies the base register.
`<imm>`	Specifies the immediate offset added to the value of `<Rn>` to form the address. `<imm>` can be omitted, meaning an offset of 0.
`<Rm>`	Specifies the register containing the offset.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    offset_addr = if add then (R[n] + offset) else (R[n] - offset);
    address = if postindex then R[n] else offset_addr;
    if postindex then R[n] = offset_addr;
    R[t] = SignExtend(MemU_unpriv[address,2], 32);
```

Exceptions

Data Abort.

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5.1.14 MLS

Multiply and Subtract multiplies two register values, and subtracts the least significant 32 bits of the result from a third register value. These 32 bits do not depend on whether signed or unsigned calculations are performed. The result is written to the destination register.

Encodings

A1 MLS<c> <Rd>,<Rn>,<Rm>,<Ra>

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

```
d = UInt(Rd);  n = UInt(Rn);  m = UInt(Rm);  a = UInt(Ra);
if d == 15 || n == 15 || m == 15 || a == 15 then UNPREDICTABLE;
```

Architecture versions

Encoding A1 All versions of the ARM instruction set from ARMv6T2 onwards.

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Assembler syntax

```
MLS<c><q>  <Rd>, <Rn>, <Rm>, <Ra>
```

where:

<c><q> See *Standard assembler syntax fields* on page 4-6.

<Rd> Specifies the destination register.

<Rn> Specifies the register that contains the first operand.

<Rm> Specifies the register that contains the second operand.

<Ra> Specifies the register containing the accumulate value.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    operand1 = SInt(R[n]);  // or UInt(R[n]) without functionality change
    operand2 = SInt(R[m]);  // or UInt(R[m]) without functionality change
    addend   = SInt(R[a]);  // or UInt(R[a]) without functionality change
    result = addend - operand1 * operand2;
    R[d] = result<31:0>;
```

Exceptions

None.

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5.1.15 MOV (immediate), new MOVW variant

This new variant of `MOV` (immediate) writes a 16-bit immediate value to the destination register.

Encodings

Encoding A1 is the existing ARM `MOV` (immediate) encoding.

A2 `MOVW<c> <Rd>,#<imm16>`

31 30 29 28	27 26 25 24	23 22 21 20	19 18 17 16	15 14 13 12	11 10 9 8 7 6 5 4 3 2 1 0
cond	0 0 1 1	0 0 0 0	imm4	Rd	imm12

```
d = UInt(Rd);  setflags = FALSE;
(imm32, carry) = (ZeroExtend(imm4:imm12, 32), APSR.C);
    // carry is a "don't care" value
if d == 15 then UNPREDICTABLE;
```

Architecture versions

Encoding A1 All versions of the ARM instruction set from ARMv6T2 onwards.

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Assembler syntax

`MOV{S}<c><q>  <Rd>, #<const>`	All encodings permitted
`MOVW<c><q>  <Rd>, #<const>`	Only encoding A2 permitted

where:

`S` If present, specifies that the instruction updates the flags. Otherwise, the instruction does not update the flags.

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<Rd>` Specifies the destination register.

`<const>` Specifies the immediate value to be placed in `<Rd>`. The range of allowed values is 0-65535 for encoding A2 and as described in the ARM Architecture Reference Manual for encoding A1. When both encodings are available for an instruction, encoding A1 is preferred to encoding A2 (if encoding A2 is required, use the `MOVW` syntax).

The pre-UAL syntax `MOV<c>S` is equivalent to `MOVS<c>`.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    result = imm32;
    R[d] = result;
    if setflags then
        APSR.N = result<31>;
        APSR.Z = IsZeroBit(result);
        APSR.C = carry;
        // APSR.V unchanged
```

Exceptions

None.

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5.1.16 MOVT

Move Top writes an immediate value to the top halfword of the destination register. It does not affect the contents of the bottom halfword.

Encodings

A1 MOVT<c> <Rd>,#<imm16>

31 30 29 28	27	26	25	24	23	22	21	20	19 18 17 16	15 14 13 12	11 10 9 8 7 6 5 4 3 2 1 0
cond	0	0	1	1	0	1	0	0	imm4	Rd	imm12

```
d = UInt(Rd);  imm16 = imm4:imm12;
if d == 15 then UNPREDICTABLE;
```

Architecture versions

Encoding A1 All versions of the ARM instruction set from ARMv6T2 onwards.

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Assembler syntax

```
MOVT<c><q>  <Rd>, #<imm16>
```

where:

`<c><q>`	See *Standard assembler syntax fields* on page 4-6.
`<Rd>`	Specifies the destination register.
`<imm16>`	Specifies the immediate value to be written to `<Rd>`. It must be in the range 0-65535.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    R[d]<31:16> = imm16;
    // R[d]<15:0> unchanged
```

Exceptions

None.

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5.1.17 NOP

No Operation does nothing.

Encodings

A1 `NOP<c>`

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

```
// Do nothing
```

Architecture versions

Encoding A1 All versions of the ARM instruction set from ARMv6T2 onwards.

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Assembler syntax

```
NOP<c><q>
```

where:

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    // Do nothing
```

Exceptions

None.

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5.1.18 PLI (immediate)

Preload Instruction signals the memory system that instruction memory accesses from a specified address are likely 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 pre-loading the cache line containing the specified address into the instruction cache.

Encodings

A1 `PLI [<Rn>,#+/-<imm12>]`

31	30	29	28	27	26	25	24	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	0	0	U	1	0	1	Rn				1	1	1	1	imm12											

```
n = UInt(Rn);  imm32 = ZeroExtend(imm12, 32);  add = (U == '1');
```

Architecture versions

Encoding A1 All versions of the ARM instruction set from v7 onwards.

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Assembler syntax

```
PLI<c><q>  [<Rn>, #+/-<imm12>]
```

where:

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

Encoding A1 only supports unconditional execution, so `<c>` must be omitted or `AL` if the instruction is to be assembled to ARM. The `<c>` qualifier is only useful when assembling to Thumb.

`<Rn>` Is the base register.

`<imm12>` Specifies the offset from the base register.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    base = if n == 15 then Align(PC,4) else R[n];
    address = if add then (base + imm32) else (base - imm32);
    Hint_PreloadInstr(address);
```

Exceptions

None.

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5.1.19 PLI (register)

Preload Instruction signals the memory system that instruction memory accesses from a specified address are likely 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 pre-loading the cache line containing the specified address into the instruction cache.

Encodings

A1 `PLI [<Rn>,<Rm>{, <shift>}]`

31 30 29 28	27 26 25 24	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	U	1 0 1	Rn	1 1 1 1	imm5	type	0	Rm

```
n = UInt(Rn);  m = UInt(Rm);  add = (U == '1');
(shift_t, shift_n) = DecodeImmShift(type, imm5);
if m == 15 then UNPREDICTABLE;
```

Architecture versions

Encoding A1 All versions of the ARM instruction set from v7 onwards.

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Assembler syntax

```
PLI<c><q>  [<Rn>, <Rm> {, <shift>}]
```

where:

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

Encoding A1 only supports unconditional execution, so `<c>` must be omitted or `AL` if the instruction is to be assembled to ARM. The `<c>` qualifier is only useful when assembling to Thumb.

`<Rn>` Is the base register.

`<Rm>` Is the optionally shifted offset register.

`<shift>` Specifies the shift to apply to the value read from `<Rm>`. See *Constant shifts applied to a register* on page 4-10 for details.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    offset = Shift(R[m], shift_t, shift_n, APSR.C);
    address = if add then (R[n] + offset) else (R[n] - offset);
    Hint_PreloadInstr(address);
```

Exceptions

None.

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5.1.20 RBIT

Reverse Bits reverses the bit order in a 32-bit register.

Encodings

A1 `RBIT<c> <Rd>,<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
cond	0	1	1	0	1	1	1	1	(1) (1) (1) (1)	Rd	(1) (1) (1) (1)	0	0	1	1	Rm

```
d = UInt(Rd);  m = UInt(Rm);
if d == 15 || m == 15 then UNPREDICTABLE;
```

Architecture versions

Encoding A1 All versions of the ARM instruction set from ARMv6T2 onwards.

Assembler syntax

```
RBIT<c><q>  <Rd>, <Rm>
```

where:

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<Rd>` Specifies the destination register.

`<Rm>` Specifies the register that contains the operand.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    bits(32) result;
    for i = 0 to 31 do
        result<31-i> = R[m]<i>;
    R[d] = result;
```

Exceptions

None.

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5.1.21 SBFX

Signed Bit Field Extract extracts any number of adjacent bits at any position from one register, sign extends them to 32 bits, and writes the result to the destination register.

Encodings

A1 `SBFX<c> <Rd>,<Rn>,#<lsb>,#<width>`

31–28	27	26	25	24	23	22	21	20–16	15–12	11–7	6	5	4	3–0
cond	0	1	1	1	1	0	1	widthm1	Rd	lsb	1	0	1	Rn

```
d = UInt(Rd);  n = UInt(Rn);
lsbit = UInt(imm3:imm2);  widthminus1 = UInt(widthm1);
if d == 15 || n == 15 then UNPREDICTABLE;
```

Architecture versions

Encoding A1 All versions of the ARM instruction set from ARMv6T2 onwards.

