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1 Introduction

Each of the following chapters describes a functional group of Cortex-M3/M4F instructions. Together they describe all the instructions supported by the Cortex-M3/M4F processor:

- "Memory Access Instructions" on page 35
- "General Data Processing Instructions" on page 53
- "Multiply and Divide Instructions" on page 105
- "Saturating Instructions" on page 131
- "Packing and Unpacking Instructions" on page 147
- "Bitfield Instructions" on page 156
- "Floating-Point" on page 159
- "Branch and Control Instructions" on page 199
- "Miscellaneous Instructions" on page 208

1.1 Instruction Set Summary

The processor implements a version of the Thumb instruction set. Table 1-1 on page 19 lists the supported instructions.

In Table 1-1 on page 19:

- Angle brackets, <>, enclose alternative forms of the operand.
- Braces, {}, enclose optional operands.
- The Operands column is not exhaustive.
- Op2 is a flexible second operand that can be either a register or a constant.
- Most instructions can use an optional condition code suffix.

For more information on the instructions and operands, see the instruction descriptions. Figure 1-1 on page 26 shows the Cortex-M3/M4F instructions by category.

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### Table 1-1. Cortex-M3/M4F Instructions (continued)

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<td>Compare two floating-point registers, or one floating-point register and zero</td>
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<td>Compare two floating-point registers, or one floating-point register and zero with extend byte check</td>
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Table 1-1. Cortex-M3/M4F Instructions (continued)

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<th>M3</th>
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<th>Operands</th>
<th>Brief Description</th>
<th>Flags</th>
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<td>Convert between floating-point and integer</td>
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<td>Copy ARM core register to single precision</td>
<td>-</td>
<td>182</td>
</tr>
<tr>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>VMOV</td>
<td>Sm, Sml, Rt, Rt2</td>
<td>Copy 2 ARM core registers to 2 single precision</td>
<td>-</td>
<td>183</td>
</tr>
<tr>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>VMOV</td>
<td>Dd[x], Rt</td>
<td>Copy ARM core register to scalar</td>
<td>-</td>
<td>184</td>
</tr>
<tr>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>VMOV</td>
<td>Rt, Dn[x]</td>
<td>Copy scalar to ARM core register</td>
<td>-</td>
<td>181</td>
</tr>
<tr>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>VMRS</td>
<td>Rt, FPSCR</td>
<td>Move FPSCR to ARM core register or APSR</td>
<td>N, Z, C, V</td>
<td>185</td>
</tr>
<tr>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>VMSR</td>
<td>FPSCR, Rt</td>
<td>Move to FPSCR from ARM core register</td>
<td>FPSCR</td>
<td>186</td>
</tr>
<tr>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>VMUL.F32</td>
<td>(Sd,) Sd, Sd</td>
<td>Floating-point multiply</td>
<td>-</td>
<td>187</td>
</tr>
<tr>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>VNEG.F32</td>
<td>Sd, Sm</td>
<td>Floating-point negate</td>
<td>-</td>
<td>188</td>
</tr>
<tr>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>VNMUL.F32</td>
<td>(Sd,) Sd, Sd</td>
<td>Floating-point multiply and add</td>
<td>-</td>
<td>189</td>
</tr>
<tr>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>VNMUL.F32</td>
<td>(Sd,) Sd, Sd</td>
<td>Floating-point multiply and subtract</td>
<td>-</td>
<td>189</td>
</tr>
<tr>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>VNMUL</td>
<td>(Sd,) Sd, Sd</td>
<td>Floating-point multiply</td>
<td>-</td>
<td>189</td>
</tr>
<tr>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>VPQP</td>
<td>list</td>
<td>Pop extension registers</td>
<td>-</td>
<td>191</td>
</tr>
<tr>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>VPUSH</td>
<td>list</td>
<td>Push extension registers</td>
<td>-</td>
<td>192</td>
</tr>
<tr>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>VSQRT.F32</td>
<td>Sd, Sm</td>
<td>Calculates floating-point square root</td>
<td>-</td>
<td>193</td>
</tr>
<tr>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>VSTM</td>
<td>Rn(!), list</td>
<td>Floating-point register store multiple</td>
<td>-</td>
<td>194</td>
</tr>
</tbody>
</table>
Table 1-1. Cortex-M3/M4F Instructions (continued)

<table>
<thead>
<tr>
<th>M3</th>
<th>M4</th>
<th>M4F</th>
<th>Mnemonic</th>
<th>Operands</th>
<th>Brief Description</th>
<th>Flags</th>
<th>See Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>✓</td>
<td>✓</td>
<td></td>
<td>VSTR.F32/64</td>
<td>Sd, [Rn]</td>
<td>Stores an extension register to memory</td>
<td>-</td>
<td>194</td>
</tr>
<tr>
<td>✓</td>
<td></td>
<td>✓</td>
<td>VSUB.F&lt;32/64</td>
<td>{Sd}, Sn, Sm</td>
<td>Floating-point subtract</td>
<td>-</td>
<td>196</td>
</tr>
<tr>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>WFE</td>
<td>-</td>
<td>Wait for event</td>
<td>-</td>
<td>219</td>
</tr>
<tr>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>WFI</td>
<td>-</td>
<td>Wait for interrupt</td>
<td>-</td>
<td>220</td>
</tr>
</tbody>
</table>

Figure 1-1. Cortex-M Extensions

1.2 About the Instruction Descriptions

The following sections give more information about using the instructions:

- “Operands” on page 27
- “Restrictions When Using the PC or SP” on page 27
- “Flexible Second Operand” on page 27
- “Shift Operations” on page 28
- “Address Alignment” on page 31
- “PC-Relative Expressions” on page 32
- “Conditional Execution” on page 32
- “Instruction Width Selection” on page 34

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1.2.1 Operands

An instruction operand can be an ARM Cortex-M3/M4F register, a constant, or another instruction-specific parameter. Instructions act on the operands and often store the result in a destination register. When there is a destination register in the instruction, it is usually specified before the operands.