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Assembler syntax

```
SBFX<c><q>  <Rd>, <Rn>, #<lsb>, #<width>
```

where:

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<Rd>` Specifies the destination register.

`<Rn>` Specifies the register that contains the first operand.

`<lsb>` is the bit number of the least significant bit in the bitfield (in the range 0-31).

`<width>` is the width of the bitfield (in the range 1-32).

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    msbit = lsbit + widthminus1;
    if msbit <= 31 then
        R[d] = SignExtend(R[n]<msbit:lsbit>, 32);
    else
        UNPREDICTABLE;
```

Exceptions

None.

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5.1.22 SEV

Send Event is a hint instruction. It causes an event to be signaled to all CPUs within the multiprocessor system.

Encodings

A1 `SEV<c>`

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

```
// Do nothing
```

Architecture versions

Encoding A1 All versions of the ARM instruction set from v6K onwards.

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Assembler syntax

```
SEV<c><q>
```

where:

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    Hint_SendEvent();
```

Exceptions

None.

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5.1.23 SMC (formerly SMI)

Secure Monitor Call causes a Secure Monitor exception.

Encodings

A1 `SMC<c> <imm4>`

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
cond				0	0	0	1	0	1	1	0	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	0	1	1	1	imm4			

```
imm32 = ZeroExtend(imm4, 32);
// imm32 is for assembly/disassembly only and is ignored by hardware
if InITBlock() && !LastInITBlock() then UNPREDICTABLE;
```

Architecture versions

Encoding A1 All versions of the ARM instruction set from v6 onwards, if Security Extensions are implemented.

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Assembler syntax

```
SMC<c><q>  <imm4>
```

where:

<c><q> See *Standard assembler syntax fields* on page 4-6.

<imm4> Is a 4-bit immediate value. This is ignored by the ARM processor. It can be used by the SMI exception handler (secure monitor code) to determine what service is being requested, but this is not recommended.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    CallSecureMonitor();
```

Exceptions

None.

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5.1.24 STREXB

Store Register Exclusive Byte derives an address from a base register value, and stores a byte from a register to memory if the executing processor has exclusive access to the memory addressed.

See *Memory accesses* on page 4-13 for information about memory accesses.

Encoding

A1 `STREXB<c> <Rd>,<Rt>,[<Rn>]`

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

```
d = UInt(Rd);  t = UInt(Rt);  n = UInt(Rn);
if d == 15 || t == 15 || n == 15 then UNPREDICTABLE;
if d == n || d == t then UNPREDICTABLE;
```

Architecture versions

Encoding A1 All versions of the ARM instruction set from v6K onwards.

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Assembler syntax

```
STREXB<c><q>  <Rd>, <Rt>, [<Rn>]
```

where:

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<Rd>` Specifies the destination register for the returned status value. The value returned is:

- `0` if the operation updates memory
- `1` if the operation fails to update memory.

`<Rt>` Specifies the source register.

`<Rn>` Specifies the base register.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    address = R[n];
    if ExclusiveMonitorsPass(address,1) then
        MemAA[address,1] = R[t];
        R[d] = 0;
    else
        R[d] = 1;
```

Exceptions

Data Abort.

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5.1.25 STREXD

Store Register Exclusive Doubleword derives an address from a base register value, and stores a 64-bit doubleword from two registers to memory if the executing processor has exclusive access to the memory addressed.

See *Memory accesses* on page 4-13 for information about memory accesses.

Encoding

A1 `STREXD<c> <Rd>,<Rt>,<Rt2>,[<Rn>]`

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

```
d = UInt(Rd);  t = UInt(Rt);  t2 = t+1;  n = UInt(Rn);
if d == 15 || Rt<0> = '1' || Rt == '1110' || n == 15 then UNPREDICTABLE;
if d == n || d == t || d == t2 then UNPREDICTABLE;
```

Architecture versions

Encoding A1 All versions of the ARM instruction set from v6K onwards.

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Assembler syntax

```
STREXD<c><q>  <Rd>, <Rt>, <Rt2>, [<Rn>]
```

where:

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<Rd>` Specifies the destination register for the returned status value. The value returned is:

- `0` if the operation updates memory
- `1` if the operation fails to update memory.

`<Rt>` Specifies the first source register. Rt must be an even-numbered register, and not R14.

`<Rt2>` Specifies the second source register. Rt2 must be R(t+1).

`<Rn>` Specifies the base register.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    address = R[n];
    // Create 64-bit value to store such that R[t] will be
    // stored at address and R[t2] at address+4.
    value = if BigEndian() then R[t]:R[t2] else R[t2]:R[t];
    if ExclusiveMonitorsPass(address,8) then
        MemAA[address,8] = value;
        R[d] = 0;
    else
        R[d] = 1;
```

Exceptions

Data Abort.

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5.1.26 STREXH

Store Register Exclusive Halfword derives an address from a base register value, and stores a halfword from a register to memory if the executing processor has exclusive access to the memory addressed.

See *Memory accesses* on page 4-13 for information about memory accesses.

Encoding

A1 `STREXH<c> <Rd>,<Rt>,[<Rn>]`

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

```
d = UInt(Rd);  t = UInt(Rt);  n = UInt(Rn);
if d == 15 || t == 15 || n == 15 then UNPREDICTABLE;
if d == n || d == t then UNPREDICTABLE;
```

Architecture versions

Encoding A1 All versions of the ARM instruction set from v6K onwards.

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Assembler syntax

```
STREXH<c><q>  <Rd>, <Rt>, [<Rn>]
```

where:

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<Rd>` Specifies the destination register for the returned status value. The value returned is:

- `0` if the operation updates memory
- `1` if the operation fails to update memory.

`<Rt>` Specifies the source register.

`<Rn>` Specifies the base register.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    address = R[n];
    if ExclusiveMonitorsPass(address,2) then
        MemAA[address,2] = R[t];
        R[d] = 0;
    else
        R[d] = 1;
```

Exceptions

Data Abort.

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5.1.27 STRHT

Store Register Halfword Unprivileged calculates an address from a base register value and an immediate offset, and stores a halfword from a register to memory. See *Memory accesses* on page 4-13 for information about memory accesses.

The memory access is restricted as if the processor were running in User mode. (This makes no difference if the processor is actually running in User mode.)

Encoding

A1 `STRHT<c> <Rt>,[<Rn>],#+/-<imm8>`

31 30 29 28	27	26	25	24	23	22	21	20	19 18 17 16	15 14 13 12	11 10 9 8	7	6	5	4	3 2 1 0
cond	0	0	0	0	U	1	1	0	Rn	Rt	imm4H:	1	0	1	1	imm4L

```
t == UInt(Rt);  n = UInt(Rn);  postindex = TRUE;  add = (U == '1');
offset = ZeroExtend(imm4H:imm4L, 32);
if t == 15 || n == 15 || n == t then UNPREDICTABLE;
```

A2 `STRHT<c> <Rt>,[<Rn>],+/-<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
cond	0	0	0	0	U	0	1	0	Rn	Rt	(0)	(0)	(0)	(0)	1	0	1	1	Rm

```
t = UInt(Rt);  n = UInt(Rn);  m = UInt(Rm);
postindex = TRUE;  add = (U == '1');
offset = R[m];
if t == 15 || n == 15 || n == t || m == 15 then UNPREDICTABLE;
```

Architecture versions

Encodings A1, A2 All versions of the ARM instruction set from ARMv6T2 onwards.

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Assembler syntax

```
STRHT<c><q>  <Rt>, [<Rn>] {, #+/-<imm>}
STRHT<c><q>  <Rt>, [<Rn>], +/-<Rm>
```

where:

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<Rt>` Specifies the source register.

`<Rn>` Specifies the base register.

`<imm>` Specifies the immediate offset that is applied to the value of `<Rn>` to form the address. `<imm>` can be omitted, meaning an offset of 0.

`<Rm>` Contains the offset that is applied to the value of `<Rn>` to form the address.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    offset_addr = if add then (R[n] + offset) else (R[n] - offset);
    address = if postindex then R[n] else offset_addr;
    if postindex then R[n] = offset_addr;
    MemU_unpriv[address,2] = R[t]<15:0>;
```

Exceptions

Data Abort.

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5.1.28 UBFX

Unsigned Bit Field Extract extracts any number of adjacent bits at any position from one register, zero extends them to 32 bits, and writes the result to the destination register.

Encodings

A1 `UBFX<c> <Rd>,<Rn>,#<lsb>,#<width>`

31–28	27	26	25	24	23	22	21	20–16	15–12	11–7	6	5	4	3–0
cond	0	1	1	1	1	1	1	widthm1	Rd	lsb	1	0	1	Rn

```
d = UInt(Rd);  n = UInt(Rn);
lsbit = UInt(imm3:imm2);  widthminus1 = UInt(widthm1);
if d == 15 || n == 15 then UNPREDICTABLE;
```

Architecture versions

Encoding A1 All versions of the ARM instruction set from ARMv6T2 onwards.

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Assembler syntax

```
UBFX<c><q>  <Rd>, <Rn>, #<lsb>, #<width>
```

where:

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

`<Rd>` Specifies the destination register.

`<Rn>` Specifies the register that contains the first operand.

`<lsb>` is the bit number of the least significant bit in the bitfield (in the range 0-31).

`<width>` is the width of the bitfield (in the range 1-32).

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    msbit = lsbit + widthminus1;
    if msbit <= 31 then
        R[d] = ZeroExtend(R[n]<msbit:lsbit>, 32);
    else
        UNPREDICTABLE;
```

Exceptions

None.