Operands in some instructions are flexible in that they can either be a register or a constant. See “Flexible Second Operand” on page 27.

See the Stellaris® Data Sheet for more information on the ARM Cortex-M3/M4F registers.

1.2.2 Restrictions When Using the PC or SP

Many instructions have restrictions on whether you can use the Program Counter (PC) or Stack Pointer (SP) for the operands or destination register. See the instruction descriptions for more information.

**Important:** Bit[0] of any address you write to the PC with a BX, BLX, LDM, LDR, or POP instruction must be 1 for correct execution, because this bit indicates the required instruction set, and the Cortex-M3/M4F processor only supports Thumb instructions.

1.2.3 Flexible Second Operand

Many general data processing instructions have a flexible second operand. This is shown as Operand2 in the descriptions of the syntax of each instruction. Operand2 can be a constant or a register with optional shift.

1.2.3.1 Constant

You specify an Operand2 constant in the form:

```
#constant
```

where constant can be (X and Y are hexadecimal digits):

- Any constant that can be produced by shifting an 8-bit value left by any number of bits within a 32-bit word.
- Any constant of the form 0x00XY00XY.
- Any constant of the form 0xXY00XY00.
- Any constant of the form 0xXYXYXYXY.

**Note:** In the constants listed above, X and Y are hexadecimal digits.

In addition, in a small number of instructions, constant can take a wider range of values. These are described in the individual instruction descriptions.

When an Operand2 constant is used with the instructions MOVs, MVNS, ANDs, ORRs, ORNs, EORS, BICS, TEQ or TST, the carry flag is updated to bit[31] of the constant, if the constant is greater than 255 and can be produced by shifting an 8-bit value. These instructions do not affect the carry flag if Operand2 is any other constant.
Your assembler might be able to produce an equivalent instruction in cases where you specify a constant that is not permitted. For example, an assembler might assemble the instruction `CMP Rd, #0xFFFFFFFEE` as the equivalent instruction `CMN Rd, #0x2`.

### 1.2.3.2 Register With Optional Shift

You specify an *Operand2* register in the form:

```
Rm {, shift}
```

where:

- `Rm` is the register holding the data for the second operand.

- `shift` is an optional shift to be applied to `Rm`. It can be one of:
  - `ASR #n`  
    Arithmetic shift right `n` bits, `1 ≤ n ≤ 32`.
  - `LSL #n`  
    Logical shift left `n` bits, `1 ≤ n ≤ 31`.
  - `LSR #n`  
    Logical shift right `n` bits, `1 ≤ n ≤ 32`.
  - `ROR #n`  
    Rotate right `n` bits, `1 ≤ n ≤ 31`.
  - `RRX`  
    Rotate right one bit, with extend.
  - `-` If omitted, no shift occurs; equivalent to `LSL #0`.

If you omit the shift, or specify `LSL #0`, the instruction uses the value in `Rm`.

If you specify a shift, the shift is applied to the value in `Rm`, and the resulting 32-bit value is used by the instruction. However, the contents in the register `Rm` remain unchanged. Specifying a register with shift also updates the carry flag when used with certain instructions. For information on the shift operations and how they affect the carry flag, see “Shift Operations” on page 28.

### 1.2.4 Shift Operations

Register shift operations move the bits in a register left or right by a specified number of bits, the *shift length*. Register shift can be performed:

- **Directly by the instructions** `ASR`, `LSR`, `LSL`, `ROR`, and `RRX`, and the result is written to a destination register.

- During the calculation of *Operand2* by the instructions that specify the second operand as a register with shift (see “Flexible Second Operand” on page 27). The result is used by the instruction.
The permitted shift lengths depend on the shift type and the instruction (see the individual instruction description or see “Flexible Second Operand” on page 27). If the shift length is 0, no shift occurs. Register shift operations update the carry flag except when the specified shift length is 0. The following sub-sections describe the various shift operations and how they affect the carry flag. In these descriptions, \( Rm \) is the register containing the value to be shifted, and \( n \) is the shift length.

### 1.2.4.1 ASR

An arithmetic shift right (ASR) by \( n \) bits moves the left-hand \( 32-n \) bits of the register \( Rm \), to the right by \( n \) places, into the right-hand \( 32-n \) bits of the result. And it copies the original bit[31] of the register into the left-hand \( n \) bits of the result. See Figure 1-2 on page 29.

You can use the \texttt{ASR} \#n operation to divide the value in the register \( Rm \) by \( 2^n \), with the result being rounded towards negative-infinity.