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5.1.29 WFE

Wait For Event is a hint instruction. If the Event Register is clear, it suspends execution in the lowest power state available consistent with a fast wakeup without the need for software restoration, until one of the following events occurs:

- an IRQ interrupt, unless masked by the CPSR I-bit
- an FIQ interrupt, unless masked by the CPSR F-bit
- an Imprecise Data abort, unless masked by the CPSR A-bit
- a Debug Entry request, if Debug is enabled
- an Event signaled by another processor using the `SEV` (Send Event) instruction
- Reset.

If the Event Register is set, Wait For Event clears it and returns immediately.

Encodings

A1 `WFE<c>`

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

```
// Do nothing
```

Architecture versions

Encoding A1 All versions of the ARM instruction set from v6K onwards.

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Assembler syntax

```
WFE<c><q>
```

where:

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    if EventRegistered() then
        ClearEventRegister();
    else
        WaitForEvent();
```

Exceptions

None.

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5.1.30 WFI

Wait For Interrupt is a hint instruction. It suspends execution, in the lowest power state available consistent with a fast wakeup without the need for software restoration, until one of the following events occurs:

- an IRQ interrupt, regardless of the CPSR I-bit
- an FIQ interrupt, regardless of the CPSR F-bit
- an Imprecise Data abort, regardless of the CPSR A-bit
- a Debug Entry request, if Debug is enabled
- Reset.

Encodings

A1 `WFI<c>`

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

```
// Do nothing
```

Architecture versions

Encoding A1 All versions of the ARM instruction set from v6K onwards.

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Assembler syntax

```
WFI<c><q>
```

where:

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    WaitForInterrupt();
```

Exceptions

None.

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5.1.31 YIELD

`YIELD` is a hint instruction. It allows software with a multithreading capability to indicate to the hardware that it is performing a task, for example a spinlock, that could be swapped out to improve overall system performance. Hardware can use this hint to suspend and resume multiple code threads if it supports the capability.

Encodings

A1 `YIELD<c>`

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

```
// Do nothing
```

Architecture versions

Encoding A1 All versions of the ARM instruction set from v6K onwards.

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Assembler syntax

```
YIELD<c><q>
```

where:

`<c><q>` See *Standard assembler syntax fields* on page 4-6.

Operation

```
if ConditionPassed() then
    EncodingSpecificOperations();
    Hint_Yield();
```

Exceptions

None.

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Appendix A
Pseudo-code definition

This appendix provides a formal definition of the pseudo-code used in this book, and lists the *helper* procedures and functions used by pseudo-code to perform useful architecture-specific jobs. It contains the following sections:

- *Instruction encoding diagrams and pseudo-code* on page A-2
- *Data Types* on page A-4
- *Expressions* on page A-8
- *Operators and built-in functions* on page A-10
- *Statements and program structure* on page A-18
- *Helper procedures and functions* on page A-22.

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A.1 Instruction encoding diagrams and pseudo-code

Instruction descriptions in this book contain:

- An Encoding section, containing one or more encoding diagrams, each followed by some encoding-specific pseudo-code that translates the fields of the encoding into inputs for the common pseudo-code of the instruction, and picks out any encoding-specific special cases.
- An Operation section, containing common pseudo-code that applies to all of the encodings being described. The Operation section pseudo-code contains a call to the `EncodingSpecificOperations()` function, either at its start or after only a condition check performed by `if ConditionPassed() then`.

An encoding diagram specifies each bit of the instruction as one of the following:

- An obligatory 0 or 1, represented in the diagram as 0 or 1. If this bit does not have this value, the encoding corresponds to a different instruction.
- A *should be* 0 or 1, represented in the diagram as (0) or (1). If this bit does not have this value, the instruction is UNPREDICTABLE.
- A named single bit or a bit within a named multi-bit field. The `cond` field in bits[31:28] of many ARM instructions has some special rules associated with it.

An encoding diagram matches an instruction if all obligatory bits are identical in the encoding diagram and the instruction, and one of the following is true:

- the encoding diagram is not for an ARM instruction
- the encoding diagram is for an ARM instruction that does not have a `cond` field in bits[31:28]
- the encoding diagram is for an ARM instruction that has a `cond` field in bits[31:28], and bits[31:28] of the instruction are not 0b1111.

The execution model for an instruction is:

1. Find all encoding diagrams that match the instruction. It is possible that no encoding diagrams match. In that case, abandon this execution model and consult the relevant instruction set chapter instead to find out how the instruction is to be treated. (The bit pattern of such an instruction is usually reserved and UNDEFINED, though there are some other possibilities. For example, unallocated hint instructions are documented as being reserved and to be executed as NOPs.)
2. If the common pseudo-code for the matching encoding diagrams starts with a condition check, perform that condition check. If the condition check fails, abandon this execution model and treat the instruction as a NOP. (If there are multiple matching encoding diagrams, either all or none of their corresponding pieces of common pseudo-code start with a condition check.)

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3. Perform the encoding-specific pseudo-code for each of the matching encoding diagrams independently and in parallel. Each such piece of encoding-specific pseudo-code starts with a bitstring variable for each named bit or multi-bit field within its corresponding encoding diagram, named the same as the bit or multi-bit field and initialized with the values of the corresponding bit(s) from the bit pattern of the instruction.

   If there are multiple matching encoding diagrams, all but one of the corresponding pieces of pseudo-code must contain a special case that indicates that it does not apply. Discard the results of all such pieces of pseudo-code and their corresponding encoding diagrams.

   There is now one remaining piece of pseudo-code and its corresponding encoding diagram left to consider. This pseudo-code might also contain a special case (most commonly one indicating that it is UNPREDICTABLE). If so, abandon this execution model and treat the instruction according to the special case.

4. Check the *should be* bits of the encoding diagram against the corresponding bits of the bit pattern of the instruction. If any of them do not match, abandon this execution model and treat the instruction as UNPREDICTABLE.

5. Perform the rest of the common pseudo-code for the instruction description that contains the encoding diagram. That pseudo-code starts with all variables set to the values they were left with by the encoding-specific pseudo-code.

The `ConditionPassed()` call in the common pseudo-code (if present) performs step 2, and the `EncodingSpecificOperations()` call performs steps 3 and 4.

A.1.1 Pseudo-code

The pseudo-code provides precise descriptions of what instructions do. Instruction fields are referred to by the names shown in the encoding diagram for the instruction.

The pseudo-code is described in detail in the following sections.

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A.2 Data Types

This section describes:

- *General data type rules*
- *Bitstrings*
- *Integers* on page A-5
- *Reals* on page A-5
- *Booleans* on page A-5
- *Enumerations* on page A-5
- *Lists* on page A-6
- *Arrays* on page A-7.

A.2.1 General data type rules

ARM Architecture pseudo-code is a strongly-typed language. Every constant and variable is of one of the following types:

- bitstring
- integer
- boolean
- real
- enumeration
- list
- array.

The type of a constant is determined by its syntax. The type of a variable is normally determined by assignment to the variable, with the variable being implicitly declared to be of the same type as whatever is assigned to it. For example, the assignments `x = 1`, `y = '1'`, and `z = TRUE` implicitly declare the variables `x`, `y` and `z` to have types integer, length-1 bitstring and boolean respectively.

Variables can also have their types declared explicitly by preceding the variable name with the name of the type. This is most often done in function definitions for the arguments and the result of the function.

These data types are described in more detail in the following sections.

A.2.2 Bitstrings

A bitstring is a finite-length string of 0s and 1s. Each length of bitstring is a different type. The minimum allowed length of a bitstring is 1.

The type name for bitstrings of length `N` is `bits(N)`. A synonym of `bits(1)` is `bit`.

Bitstring constants are written as a single quotation mark, followed by the string of 0s and 1s, followed by another single quotation mark. For example, the two constants of type `bit` are `'0'` and `'1'`.

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Every bitstring value has a left-to-right order, with the bits being numbered in standard *little-endian* order. That is, the leftmost bit of a bitstring of length N is bit N-1 and its rightmost bit is bit 0. This order is used as the most-significant-to-least-significant bit order in conversions to and from integers. For bitstring constants and bitstrings derived from encoding diagrams, this order matches the way they are printed.