When the instruction is \texttt{ASRS} or when ASR \#n is used in \textit{Operand2} with the instructions \texttt{MOVS}, \texttt{MVNS}, \texttt{ANDS}, \texttt{ORRS}, \texttt{ORNS}, \texttt{EORS}, \texttt{BICS}, \texttt{TEQ} or \texttt{TST}, the carry flag is updated to the last bit shifted out, bit[\( n-1 \)], of the register \( Rm \).

**Note:**
- If \( n \) is 32 or more, then all the bits in the result are set to the value of bit[31] of \( Rm \).
- If \( n \) is 32 or more and the carry flag is updated, it is updated to the value of bit[31] of \( Rm \).

![Figure 1-2. ASR #3](image)

### 1.2.4.2 LSR

A logical shift right (LSR) by \( n \) bits moves the left-hand \( 32-n \) bits of the register \( Rm \), to the right by \( n \) places, into the right-hand \( 32-n \) bits of the result. And it sets the left-hand \( n \) bits of the result to 0. See Figure 1-3 on page 30.

You can use the \texttt{LSR} \#n operation to divide the value in the register \( Rm \) by \( 2^n \), if the value is regarded as an unsigned integer.

When the instruction is \texttt{LSRS} or when LSR \#n is used in \textit{Operand2} with the instructions \texttt{MOVS}, \texttt{MVNS}, \texttt{ANDS}, \texttt{ORRS}, \texttt{ORNS}, \texttt{EORS}, \texttt{BICS}, \texttt{TEQ} or \texttt{TST}, the carry flag is updated to the last bit shifted out, bit[\( n-1 \)], of the register \( Rm \).

**Note:**
- If \( n \) is 32 or more, then all the bits in the result are cleared to 0.
- If \( n \) is 33 or more and the carry flag is updated, it is updated to 0.
1.2.4.3 LSL

A logical shift left (LSL) by $n$ bits moves the right-hand $32-n$ bits of the register $Rm$, to the left by $n$ places, into the left-hand $32-n$ bits of the result. And it sets the right-hand $n$ bits of the result to 0. See Figure 1-4 on page 30.

You can use the LSL #n operation to multiply the value in the register $Rm$ by $2^n$, if the value is regarded as an unsigned integer or a two’s complement signed integer. Overflow can occur without warning.

When the instruction is LSLS or when LSL #n, with non-zero $n$, is used in Operand2 with the instructions MOVS, MVNS, ANDS, ORRS, ORNS, EORS, BICS, TEQ or TST, the carry flag is updated to the last bit shifted out, bit[32-n], of the register $Rm$. These instructions do not affect the carry flag when used with LSL #0.

Note:  
- If $n$ is 32 or more, then all the bits in the result are cleared to 0.
- If $n$ is 33 or more and the carry flag is updated, it is updated to 0.

1.2.4.4 ROR

A rotate right (ROR) by $n$ bits moves the left-hand $32-n$ bits of the register $Rm$, to the right by $n$ places, into the right-hand $32-n$ bits of the result. And it moves the right-hand $n$ bits of the register into the left-hand $n$ bits of the result. See Figure 1-5 on page 31.

When the instruction is RORS or when ROR #n is used in Operand2 with the instructions MOVS, MVNS, ANDS, ORRS, ORNS, EORS, BICS, TEQ, or TST, the carry flag is updated to the last bit rotation, bit[n-1], of the register $Rm$.

Note:  
- If $n$ is 32, then the value of the result is the same as the value in $Rm$, and if the carry flag is updated, it is updated to bit[31] of $Rm$.
- ROR with shift length, $n$, more than 32 is the same as ROR with shift length $n-32$. 

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November 04, 2011
### 1.2.4.5 RRX

A rotate right with extend (RRX) moves the bits of the register $R_m$ to the right by one bit. And it copies the carry flag into bit[31] of the result. See Figure 1-6 on page 31.

When the instruction is RRXS or when RRX is used in Operand2 with the instructions MOVs, MVNS, ANDs, ORRs, ORNs, EORS, BICS, TEQ, or TST, the carry flag is updated to bit[0] of the register $R_m$.

### 1.2.5 Address Alignment

An aligned access is an operation where a word-aligned address is used for a word, dual word, or multiple word access, or where a halfword-aligned address is used for a halfword access. Byte accesses are always aligned.

The Cortex-M3/M4F processors support unaligned access only for the following instructions:

- LDR, LDRT
- LDRH, LDRHT
- LDRSH, LDRSHT
- STR, STRT
- STRH, STRHT

All other load and store instructions generate a usage fault exception if they perform an unaligned access, and therefore their accesses must be address aligned. For more information about usage faults, see "Fault Handling" in the Stellaris® Data Sheet.

Unaligned accesses are usually slower than aligned accesses. In addition, some memory regions might not support unaligned accesses. Therefore, ARM recommends that programmers ensure that accesses are aligned. To avoid accidental generation of unaligned accesses, use the UNALIGNED bit in the Configuration and Control (CFGCTRL) register to trap all unaligned accesses (see CFGCTRL in the Stellaris® Data Sheet).
1.2.6 PC-Relative Expressions

A PC-relative expression or *label* is a symbol that represents the address of an instruction or literal data. It is represented in the instruction as the PC value plus or minus a numeric offset. The assembler calculates the required offset from the label and the address of the current instruction. If the offset is too big, the assembler produces an error.

**Note:**
- For **B**, **BL**, **CBNZ**, and **CBZ** instructions, the value of the PC is the address of the current instruction plus 4 bytes.
- For all other instructions that use labels, the value of the PC is the address of the current instruction plus 4 bytes, with bit[1] of the result cleared to 0 to make it word-aligned.
- Your assembler might permit other syntaxes for PC-relative expressions, such as a label plus or minus a number, or an expression of the form [PC, #number].

1.2.7 Conditional Execution

Most data processing instructions can optionally update the condition flags in the Application Program Status Register (APSR) register according to the result of the operation (see APSR in the Stellaris® Data Sheet). Some instructions update all flags, and some only update a subset. If a flag is not updated, the original value is preserved. See the instruction descriptions for the flags they affect.

You can execute an instruction conditionally, based on the condition flags set in another instruction, either immediately after the instruction that updated the flags, or after any number of intervening instructions that have not updated the flags.

Conditional execution is available by using conditional branches or by adding condition code suffixes to instructions. See Table 1-2 on page 33 for a list of the suffixes to add to instructions to make them conditional instructions. The condition code suffix enables the processor to test a condition based on the flags. If the condition test of a conditional instruction fails, the instruction:

- Does not execute
- Does not write any value to its destination register
- Does not affect any of the flags
- Does not generate any exception

Conditional instructions, except for conditional branches, must be inside an If-Then instruction block. See "IT" on page 203 for more information and restrictions when using the IT instruction. Depending on the vendor, the assembler might automatically insert an IT instruction if you have conditional instructions outside the IT block. See "IT" on page 203 for more on the IT block.

Use the **CBZ** and **CBNZ** instructions to compare the value of a register against zero and branch on the result.

1.2.7.1 Condition Flags

The Application Program Status Register (APSR) contains the following condition flags:

- **N.** Set to 1 when the result of the operation was negative; cleared to 0 otherwise.
- **Z.** Set to 1 when the result of the operation was zero; cleared to 0 otherwise.
C. Set to 1 when the operation resulted in a carry; cleared to 0 otherwise.

V. Set to 1 when the operation caused overflow; cleared to 0 otherwise.

For more information about APSR, see the Stellaris® Data Sheet.

A carry occurs:

- If the result of an addition is greater than or equal to $2^{32}$
- If the result of a subtraction is positive or zero
- As the result of an inline barrel shifter operation in a move or logical instruction

Overflow occurs if the result of an add, subtract, or compare is greater than or equal to $2^{31}$, or less than $-2^{31}$.

Note: Most instructions update the status flags only if the S suffix is specified. See the instruction descriptions for more information.

### 1.2.7.2 Condition Code Suffixes

The instructions that can be conditional have an optional condition code, shown in syntax descriptions as `{cond}`. Conditional execution requires a preceding **IT** instruction. An instruction with a condition code is only executed if the condition code flags in APSR meet the specified condition. Table 1-2 on page 33 shows the condition codes to use.

You can use conditional execution with the **IT** instruction to reduce the number of branch instructions in code.

Table 1-2 on page 33 also shows the relationship between condition code suffixes and the **N**, **Z**, **C**, and **V** flags.

### Table 1-2. Condition Code Suffixes

<table>
<thead>
<tr>
<th>Suffix</th>
<th>Flags</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>EQ</td>
<td>$Z = 1$</td>
<td>Equal</td>
</tr>
<tr>
<td>NE</td>
<td>$Z = 0$</td>
<td>Not equal</td>
</tr>
<tr>
<td>CS or HS</td>
<td>$C = 1$</td>
<td>Higher or same, unsigned $\geq$</td>
</tr>
<tr>
<td>CC or LO</td>
<td>$C = 0$</td>
<td>Lower, unsigned $&lt;$</td>
</tr>
<tr>
<td>MI</td>
<td>$N = 1$</td>
<td>Negative</td>
</tr>
<tr>
<td>PL</td>
<td>$N = 0$</td>
<td>Positive or zero</td>
</tr>
<tr>
<td>VS</td>
<td>$V = 1$</td>
<td>Overflow</td>
</tr>
<tr>
<td>VC</td>
<td>$V = 0$</td>
<td>No overflow</td>
</tr>
<tr>
<td>HI</td>
<td>$C = 1 \ and \ Z = 0$</td>
<td>Higher, unsigned $&gt;$</td>
</tr>
<tr>
<td>LS</td>
<td>$C = 0 \ or \ Z = 1$</td>
<td>Lower or same, unsigned $\leq$</td>
</tr>
<tr>
<td>GE</td>
<td>$N = V$</td>
<td>Greater than or equal, signed $\geq$</td>
</tr>
<tr>
<td>LT</td>
<td>$N \neq V$</td>
<td>Less than, signed $&lt;$</td>
</tr>
<tr>
<td>GT</td>
<td>$Z = 0 \ and \ N = V$</td>
<td>Greater than, signed $&gt;$</td>
</tr>
<tr>
<td>LE</td>
<td>$Z = 1 \ and \ N \neq V$</td>
<td>Less than or equal, signed $\leq$</td>
</tr>
<tr>
<td>AL</td>
<td></td>
<td>Can have any value</td>
</tr>
</tbody>
</table>
Example 1-1, “Absolute Value” on page 34 shows the use of a conditional instruction to find the absolute value of a number. \( R0 = \text{ABS}(R1) \).