Bitstrings are the only concrete data type in pseudo-code, in the sense that they correspond directly to the contents of registers, memory locations, instructions, and so on. All of the remaining data types are abstract.

A.2.3 Integers

Pseudo-code integers are unbounded in size and can be either positive or negative. That is, they are mathematical integers rather than what computer languages and architectures commonly call integers. Computer integers are represented in pseudo-code as bitstrings of the appropriate length, associated with suitable functions to interpret those bitstrings as integers.

The type name for integers is `integer`.

Integer constants are normally written in decimal, such as `0`, `15`, `-1234`. They can also be written in C-style hexadecimal, such as `0x55` or `0x80000000`. Hexadecimal integer constants are treated as positive unless they have a preceding minus sign. For example, `0x80000000` is the integer $+2^{31}$. If -2^{31} needs to be written in hexadecimal, it should be written as `-0x80000000`.

A.2.4 Reals

Pseudo-code reals are unbounded in size and precision. That is, they are mathematical real numbers, not computer floating-point numbers. Computer floating-point numbers are represented in pseudo-code as bitstrings of the appropriate length, associated with suitable functions to interpret those bitstrings as reals.

The type name for reals is `real`.

Real constants are written in decimal with a decimal point (so `0` is an integer constant, but `0.0` is a real constant).

A.2.5 Booleans

A boolean is a logical true or false value.

The type name for booleans is `boolean`. This is not the same type as `bit`, which is a length-1 bitstring.

Boolean constants are `TRUE` and `FALSE`.

A.2.6 Enumerations

An enumeration is a defined set of symbolic constants, such as:

```
enumeration InstrSet {InstrSet_ARM, InstrSet_Thumb, InstrSet_Java,
InstrSet_ThumbEE};
```

An enumeration always contains at least one symbolic constant, and symbolic constants are not allowed to be shared between enumerations.

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Enumerations must be declared explicitly, though a variable of an enumeration type can be declared implicitly as usual by assigning one of the symbolic constants to it. By convention, each of the symbolic constants starts with the name of the enumeration followed by an underscore. The name of the enumeration is its type name, and the symbolic constants are its possible constants.

Note

Booleans are basically a pre-declared enumeration:

```
enumeration boolean {FALSE, TRUE};
```

that does not follow the normal naming convention and that has a special role in some pseudo-code constructs, such as `if` statements.

A.2.7 Lists

A list is an ordered set of other data items, separated by commas and enclosed in parentheses, such as:

```
(bits(32) shifter_result, bit shifter_carry_out)
```

A list always contains at least one data item.

Lists are often used as the return type for a function that returns multiple results. For example, this particular list is the return type of the function `Shift_C()` that performs a standard ARM shift or rotation, when its first operand is of type `bits(32)`.

Some specific pseudo-code operators use lists surrounded by other forms of bracketing than parentheses. These are:

- Bitstring extraction operators, which use lists of bit numbers or ranges of bit numbers surrounded by angle brackets "<...>".
- Array indexing, which uses lists of array indexes surrounded by square brackets "[...]".
- Array-like function argument passing, which uses lists of function arguments surrounded by square brackets "[...]".

Each combination of data types in a list is a separate type, with type name given by just listing the data types (that is, `(bits(32),bit)` in the above example). The general principle that types can be declared by assignment extends to the types of the individual list items within a list. For example:

```
(shift_t, shift_n) = ('00', 0);
```

implicitly declares `shift_t`, `shift_n` and `(shift_t,shift_n)` to be of types `bits(2)`, `integer` and `(bits(2),integer)` respectively.

A list type can also be explicitly named, with explicitly named elements in the list. For example:

```
type ShiftSpec is (bits(2) shift, integer amount);
```

After this definition and the declaration:

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```
ShiftSpec abc;
```

the elements of the resulting list can then be referred to as `"abc.shift"` and `"abc.amount"`. This sort of qualified naming of list elements is only permitted for variables that have been explicitly declared, not for those that have been declared by assignment only.

Explicitly naming a type does not alter what type it is. For example, after the above definition of `ShiftSpec`, `ShiftSpec` and `(bits(2),integer)` are two different names for the same type, not the names of two different types. In order to avoid ambiguity in references to list elements, it is an error to declare a list variable multiple times using different names of its type or to qualify it with list element names not associated with the name by which it was declared.

An item in a list that is being assigned to may be written as `"-"` to indicate that the corresponding item of the assigned list value is discarded. For example:

```
(shifted, -) = LSL_C(operand, amount);
```

List constants are written as a list of constants of the appropriate types, like `('00', 0)` in the above example.

A.2.8 Arrays

Pseudo-code arrays are indexed by either enumerations or integer ranges (represented by the lower inclusive end of the range, then `".."`, then the upper inclusive end of the range). For example:

```
enumeration PhysReg {
    PhysReg_R0,    PhysReg_R1,     PhysReg_R2,    PhysReg_R3,
    PhysReg_R4,    PhysReg_R5,     PhysReg_R6,    PhysReg_R7,
    PhysReg_R8,    PhysReg_R8fiq,  PhysReg_R9,    PhysReg_R9fiq,
    PhysReg_R10,   PhysReg_R10fiq, PhysReg_R11,   PhysReg_R11fiq,
    PhysReg_R12,   PhysReg_R12fiq,
    PhysReg_SP,    PhysReg_SPfiq,  PhysReg_SPirq, PhysReg_SPsvc, PhysReg_SPabt,
    PhysReg_SPund, PhysReg_SPmon,
    PhysReg_LR,    PhysReg_LRfiq,  PhysReg_LRirq, PhysReg_LRsvc, PhysReg_LRabt,
    PhysReg_LRund, PhysReg_LRmon,
    PhysReg_PC};

array bits(32) _R[PhysReg];

array bits(8) _Memory[0..0xFFFFFFFF];
```

Arrays are always explicitly declared, and there is no notation for a constant array. Arrays always contain at least one element, because enumerations always contain at least one symbolic constant and integer ranges always contain at least one integer.

Arrays do not usually appear directly in pseudo-code. The items that syntactically look like arrays in pseudo-code are usually array-like functions such as `R[i]`, `MemU[address,size]` or `Element[i,type]`. These functions package up and abstract additional operations normally performed on accesses to the underlying arrays, such as register banking, memory protection, endian-dependent byte ordering, exclusive-access housekeeping and Neon element processing.

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A.3 Expressions

This section describes:

- *General expression syntax*
- *Operators and functions - polymorphism and prototypes* on page A-9
- *Precedence rules* on page A-9.

A.3.1 General expression syntax

An expression is one of the following:

- a constant
- a variable, optionally preceded by a data type name to declare its type
- the word `UNKNOWN` preceded by a data type name to declare its type
- the result of applying a language-defined operator to other expressions
- the result of applying a function to other expressions.

An expression like `"bits(32) UNKNOWN"` indicates that the result of the expression is a value of the given type, but the architecture does not specify what value it is and software must not rely on such values. The value produced must not constitute a security hole and must not be promoted as providing any useful information to software. (This was called an UNPREDICTABLE value in previous ARM Architecture documentation. It is related to but not the same as `UNPREDICTABLE`, which says that the entire architectural state becomes similarly unspecified.)

A subset of expressions are assignable. That is, they can be placed on the left-hand side of an assignment. This subset consists of:

- Variables
- The results of applying some operators to other expressions. The description of each language-defined operator that can generate an assignable expression specifies the circumstances under which it does so. (For example, those circumstances might include one or more of the expressions the operator operates on themselves being assignable expressions.)
- The results of applying array-like functions to other expressions. The description of an array-like function specifies the circumstances under which it can generate an assignable expression.

Every expression has a data type. This is determined by:

- For a constant, the syntax of the constant.
- For a variable, there are three possible sources for the type
  - its optional preceding data type name
  - a data type it was given earlier in the pseudo-code by recursive application of this rule
  - a data type it is being given by assignment (either by direct assignment to it, or by assignment to a list of which it is a member).

  It is a pseudo-code error if none of these data type sources exists for a variable, or if more than one of them exists and they do not agree about the type.

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- For a language-defined operator, the definition of the operator.
- For a function, the definition of the function.

A.3.2 Operators and functions - polymorphism and prototypes

Operators and functions in pseudo-code can be polymorphic, producing different functionality when applied to different data types. Each of the resulting forms of an operator or function has a different prototype definition. For example, the operator + has forms that act on various combinations of integers, reals and bitstrings.

One particularly common form of polymorphism is between bitstrings of different lengths. This is represented by using `bits(N)`, `bits(M)`, and so on, in the prototype definition.

A.3.3 Precedence rules

The precedence rules for expressions are:

1. Constants, variables and function invocations are evaluated with higher priority than any operators using their results.
2. Expressions on integers follow the normal *exponentiation before multiply/divide before add/subtract* operator precedence rules, with sequences of multiply/divides or add/subtracts evaluated left-to-right.
3. Other expressions must be parenthesized to indicate operator precedence if ambiguity is possible, but need not be if all allowable precedence orders under the type rules necessarily lead to the same result. For example, if `i`, `j` and `k` are integer variables, `i > 0 && j > 0 && k > 0` is acceptable, but `i > 0 && j > 0 || k > 0` is not.

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A.4 Operators and built-in functions

This section describes:

- *Operations on generic types*
- *Operations on booleans*
- *Bitstring manipulation*
- *Arithmetic* on page A-14.

A.4.1 Operations on generic types

The following operations are defined for all types.

Equality and non-equality testing

Any two values `x` and `y` of the same type can be tested for equality by the expression `x == y` and for non-equality by the expression `x != y`. In both cases, the result is of type `boolean`.

Conditional selection

If `x` and `y` are two values of the same type and `t` is a value of type `boolean`, then `if t then x else y` is an expression of the same type as `x` and `y` that produces `x` if `t` is `TRUE` and `y` if `t` is `FALSE`.

A.4.2 Operations on booleans

If `x` is a `boolean`, then `!x` is its logical inverse.

If `x` and `y` are booleans, then `x && y` is the result of ANDing them together. As in the C language, if `x` is `FALSE`, the result is determined to be `FALSE` without evaluating `y`.

If `x` and `y` are booleans, then `x || y` is the result of ORing them together. As in the C language, if `x` is `TRUE`, the result is determined to be `TRUE` without evaluating `y`.

If `x` and `y` are booleans, then `x ^ y` is the result of exclusive-ORing them together.

A.4.3 Bitstring manipulation

The following bitstring manipulation functions are defined:

Bitstring length and top bit

If `x` is a bitstring, the bitstring length function `Len(x)` returns its length as an integer, and `TopBit(x)` is the leftmost bit of `x (= x<Len(x)-1>` using bitstring extraction.

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Bitstring concatenation and replication

If x and y are bitstrings of lengths N and M respectively, then x:y is the bitstring of length N+M constructed by concatenating x and y in left-to-right order.

If x is a bitstring and n is an integer with n > 0, Replicate(x,n) is the bitstring of length n*Len(x) consisting of n copies of x concatenated together.

Bitstring extraction

The bitstring extraction operator extracts a bitstring from either another bitstring or an integer. Its syntax is x<integer_list>, where x is the integer or bitstring being extracted from, and <integer_list> is a list of integers enclosed in angle brackets rather than the usual parentheses. The length of the resulting bitstring is equal to the number of integers in <integer_list>.

In x<integer_list>, each of the integers in <integer_list> must be:

- >= 0
- < Len(x) if x is a bitstring.

The definition of x<integer_list> depends on whether integer_list contains more than one integer. If it does, x<i,j,k,...,n> is defined to be the concatenation:

```
x<i> : x<j> : x<k> : ... : x<n>
```

If integer_list consists of just one integer i, x<i> is defined to be:

- if x is a bitstring, '0' if bit i of x is a zero and '1' if bit i of x is a one.
- if x is an integer, let y be the unique integer in the range 0 to 2^(i+1)-1 that is congruent to x modulo 2^(i+1). Then **x<i>** is '0' if y < 2^i and '1' if y >= 2^i.

Loosely, this second definition treats an integer as equivalent to a sufficiently long 2's complement representation of it as a bitstring.

In <integer_list>, the notation i:j with i >= j is shorthand for the integers in order from i down to j, both ends inclusive. For example, instr<31:28> is shorthand for instr<31,30,29,28>.

The expression x<integer_list> is assignable provided x is an assignable bitstring and no integer appears more than once in <integer_list>. In particular, x<i> is assignable if x is an assignable bitstring and 0 <= i < Len(x).

Logical operations on bitstrings

If x is a bitstring, NOT(x) is the bitstring of the same length obtained by logically inverting every bit of x.

If x and y are bitstrings of the same length, x AND y, x OR y, and x EOR y are the bitstrings of that same length obtained by logically ANDing, ORing, and exclusive-ORing corresponding bits of x and y together.

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Bitstring count

If x is a bitstring, `BitCount(x)` produces an integer result equal to the number of bits of `x` that are ones.

Testing a bitstring for being all zero

If `x` is a bitstring, `IsZero(x)` produces `TRUE` if all of the bits of `x` are zeros and `FALSE` if any of them are ones, and `IsZeroBit(x)` produces `'1'` if all of the bits of `x` are zeros and `'0'` if any of them are ones. So:

```
IsZero(x)    = (BitCount(x) == 0)

IsZeroBit(x) = if IsZero(x) then '1' else '0'
```

Lowest and highest set bits of a bitstring

If `x` is a bitstring:

- `LowestSetBit(x)` is the minimum bit number of any of its bits that are ones. If all of its bits are zeros, `LowestSetBit(x) = Len(x)`.
- `HighestSetBit(x)` is the maximum bit number of any of its bits that are ones. If all of its bits are zeros, `HighestSetBit(x) = -1`.

Zero-extension and sign-extension of bitstrings

If `x` is a bitstring and `i` is an integer, then `ZeroExtend(x,i)` is `x` extended to a length of `i` bits, by adding sufficient zero bits to its left. That is, if `i == Len(x)`, then `ZeroExtend(x,i) = x`, and if `i > Len(x)`, then:

```
ZeroExtend(x,i) = Replicate('0', i-Len(x)) : x
```

If `x` is a bitstring and `i` is an integer, then `SignExtend(x,i)` is `x` extended to a length of `i` bits, by adding sufficient copies of its leftmost bit to its left. That is, if `i == Len(x)`, then `SignExtend(x,i) = x`, and if `i > Len(x)`, then:

```
SignExtend(x,i) = Replicate(TopBit(x), i-Len(x)) : x
```

It is a pseudo-code error to use either `ZeroExtend(x,i)` or `SignExtend(x,i)` in a context where it is possible that `i < Len(x)`.

Shifting and rotating bitstrings

Functions are defined to perform logical shift left, logical shift right, arithmetic shift right, rotate left, rotate right and rotate right extended functions on bitstrings.

The first group of such functions are shifts producing a result bitstring of the same length as their bitstring operand and a carry out bit, as follows:

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```
(bits(N), bit) LSL_C(bits(N) x, integer n)
    assert n > 0;
    extended_x = x : Replicate('0', n);
    result = extended_x<Len(x)-1:0>;
    c_out = extended_x<Len(x)>;
    return (result, c_out);

(bits(N), bit) LSR_C(bits(N) x, integer n)
    assert n > 0;
    extended_x = Replicate('0', n) : x;
    result = extended_x<n+Len(x)-1:n>;
    c_out = extended_x<n-1>;
    return (result, c_out);

(bits(N), bit) ASR_C(bits(N) x, integer n)
    assert n > 0;
    extended_x = Replicate(TopBit(x), n) : x;
    result = extended_x<n+Len(x)-1:n>;
    c_out = extended_x<n-1>;
    return (result, c_out);
```

Versions of these functions that do not produce the carry out bit are:

```
bits(N) LSL(bits(N) x, integer n)
    assert n >= 0;
    if n == 0 then
        result = x;
    else
        (result, -) = LSL_C(x, n);
    return result;

bits(N) LSR(bits(N) x, integer n)
    assert n >= 0;
    if n == 0 then
        result = x;
    else
        (result, -) = LSR_C(x, n);
    return result;

bits(N) ASR(bits(N) x, integer n)
    assert n >= 0;
    if n == 0 then
        result = x;
    else
        (result, -) = ASR_C(x, n);
    return result;
```

The corresponding rotation functions are then defined by:

```
(bits(N), bit) ROR_C(bits(N) x, integer n)
    m = n DIV Len(x);
    result = if m == 0 then x else LSR(x,m) OR LSL(x,Len(x)-m);
    c_out = result<Len(x)-1>;
```

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```
    return (result, c_out);

(bits(N), bit) ROL_C(bits(N) x, integer n)
    m = n DIV Len(x);
    result = if m == 0 then x else LSL(x,m) OR LSR(x,Len(x)-m);
    c_out = result<0>;
    return (result, c_out);

(bits(N), bit) RRX_C(bits(N) x, bit c_in)
    result = c_in : x<Len(x)-1:1>;
    c_out = x<0>;
    return (result, c_out);

bits(N) ROR(bits(N) x, integer n)
    (result, -) = ROR_C(x, n);
    return result;

bits(N) ROL(bits(N) x, integer n)
    (result, -) = ROL_C(x, n);
    return result;

bits(N) RRX(bits(N) x, bit c_in)
    (result, -) = RRX_C(x, c_in);
    return result;
```

Converting bitstrings to integers

If `x` is a bitstring, `SInt(x)` is the integer whose 2's complement representation is `x`:

```
integer SInt(bits(N) x)
    integer result = 0;
    for i = 0 to Len(x)-1
        if x<i> == '1' then result = result + 2^i;
    if x<Len(x)-1> == '1' then result = result - 2^Len(x);
    return result;
```

`UInt(x)` is the integer whose unsigned representation is `x`:

```
integer SInt(bits(N) x)
    integer result = 0;
    for i = 0 to Len(x)-1
        if x<i> == '1' then result = result + 2^i;
    return result;
```

A.4.4 Arithmetic

Most pseudo-code arithmetic is performed on integer or real values, with operands being obtained by conversions from bitstrings and results converted back to bitstrings afterwards. As these data types are the unbounded mathematical types, no issues arise about overflow or similar errors.

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Unary plus, minus and absolute value

If x is an integer or real, then +x is x unchanged, -x is x with its sign reversed, and ABS(x) is the absolute value of x. All three are of the same type as x.

Addition and subtraction

If x and y are integers or reals, x+y and x-y are their sum and difference. Both are of type integer if x and y are both of type integer, and real otherwise.

Addition and subtraction are particularly common arithmetic operations in pseudo-code, and so it is also convenient to have definitions of addition and subtraction acting directly on bitstring operands.

If x and y are bitstrings of the same length N = Len(x) = Len(y), then x+y and x-y are the least significant N bits of the results of converting them to integers and adding or subtracting them. Signed and unsigned conversions produce the same result:

```
x+y = (SInt(x) + SInt(y))<N-1:0>
    = (UInt(x) + UInt(y))<N-1:0>

x-y = (SInt(x) - SInt(y))<N-1:0>
    = (UInt(x) - UInt(y))<N-1:0>
```

If x is a bitstring of length N and y is an integer, x+y and x-y are the bitstrings of length N defined by x+y = x + y<N-1:0> and x-y = x - y<N-1:0>. Similarly, if x is an integer and y is a bitstring of length M, x+y and x-y are the bitstrings of length M defined by x+y = x<M-1:0> + y and x-y = x<M-1:0> - y.

A function AddWithCarry() is also defined that returns unsigned carry and signed overflow information as well as the result of a bitstring addition of two equal-length bitstrings and a carry-in bit:

```
(bits(N), bit, bit) AddWithCarry(bits(N) x, bits(N) y, bit carry_in)
    unsigned_sum = UInt(x) + UInt(y) + UInt(carry_in);
    signed_sum   = SInt(x) + SInt(y) + UInt(carry_in);
    result       = unsigned_sum<N-1:0>;  // = signed_sum<N-1:0>
    carry_out    = if UInt(result) == unsigned_sum then '0' else '1';
    overflow     = if SInt(result) == signed_sum then '0' else '1';
    return (result, carry_out, overflow);
```

An important property of the AddWithCarry() function is that if:

```
(result, carry_out, overflow) = AddWithCarry(x, NOT(y), carry_in)
```

then:

- If carry_in == '1', then result == x-y with overflow == '1' if signed overflow occurred during the subtraction and carry_out == '1' if unsigned borrow did not occur during the subtraction (that is, if x >= y).
- If carry_in == '0', then result == x-y-1 with overflow == '1' if signed overflow occurred during the subtraction and carry_out = '1' if unsigned borrow did not occur during the subtraction (that is, if x > y).

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Together, these mean that the `carry_in` and `carry_out` bits in `AddWithCarry()` calls can act as *NOT borrow* flags for subtractions as well as *carry* flags for additions. This is used extensively in the definitions of the main addition/subtraction instructions.

Comparisons

If `x` and `y` are integers or reals, then `x == y`, `x != y`, `x < y`, `x <= y`, `x > y`, and `x >= y` are equal, not equal, less than, less than or equal, greater than, and greater than or equal comparisons between them, producing boolean results. In the case of `==` and `!=`, this extends the generic definition applying to any two values of the same type to also act between integers and reals.

Multiplication

If `x` and `y` are integers or reals, then `x * y` is the product of `x` and `y`, of type `integer` if both `x` and `y` are of type `integer` and otherwise of type `real`.

Division and modulo

If `x` and `y` are integers or reals, then `x / y` is the result of dividing `x` by `y`, and is always of type `real`.

If `x` and `y` are integers, then `x DIV y` and `x MOD y` are defined by:

```
x DIV y = RoundDown(x / y)
x MOD y = x - y * (x DIV y)
```

It is a pseudo-code error to use any `x / y`, `x MOD y`, or `x DIV y` in any context where `y` can be zero.

Rounding and aligning

If x is a real:

- `RoundDown(x)` produces the largest integer `n` such that `n <= x`.
- `RoundUp(x)` produces the smallest integer `n` such that `n >= x`.
- `RoundTowardsZero(x)` produces `RoundDown(x)` if `x > 0.0`, `0 if x == 0.0`, and `RoundUp(x) if x < 0.0`.

If `x` and `y` are integers, `Align(x,y) = y * (x DIV y)` is an integer.

If `x` is a bitstring and `y` is an integer, `Align(x,y) = (Align(UInt(x),y))<Len(x)-1:0>` is a bitstring of the same length as `x`.

It is a pseudo-code error to use either form of `Align(x,y)` in any context where `y` can be 0. In practice, `Align(x,y)` is only used with `y` a constant power of two, and the bitstring form used with `y = 2^n` has the effect of producing its argument with its n low-order bits forced to zero.

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Scaling

If `n` is an integer, `2^n` is the result of raising `2` to the power `n` and is of type `real`.

If `x` and `n` are integers, then:

- `x << n = RoundDown(x * 2^n)`
- `x >> n = RoundDown(x * 2^(-n))`.

Maximum and minimum

If `x` and `y` are integers or reals, then `Max(x,y)` and `Min(x,y)` are their maximum and minimum respectively. Both are of type `integer` if both `x` and `y` are of type `integer` and of type `real` otherwise.

Saturation

If `i` and `j` are integers with `j > 0`, `SignedSatQ(i,j)` produces the j-bit 2's complement representation of the result of saturating `i` to the j-bit signed range together with a boolean that indicates whether saturation occurred:

```
(bits(j), boolean) SignedSatQ(integer i, integer j)
    assert j > 0;
    saturated_i = Min(Max(i, -(2^(j-1))), (2^(j-1))-1);
    result      = saturated_i<j-1:0>;
    sat         = (i < -(2^(j-1))) || (i >= 2^(j-1));
    return (result, sat);
```

`UnsignedSatQ(i,j)` performs the corresponding unsigned saturation:

```
(bits(j), boolean) SignedSatQ(integer i, integer j)
    assert j > 0;
    saturated_i = Min(Max(i, 0), (2^j)-1);
    result      = saturated_i<j-1:0>;
    sat         = (i < 0) || (i >= 2^j);
    return (result, sat);
```

`SignedSat(i,j)` and `UnsignedSat(i,j)` produce the equivalent operations without the boolean result:

```
bits(j) SignedSat(integer i, integer j)
    (result, -) = SignedSatQ(i, j);
    return result;

bits(j) UnsignedSat(integer i, integer j)
    (result, -) = UnsignedSatQ(i, j);
    return result;
```


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A.5 Statements and program structure

This section describes the control statements used in the pseudo-code.

A.5.1 Simple statements

The following simple statements must all be terminated with a semicolon, as shown.

Assignments

An assignment statement takes the form:

```
<assignable_expression> = <expression>;
```

Procedure calls

A procedure call takes the form:

```
<procedure_name>(<arguments>);
```

Return statements

A procedure return takes the form:

```
return;
```

and a function return takes the form:

```
return <expression>;
```

where `<expression>` is of the type the function prototype line declared.

UNDEFINED

The statement:

```
UNDEFINED;
```

indicates a special case that replaces the behavior defined by the current pseudo-code (apart from behavior required to determine that the special case applies). The replacement behavior is that the Undefined Instruction exception is taken.

UNPREDICTABLE

The statement:

```
UNPREDICTABLE;
```

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indicates a special case that replaces the behavior defined by the current pseudo-code (apart from behavior required to determine that the special case applies). The replacement behavior is not architecturally defined and must not be relied upon by software. It must not constitute a security hole or halt or hang the system, and must not be promoted as providing any useful information to software.

SEE...

The statement:

```
SEE <reference>;
```

indicates a special case that replaces the behavior defined by the current pseudo-code (apart from behavior required to determine that the special case applies). The replacement behavior is that nothing occurs as a result of the current pseudo-code because some other piece of pseudo-code defines the required behavior. The `<reference>` indicates where that other pseudo-code can be found.

A.5.2 Compound statements

Indentation is normally used to indicate structure in compound statements. The statements contained in structures such as `if ... then ... else ...` or procedure and function definitions are indented more deeply than the statement itself, and their end is indicated by returning to the original indentation level or less.

Indentation is normally done by four spaces for each level.

if ... then ... else ...

A multi-line `if ... then ... else ...` structure takes the form:

```
if <boolean_expression> then
    <statement 1>
    <statement 2>
    ...
    <statement n>
else
    <statement A>
    <statement B>
    ...
    <statement Z>
```

The `else` and its following statements are optional.

Abbreviated one-line forms can be used when there is just one simple statement in the `then` part and (if present) the `else` part, as follows:

```
if <boolean_expression> then <statement 1>

if <boolean_expression> then <statement 1> else <statement A>
```


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Note

In these forms, `<statement 1>` and `<statement A>` are necessarily terminated by semicolons. This and the fact that the `else` part is optional are differences from the `if ... then ... else ...` expression.

repeat ... until ...

A `repeat ... until ...` structure takes the form:

```
repeat
    <statement 1>
    <statement 2>
    ...
    <statement n>
until <boolean_expression>;
```

for ...

A `for ...` structure takes the form:

```
for <assignable_expression> = <integer_expr1> to <integer_expr2>
    <statement 1>
    <statement 2>
    ...
    <statement n>
```

case ... of ...

A `case ... of ...` structure takes the form:

```
case <expression> of
    when <constant values>
        <statement 1>
        <statement 2>
        ...
        <statement n>
    ... more "when" groups ...
    otherwise
        <statement A>
        <statement B>
        ...
        <statement Z>
```

where `<constant values>` consists of one or more constant values of the same type as `<expression>`, separated by commas.

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Procedure and function definitions

A procedure definition takes the form:

```
<procedure name>(<argument prototypes>)
    <statement 1>
    <statement 2>
    ...
    <statement n>
```

where the `<argument prototypes>` consists of zero or more argument definitions, separated by commas. Each argument definition consists of a type name followed by the name of the argument.

Note

This first prototype line is not terminated by a semicolon. This helps to distinguish it from a procedure call.

A function definition is similar, but also declares the return type of the function:

```
<return type> <function name>(<argument prototypes>)
    <statement 1>
    <statement 2>
    ...
    <statement n>
```

A.5.3 Comments

Two styles of pseudo-code comment exist:

- `//` starts a comment that is terminated by the end of the line.
- `/*` starts a comment that is terminated by `*/`.

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A.6 Helper procedures and functions

The functions described in this section are not part of the pseudo-code specification. They are *helper* procedures and functions used by pseudo-code to perform useful architecture-specific jobs. Each has a brief description and a pseudo-code prototype. Some have had a pseudo-code definition added.

A.6.1 ALUWritePC()

This procedure writes a value to the PC with the correct semantics for such a write by data-processing instructions. That is, it has `BX`-like interworking behavior if performed by an ARM instruction in ARMv7 or above, and only a change to the PC otherwise.

```
ALUWritePC(bits(32) value)
```

A.6.2 ArchVersion()

This function returns the major version number of the architecture.

```
integer ArchVersion()
```

A.6.3 ARMExpandImm(), ARMExpandImmWithC()

These functions do the standard expansion of the 12 bits specifying an ARM data-processing immediate to its 32-bit value. The `WithC` version also produces a `carry out` bit.

```
// ARMExpandImm()
// --------------
bits(32) ARMExpandImm(bits(12) imm12)
(imm32, -) = ARMExpandImmWithC(imm12);
return imm12;
// ARMExpandImmWithC()
// -------------------
(bits(32), bit) ARMExpandImmWithC(bits(12) imm12)
if imm12<11:8> == '0000' then
    imm32 = ZeroExtend(imm12<7:0>, 32);
    carry_out = APSR.C;
else
    unrotated_value = ZeroExtend(imm12<7:0>, 32);
    (imm32, carry_out) = ROR_C(unrotated_value, 2*UInt(imm12<11:8>));
return (imm32, carry_out);
```

A.6.4 BadReg()

This function performs the check for the register numbers 13 and 15 that are disallowed for many Thumb register specifiers.

```
boolean BadReg(integer n)
return n == 13 || n == 15;
```


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A.6.5 BigEndian()

This function returns TRUE if load/store operations are currently big-endian, and FALSE if they are little-endian.

```
boolean BigEndian()
```

A.6.6 BranchWritePC()

This procedure writes a value to the PC with the correct semantics for such writes by simple branches - that is, just a change to the PC in all circumstances.

```
BranchWritePC(bits(32) value)
```

A.6.7 BreakPoint()

This procedure causes a debug breakpoint to occur.

A.6.8 BXWritePC()

This procedure writes a value to the PC with the correct semantics for such writes by interworking instructions. That is, with BX-like interworking behavior in all circumstances.

```
BXWritePC(bits(32) value)
```

A.6.9 CallSecureMonitor()

This procedure calls the Secure Monitor.

A.6.10 CallSupervisor()

This procedure calls the Supervisor.

A.6.11 ClearEventRegister()

This procedure clears the event register on the current processor. See *EventRegistered()* on page A-26 for details of the event register.

A.6.12 ClearExclusiveMonitors()

This procedure clears the monitors used by the load/store exclusive instructions.

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A.6.13 ConditionPassed()

This function performs the condition test for an instruction, based on:

- the 4-bit cond field of the instruction for ARM instructions and for the two Thumb conditional branch encodings (encodings T1 andT3 of the B instruction)
- the current values of the CPSR.IT[7:0] bits for other Thumb instructions.

```
boolean ConditionPassed()
```

A.6.14 Coproc_Accepted()

This function determines whether a coprocessor accepts an instruction.

```
boolean Coproc_Accepted(integer cp_num, bits(32) instr)
```

A.6.15 Coproc_DoneLoading()

This function determines for an `LDC` instruction whether enough words have been loaded.

```
boolean Coproc_DoneLoading(integer cp_num, bits(32) instr)
```

A.6.16 Coproc_DoneStoring()

This function determines for an STC instruction whether enough words have been stored.

```
boolean Coproc_DoneStoring(integer cp_num, bits(32) instr)
```

A.6.17 Coproc_GetOneWord()

This function obtains the word for an `MRC` instruction from the coprocessor.

```
bits(32) Coproc_GetOneWord(integer cp_num, bits(32) instr)
```

A.6.18 Coproc_GetTwoWords()

This function obtains the two words for an `MRRC` instruction from the coprocessor.

```
(bits(32), bits(32)) Coproc_GetTwoWords(integer cp_num, bits(32) instr)
```

A.6.19 Coproc_GetWordToStore()

This function obtains the next word to store for an `STC` instruction from the coprocessor

```
bits(32) Coproc_GetWordToStore(integer cp_num, bits(32) instr)
```


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A.6.20 Coproc_InternalOperation()

This procedure instructs a coprocessor to perform the internal operation requested by a CDP instruction.

```
Coproc_InternalOperation(integer cp_num, bits(32) instr)
```

A.6.21 Coproc_SendLoadedWord()

This procedure sends a loaded word for an LDC instruction to the coprocessor.

```
Coproc_SendLoadedWord(bits(32) word, integer cp_num, bits(32) instr)
```

A.6.22 Coproc_SendOneWord()

This procedure sends the word for an MCR instruction to the coprocessor.

```
Coproc_SendOneWord(bits(32) word, integer cp_num, bits(32) instr)
```

A.6.23 Coproc_SendTwoWords()

This procedure sends the two words for an MCRR instruction to the coprocessor.

```
Coproc_SendTwoWords(bits(32) word1, bits(32) word2, integer cp_num,
                    bits(32) instr)
```

A.6.24 CurrentInstrSet()

This function returns an enumeration value that identifies the current instruction set.

```
enumeration InstrSet (InstrSetARM, InstrSet_Thumb, InstrSet_Java,
                      InstrSet_ThumbEE);
InstrSet CurrentInstrSet()
```

A.6.25 CurrentModeHasSPSR()

This function determines whether the current processor mode has an SPSR. All modes except User or System mode have an SPSR.

```
boolean CurrentModeHasSPSR()
```

A.6.26 CurrentModeIsPrivileged()

This function determines whether the current processor mode is privileged. All modes except User mode are privileged.

```
boolean CurrentModeHasSPSR()
```


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A.6.27 DataMemoryBarrier()

This procedure produces a Data Memory Barrier.

```
DataMemoryBarrier(bits(4) option)
```

A.6.28 DataSynchronizationBarrier()

This procedure produces a Data Synchronization Barrier.

```
DataSynchronizationBarrier(bits(4) option)
```

A.6.29 DecodeImmShift(), DecodeRegShift()

These functions perform the standard *2-bit type, 5-bit amount* and *2-bit type* decodes for immediate and register shifts respectively. See *Shift operations* on page 4-11.

A.6.30 EventRegistered()

This function returns TRUE if the event register on the current processor is set and FALSE if it is clear. The event register is set as a result of any of the following events:

- an IRQ interrupt, unless masked by the CPSR I-bit
- an FIQ interrupt, unless masked by the CPSR F-bit
- an Imprecise Data abort, unless masked by the CPSR A-bit
- a Debug Entry request, if Debug is enabled
- an event sent by any processor in the multi-processor system as a result of that processor executing a `Hint_SendEvent()`
- an exception return
- implementation-specific reasons, that might be IMPLEMENTATION DEFINED but also might occur arbitrarily.

The state of the event register is UNKNOWN at Reset.

A.6.31 EncodingSpecificOperations()

This procedure invokes the encoding-specific pseudo-code for an instruction encoding and performs other encoding-specific operations, as defined in the pseudocode beneath the encoding diagram for the particular encoding.

A.6.32 ExclusiveMonitorsPass()

This function determines whether a store exclusive instruction is successful. A store exclusive is successful if it still has possession of the exclusive monitors.

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```
boolean ExclusiveMonitorsPass(bits(32) address, integer size)
```

A.6.33 Hint_Debug()

This procedure supplies a hint to the debug system.

```
Hint_Debug(bits(4) option)
```

A.6.34 Hint_PreloadData()

This procedure performs a *preload data* hint.

```
Hint_PreloadData(bits(32) address)
```

A.6.35 Hint_PreloadInstr()

This procedure performs a *preload instructions* hint.

```
Hint_PreloadInstr(bits(32) address)
```

A.6.36 Hint_SendEvent()

This procedure performs a *send event* hint.