**Example 1-1. Absolute Value**

```
MOV S R0, R1          ; R0 = R1, setting flags.
IT MI                 ; IT instruction for the negative condition.
RSBMI R0, R1, #0      ; If negative, R0 = -R1.
```

Example 1-2, “Compare and Update Value” on page 34 shows the use of conditional instructions to update the value of \( R4 \) if the signed value \( R0 \) is greater than \( R1 \) and \( R2 \) is greater than \( R3 \).

**Example 1-2. Compare and Update Value**

```
CMP R0, R1            ; Compare R0 and R1, setting flags
ITT GT                ; IT instruction for the two GT conditions
CMPGT R2, R3          ; If 'greater than', compare R2 and R3, setting flags
MOVGT R4, R5          ; If still 'greater than', do R4 = R5
```

1.2.8 **Instruction Width Selection**

There are many instructions that can generate either a 16-bit encoding or a 32-bit encoding depending on the operands and destination register specified. For some of these instructions, you can force a specific instruction size by using an instruction width suffix. The \( .W \) suffix forces a 32-bit instruction encoding. The \( .N \) suffix forces a 16-bit instruction encoding.

If you specify an instruction width suffix and the assembler cannot generate an instruction encoding of the requested width, it generates an error.

**Note:** In some cases it might be necessary to specify the \( .W \) suffix, for example if the operand is the label of an instruction or literal data, as in the case of branch instructions. This is because the assembler might not automatically generate the right size encoding.

To use an instruction width suffix, place it immediately after the instruction mnemonic and condition code, if any. Example 1-3, “Instruction Width Selection” on page 34 shows instructions with the instruction width suffix.

**Example 1-3. Instruction Width Selection**

```
BCS.W label           ; creates a 32-bit instruction even for a short branch
ADDS.W R0, R0, R1     ; creates a 32-bit instruction even though the same
                       ; operation can be done by a 16-bit instruction
```
## 2 Memory Access Instructions

Table 2-1 on page 35 shows the memory access instructions:

### Table 2-1. Memory Access Instructions

<table>
<thead>
<tr>
<th>Mnemonic</th>
<th>Brief Description</th>
<th>See Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>ADR</td>
<td>Load PC-relative address</td>
<td>36</td>
</tr>
<tr>
<td>CLREX</td>
<td>Clear exclusive</td>
<td>52</td>
</tr>
<tr>
<td>LDM{mode}</td>
<td>Load multiple registers</td>
<td>46</td>
</tr>
<tr>
<td>LDR{type}</td>
<td>Load register using immediate offset</td>
<td>37</td>
</tr>
<tr>
<td>LDR{type}</td>
<td>Load register using register offset</td>
<td>40</td>
</tr>
<tr>
<td>LDR{type}T</td>
<td>Load register with unprivileged access</td>
<td>42</td>
</tr>
<tr>
<td>LDR{type}</td>
<td>Load register using PC-relative address</td>
<td>44</td>
</tr>
<tr>
<td>LDRD</td>
<td>Load register using PC-relative address (two words)</td>
<td>44</td>
</tr>
<tr>
<td>LDREX{type}</td>
<td>Load register exclusive</td>
<td>50</td>
</tr>
<tr>
<td>POP</td>
<td>Pop registers from stack</td>
<td>48</td>
</tr>
<tr>
<td>PUSH</td>
<td>Push registers onto stack</td>
<td>48</td>
</tr>
<tr>
<td>STM{mode}</td>
<td>Store multiple registers</td>
<td>46</td>
</tr>
<tr>
<td>STR{type}</td>
<td>Store register using immediate offset</td>
<td>37</td>
</tr>
<tr>
<td>STR{type}</td>
<td>Store register using register offset</td>
<td>40</td>
</tr>
<tr>
<td>STR{type}T</td>
<td>Store register with unprivileged access</td>
<td>42</td>
</tr>
<tr>
<td>STREX{type}</td>
<td>Store register exclusive</td>
<td>50</td>
</tr>
</tbody>
</table>
2.1 ADR
Generate PC-relative address.

<table>
<thead>
<tr>
<th>Applies to...</th>
<th>M3</th>
<th>M4</th>
<th>M4F</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
</tr>
</tbody>
</table>

2.1.1 Syntax

ADR\{cond\} Rd, label

where:

cond
Is an optional condition code. See Table 1-2 on page 33.

Rd
Is the destination register.

label
Is a PC-relative expression. See "PC-Relative Expressions" on page 32.

2.1.2 Operation

ADR determines the address by adding an immediate value to the PC, and writes the result to the destination register.

ADR produces position-independent code, because the address is PC-relative.

If you use ADR to generate a target address for a BX or BLX instruction, you must ensure that bit[0] of the address you generate is set to 1 for correct execution.

Values of label must be within the range of −4095 to +4095 from the address in the PC.

Note: You might have to use the .W suffix to get the maximum offset range or to generate addresses that are not word-aligned. See "Instruction Width Selection" on page 34.

2.1.3 Restrictions

Rd must not be SP and must not be PC.

2.1.4 Condition Flags

This instruction does not change the flags.

2.1.5 Examples

ADR R1, TextMessage ; Write address value of a location labeled as TextMessage to R1.
2.2 LDR and STR (Immediate Offset)

Load and Store with immediate offset, pre-indexed immediate offset, or post-indexed immediate offset.

<table>
<thead>
<tr>
<th>Applies to...</th>
<th>M3</th>
<th>M4</th>
<th>M4F</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

2.2.1 Syntax

\[
\begin{align*}
op\{type\}\{cond\} \ Rt, \ [Rn \{, \#offset\}] & \quad ; \text{immediate offset} \\
op\{type\}\{cond\} \ Rt, \ [Rn, \#offset]! & \quad ; \text{pre-indexed} \\
op\{type\}\{cond\} \ Rt, \ [Rn], \#offset & \quad ; \text{post-indexed} \\
opD\{cond\} \ Rt, \ Rt2, \ [Rn \{, \#offset\}] & \quad ; \text{immediate offset, two words} \\
opD\{cond\} \ Rt, \ Rt2, \ [Rn, \#offset]! & \quad ; \text{pre-indexed, two words} \\
opD\{cond\} \ Rt, \ Rt2, \ [Rn], \#offset & \quad ; \text{post-indexed, two words}
\end{align*}
\]

where:

- **op**
  Is one of:
  
  \[
  \begin{align*}
  \text{LDR} & \quad \text{Load Register.} \\
  \text{STR} & \quad \text{Store Register.}
  \end{align*}
  \]

- **type**
  Is one of:
  
  \[
  \begin{align*}
  B & \quad \text{Unsigned byte, zero extend to 32 bits on loads.} \\
  SB & \quad \text{Signed byte, sign extend to 32 bits (LDR only).} \\
  H & \quad \text{Unsigned halfword, zero extend to 32 bits on loads.} \\
  SH & \quad \text{Signed halfword, sign extend to 32 bits (LDR only).} \\
  - & \quad \text{Omit, for word.}
  \end{align*}
  \]

- **cond**
  Is an optional condition code. See Table 1-2 on page 33.
Load and store instructions with immediate offset can use the following addressing modes:

Offset addressing
The offset value is added to or subtracted from the address obtained from the register \( Rn \). The result is used as the address for the memory access. The register \( Rn \) is unaltered. The assembly language syntax for this mode is:

\[
[Rn, \#\text{offset}]
\]

Pre-indexed addressing
The offset value is added to or subtracted from the address obtained from the register \( Rn \). The result is used as the address for the memory access and written back into the register \( Rn \). The assembly language syntax for this mode is:

\[
[Rn, \#\text{offset}]!
\]

Post-indexed addressing
The address obtained from the register \( Rn \) is used as the address for the memory access. The offset value is added to or subtracted from the address, and written back into the register \( Rn \). The assembly language syntax for this mode is:

\[
[Rn], \#\text{offset}
\]

The value to load or store can be a byte, halfword, word, or two words. Bytes and halfwords can either be signed or unsigned. See “Address Alignment” on page 31.

Table 2-2 on page 38 shows the ranges of offset for immediate, pre-indexed and post-indexed forms.

<table>
<thead>
<tr>
<th>Instruction Type</th>
<th>Immediate Offset</th>
<th>Pre-Indexed</th>
<th>Post-Indexed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Word, halfword, signed halfword,</td>
<td>−255 to 4095</td>
<td>−255 to 255</td>
<td>−255 to 255</td>
</tr>
<tr>
<td>byte, or signed byte</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Two words</td>
<td>Multiple of 4 in the range −1020 to 1020</td>
<td>Multiple of 4 in the range −1020 to 1020</td>
<td>Multiple of 4 in the range −1020 to 1020</td>
</tr>
</tbody>
</table>
2.2.3 Restrictions

For load instructions:

- \( Rt \) can be \( SP \) or \( PC \) for word loads only.
- \( Rt \) must be different from \( Rt_2 \) for two-word loads.
- \( Rn \) must be different from \( Rt \) and \( Rt_2 \) in the pre-indexed or post-indexed forms.

When \( Rt \) is \( PC \) in a word load instruction:

- Bit[0] of the loaded value must be 1 for correct execution.
- A branch occurs to the address created by changing bit[0] of the loaded value to 0.
- If the instruction is conditional, it must be the last instruction in the IT block.

For store instructions:

- \( Rt \) can be \( SP \) for word stores only.
- \( Rt \) must not be \( PC \).
- \( Rn \) must not be \( PC \).
- \( Rn \) must be different from \( Rt \) and \( Rt_2 \) in the pre-indexed or post-indexed forms.

2.2.4 Condition Flags

These instructions do not change the flags.