A.6.37 Hint_Yield()

This procedure performs a *Yield* hint.

A.6.38 InITBlock()

This function returns `TRUE` if execution is currently in an IT block and `FALSE` otherwise.

```
boolean InITBlock()
```

A.6.39 InstructionSynchronizationBarrier()

This procedure produces an Instruction Synchronization Barrier.

```
InstructionSynchronizationBarrier(bits(4) option)
```

A.6.40 IntegerZeroDivideTrappingEnabled()

This function returns TRUE if the trapping of divisions by zero in the integer division instructions `SDIV` and `UDIV` is enabled, and FALSE otherwise.

In the R profile, this is controlled by the DZ bit (bit[19]) of CP15 register 1. TRUE is returned if the bit is 1 and FALSE if it is 0. This function is never called in the A profile.

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A.6.41 JazelleAcceptsExecution()

This function indicates whether Jazelle hardware will take over execution when a `BXJ` instruction is executed.

```
boolean JazelleAcceptsExecution()
```

A.6.42 LastInITBlock()

This function returns TRUE if the current instruction is the last instruction in an IT block, and FALSE otherwise.

A.6.43 LoadWritePC()

This procedure writes a value to the PC with the correct semantics for such writes by load instructions. That is, with `BX`-like interworking behavior in ARMv5 and above, and just a change to the PC in ARMv4T.

```
LoadWritePC(bits(32) value)
```

A.6.44 MemA[]

This array-like function performs a memory access that is required to be aligned, using the current privilege level.

```
bits(8*size) MemA[bits(32) address, integer size]
MemA[bits(32) address, integer size] = bits(8*size) value
```

A.6.45 MemAA[]

This array-like function performs a memory access that is required to be aligned and atomic, using the current privilege level.

```
bits(8*size) MemAA[bits(32) address, integer size]
MemAA[bits(32) address, integer size] = bits(8*size) value
```

A.6.46 MemU[]

This array-like function performs a memory access that is allowed to be unaligned, using the current privilege level.

```
bits(8*size) MemU[bits(32) address, integer size]
MemU[bits(32) address, integer size] = bits(8*size) value
```

A.6.47 MemU_unpriv[]

This array-like function performs a memory access that is allowed to be unaligned, as an unprivileged access regardless of the current privilege level.

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```
bits(8*size) MemU_unpriv[bits(32) address, integer size]
MemU_unpriv[bits(32) address, integer size] = bits(8*size) value
```

A.6.48 PCStoreValue()

This function returns the value to be stored by an instruction that stores the PC. It is IMPLEMENTATION DEFINED whether this is the address of the instruction plus 8 or the address of the instruction plus 12. This only applies to ARM instructions, because no Thumb instructions store the PC.

```
bits(32) PCStoreValue()
```

A.6.49 R[]

This array-like function reads or writes a register. Reading register 13, 14, or 15 reads the SP, LR or PC respectively and writing register 13 or 14 writes the SP or LR respectively.

```
bits(32) R[integer n]
R[integer n] = bits(32) value;
```

A.6.50 RaiseCoprocessorException()

This procedure raises the appropriate exception for a rejected coprocessor instruction.

In the A and R profiles, this is an Undefined Instruction exception.

A.6.51 RaiseIntegerZeroDivide()

This procedure raises the appropriate exception for a division by zero in the integer division instructions `SDIV` and `UDIV`.

In the R profile, this is an Undefined Instruction exception. This exception is never raised in the A profile.

A.6.52 Rmode[]

This array-like function reads or write a register belonging to a specified processor mode, and is otherwise identical to R[].

```
bits(32) R[integer n, integer mode]
R[integer n, integer mode] = bits(32) value;
```

A.6.53 Select_InstrSet()

This procedure selects a new instruction set to execute.

```
enumeration InstrSet (InstrSetARM, InstrSet_Thumb, InstrSet_Java,
                      InstrSet_ThumbEE);
Select_InstrSet(InstrSet iset)
```


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A.6.54 SetEndianness()

This procedure sets the current endianness for load/store instructions.

```
enumeration Endian (Endian_Little, Endian_Big);
SetEndianness(Endian new)
```

A.6.55 SetExclusiveMonitors()

This procedure sets the exclusive monitors for a load exclusive instruction.

```
SetExclusiveMonitors(bits(32) address, integer size)
```

A.6.56 Shift(), Shift_C()

These functions perform standard ARM shifts on values, returning a result value and in the case of `Shift_C()`, a carry out bit. See *Shift operations* on page 4-11.

A.6.57 StartITBlock()

This procedure starts an IT block with specified *first condition* and *mask* values.

```
StartITBlock(bits(4) firstcond, bits(4) mask)
```

A.6.58 SwitchToJazelleExecution()

This procedure passes control of execution to Jazelle hardware (for a `BXJ` instruction).

A.6.59 ThisInstr()

This function returns the currently-executing instruction. It is only used on 32-bit instruction encodings at present.

```
bits(32) ThisInstr()
```

A.6.60 ThumbExpandImm(), ThumbExpandImmWithC()

These functions do the standard expansion of the 12 bits specifying an Thumb data-processing immediate to its 32-bit value. The `WithC` version also produces a carry out bit. See *Operation* on page 4-9.

A.6.61 WaitForEvent()

This procedure causes the processor to suspend execution until any processor in the multiprocessor system executes a `SEV` instruction, or any of the following occurs for the processor itself:

- an IRQ interrupt, unless masked by the CPSR I-bit
- an FIQ interrupt, unless masked by the CPSR F-bit

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- an Imprecise Data abort, unless masked by the CPSR A-bit
- a Debug Entry request, if Debug is enabled
- implementation-specific reasons, that might be IMPLEMENTATION DEFINED but also might occur arbitrarily
- Reset.

It is IMPLEMENTATION DEFINED whether or not restarting execution after the period of suspension causes a `ClearEventRegister()` to occur.

A.6.62 WaitForInterrupt()

This procedure causes the processor to suspend execution until any of the following occurs for that processor:

- an IRQ interrupt, regardless of the CPSR I-bit
- an FIQ interrupt, regardless of the CPSR F-bit
- an Imprecise Data abort, regardless of the CPSR A-bit
- a Debug Entry request, if Debug is enabled
- implementation-specific reasons, that might be IMPLEMENTATION DEFINED but also might occur arbitrarily
- Reset.

A.6.63 WriteCPSRUnderMask()

This procedure performs the *write CPSR* actions for an `MSR CPSR` instruction in the ARMv7-A or ARMv7-R profiles.

```
WriteCPSRUnderMask(bits(32) value, bits(4) mask
```

A.6.64 WriteSPSRUnderMask()

This procedure performs the *write SPSR* actions for an `MSR SPSR` instruction in the ARMv7-A or ARMv7-R profiles.

```
WriteSPSRUnderMask(bits(32) value, bits(4) mask
```


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Glossary

APSR *See* Application Program Status Register.

Application Program Status Register
The register containing those bits that deliver status information about the results of instructions. In this manual, synonymous with the CPSR, but only the N, Z, C, V, Q and GE[3:0] bits of the CPSR are accessed using the APSR name.

IMPLEMENTATION DEFINED
Means that the behavior is not architecturally defined, but must be defined and documented by individual implementations.

IT block An IT block is a block of up to four instructions following an *If-Then* (IT) instruction. Each instruction in the block is conditional. The conditions for the instructions are either all the same, or some can be the inverse of others. See *IT* on page 4-92 for additional information.

Memory hint
A memory hint instruction allows you to provide advance information to memory systems about future memory accesses, without actually loading or storing any data. `PLD` and `PLI` are the only memory hint instructions currently provided.

Single Instruction, Multiple Data (SIMD)
Single Instruction, Multiple Data (SIMD) instructions perform similar operations on four 8-bit, or two 16-bit, data items held in 32-bit registers. See *SIMD add and subtract* on page 3-21 for additional information.

UAL *See* Unified Assembler Language.

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UNDEFINED

An attempt to execute an UNDEFINED instruction causes an Undefined Instruction exception.

Unified Assembler Language

The new assembler language used in this document. See *Unified Assembler Language* on page ix for details.

UNPREDICTABLE

The result of an UNPREDICTABLE instruction cannot be relied upon. UNPREDICTABLE instructions or results must not represent security holes. UNPREDICTABLE instructions must not halt or hang the processor, or any parts of the system.

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