2.2.5 Examples

LDR    R8, [R10] ; Loads R8 from the address in R10.
LDRNE R2, [R5, #960]! ; Loads (conditionally) R2 from a word
                     ; 960 bytes above the address in R5, and
                     ; increments R5 by 960.
STR    R2, [R9,#const-struc] ; const-struc is an expression evaluating
                     ; to a constant in the range 0-4095.
STRH   R3, [R4], #4 ; Store R3 as halfword data into address in
                     ; R4, then increment R4 by 4.
LDRD   R8, R9, [R3, #0x20] ; Load R8 from a word 32 bytes above the
                     ; address in R3, and load R9 from a word 36
                     ; bytes above the address in R3.
STRD   R0, R1, [R8], #-16 ; Store R0 to address in R8, and store R1 to
                     ; a word 4 bytes above the address in R8,
                     ; and then decrement R8 by 16.
2.3 LDR and STR (Register Offset)

Load and Store with register offset.

<table>
<thead>
<tr>
<th>Applies to...</th>
<th>M3</th>
<th>M4</th>
<th>M4F</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

2.3.1 Syntax

\[ op\{type}\{cond\} \ Rt, [\ Rn, \ Rm \{, \ LSL \#n\}] \]

where:

- **op**
  - Is one of:
    - **LDR**
      - Load Register.
    - **STR**
      - Store Register.

- **type**
  - Is one of:
    - **B**
      - Unsigned byte, zero extend to 32 bits on loads.
    - **SB**
      - Signed byte, sign extend to 32 bits (**LDR** only).
    - **H**
      - Unsigned halfword, zero extend to 32 bits on loads.
    - **SH**
      - Signed halfword, sign extend to 32 bits (**LDR** only).
    - **-**
      - Omit, for word.

- **cond**
  - Is an optional condition code. See Table 1-2 on page 33.

- **Rt**
  - Is the register to load or store.

- **Rn**
  - Is the register on which the memory address is based.

- **Rm**
  - Is a register containing a value to be used as the offset.

- **LSL \#n**
  - Is an optional shift, with \( n \) in the range 0 to 3.
2.3.2 Operation

LDR instructions load a register with a value from memory.

STR instructions store a register value into memory.

The memory address to load from or store to is at an offset from the register \( R_n \). The offset is specified by the register \( R_m \) and can be shifted left by up to 3 bits using LSL.

The value to load or store can be a byte, halfword, or word. For load instructions, bytes and halfwords can either be signed or unsigned. See "Address Alignment" on page 31.

2.3.3 Restrictions

In these instructions:

- \( R_n \) must not be \( PC \).
- \( R_m \) must not be \( SP \) and must not be \( PC \).
- \( Rt \) can be \( SP \) only for word loads and word stores.
- \( Rt \) can be \( PC \) only for word loads.

When \( Rt \) is \( PC \) in a word load instruction:

- Bit[0] of the loaded value must be 1 for correct execution, and a branch occurs to this halfword-aligned address.
- If the instruction is conditional, it must be the last instruction in the IT block.

2.3.4 Condition Flags

These instructions do not change the flags.

2.3.5 Examples

```
STR R0, [R5, R1] ; Store value of R0 into an address equal to sum of R5 and R1.
LDRSB R0, [R5, R1, LSL #1] ; Read byte value from an address equal to sum of R5 and two times R1, sign extend it to a word value and put it in R0.
STR R0, [R1, R2, LSL #2] ; Store R0 to an address equal to sum of R1 and four times R2.
```
2.4 LDR and STR (Unprivileged Access)

Load and Store with unprivileged access.

<table>
<thead>
<tr>
<th>Applies to...</th>
<th>M3</th>
<th>M4</th>
<th>M4F</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

2.4.1 Syntax

\[ op(type)T{cond} \ Rt, [Rn \{, \#offset\}] \]; immediate offset

where:

- **op**
  - Is one of:
    - LDR
      - Load Register.
    - STR
      - Store Register.

- **type**
  - Is one of:
    - B
      - Unsigned byte, zero extend to 32 bits on loads.
    - SB
      - Signed byte, sign extend to 32 bits (LDR only).
    - H
      - Unsigned halfword, zero extend to 32 bits on loads.
    - SH
      - Signed halfword, sign extend to 32 bits (LDR only).
    - -
      - Omit, for word.

- **cond**
  - Is an optional condition code. See Table 1-2 on page 33.

- **Rt**
  - Is the register to load or store.

- **Rn**
  - Is the register on which the memory address is based.

- **offset**
  - Is an offset from \( Rn \) and can be 0 to 255. If \( offset \) is omitted, the address is the value in \( Rn \).
2.4.2 Operation

These load and store instructions perform the same function as the memory access instructions with immediate offset (see “LDR and STR (Immediate Offset)” on page 37). The difference is that these instructions have only unprivileged access even when used in privileged software.

When used in unprivileged software, these instructions behave in exactly the same way as normal memory access instructions with immediate offset.

2.4.3 Restrictions

In these instructions:

- \( R_n \) must not be \( \text{PC} \).
- \( R_t \) must not be \( \text{SP} \) and must not be \( \text{PC} \).

2.4.4 Condition Flags

These instructions do not change the flags.

2.4.5 Examples

```
STRBTEQ R4, [R7] ; Conditionally store least significant byte in
                 ; R4 to an address in R7, with unprivileged access.
LDRHT R2, [R2, #8] ; Load halfword value from an address equal to
                    ; sum of R2 and 8 into R2, with unprivileged access.
```
2.5 **LDR (PC-Relative)**

Load register from memory.

<table>
<thead>
<tr>
<th>Applies to...</th>
<th>M3</th>
<th>M4</th>
<th>M4F</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

### 2.5.1 Syntax

\[
\text{LDR}\{\text{type}\}\{\text{cond}\} \text{ Rt, label}
\]

\[
\text{LDRD}\{\text{cond}\} \text{ Rt, Rt2, label} \quad ; \text{Load two words}
\]

where:

- **type**
  - Is one of:
    - B
      - Unsigned byte, zero extend to 32 bits.
    - SB
      - Signed byte, sign extend to 32 bits.
    - H
      - Unsigned halfword, zero extend to 32 bits.
    - SH
      - Signed halfword, sign extend to 32 bits.
    - 
      - Omit, for word.

- **cond**
  - Is an optional condition code. See Table 1-2 on page 33.

- **Rt**
  - Is the register to load or store.

- **Rt2**
  - Is the second register to load or store.

- **label**
  - Is a PC-relative expression. See “PC-Relative Expressions” on page 32.

### 2.5.2 Operation

LDR loads a register with a value from a PC-relative memory address. The memory address is specified by a label or by an offset from the PC.

The value to load or store can be a byte, halfword, or word. For load instructions, bytes and halfwords can either be signed or unsigned. See "Address Alignment" on page 31.

**label** must be within a limited range of the current instruction. Table 2-3 on page 45 shows the possible offsets between **label** and the PC.
Table 2-3. Offset Ranges

<table>
<thead>
<tr>
<th>Instruction Type</th>
<th>Offset Range&lt;sup&gt;a&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Word, halfword, signed halfword, byte, signed byte</td>
<td>−4095 to 4095</td>
</tr>
<tr>
<td>Two words</td>
<td>−1020 to 1020</td>
</tr>
</tbody>
</table>

<sup>a</sup> You might have to use the .W suffix to get the maximum offset range. See “Instruction Width Selection” on page 34.

2.5.3 Restrictions

In these instructions:

- Rt can be SP or PC only for word loads.
- Rt<sub>2</sub> must not be SP and must not be PC.
- Rt must be different from Rt<sub>2</sub>.

When Rt is PC in a word load instruction:

- Bit[0] of the loaded value must be 1 for correct execution, and a branch occurs to this halfword-aligned address.
- If the instruction is conditional, it must be the last instruction in the IT block.

2.5.4 Condition Flags

These instructions do not change the flags.

2.5.5 Examples

LDR R0, LookUpTable ; Load R0 with a word of data from an address labeled as LookUpTable.
LDRSB R7, localdata ; Load a byte value from an address labeled as localdata, sign extend it to a word value, and put it in R7.
2.6 LDM and STM

Load and Store Multiple registers.

<table>
<thead>
<tr>
<th>Applies to...</th>
<th>M3</th>
<th>M4</th>
<th>M4F</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

2.6.1 Syntax

\[ op\{addr\_mode\}{\{cond\}}\ Rn(!),\ \text{reglist} \]

where:

- **op**
  - Is one of:
    - **LDM**
      - Load Multiple registers.
    - **STM**
      - Store Multiple registers.

- **addr\_mode**
  - Is any one of the following:
    - **IA**
      - Increment address After each access. This is the default.
    - **DB**
      - Decrement address Before each access.

- **cond**
  - Is an optional condition code. See Table 1-2 on page 33.

- **Rn**
  - Is the register on which the memory addresses are based.

- **!**
  - Is an optional writeback suffix. If ! is present then the final address, that is loaded from or stored to, is written back into \( Rn \).

- **reglist**
  - Is a list of one or more registers to be loaded or stored, enclosed in braces. It can contain register ranges. It must be comma separated if it contains more than one register or register range. See 47.

**LDM** and **LDMFD** are synonyms for **LDMIA**. **LDMFD** refers to its use for popping data from Full Descending stacks.

**LDMEA** is a synonym for **LDMDB**, and refers to its use for popping data from Empty Ascending stacks.

**STM** and **STMEA** are synonyms for **STMIA**. **STMEA** refers to its use for pushing data onto Empty Ascending stacks.

**STMFD** is a synonym for **STMDB**, and refers to its use for pushing data onto Full Descending stacks.
2.6.2 Operation

LDM instructions load the registers in reglist with word values from memory addresses based on \( Rn \).

STM instructions store the word values in the registers in reglist to memory addresses based on \( Rn \).

For LDM, LDMAIA, LDMAFD, STM, STMAIA, and STMEA, the memory addresses used for the accesses are at 4-byte intervals ranging from \( Rn \) to \( Rn + 4 \times (n-1) \), where \( n \) is the number of registers in reglist. The accesses happen in order of increasing register numbers, with the lowest numbered register using the lowest memory address and the highest number register using the highest memory address. If the writeback suffix is specified, the value of \( Rn + 4 \times (n-1) \) is written back to \( Rn \).

For LDMDB, LDMEA, STMDB, and STMFD, the memory addresses used for the accesses are at 4-byte intervals ranging from \( Rn \) to \( Rn - 4 \times (n-1) \), where \( n \) is the number of registers in reglist. The accesses happen in order of decreasing register numbers, with the highest numbered register using the highest memory address and the lowest number register using the lowest memory address. If the writeback suffix is specified, the value of \( Rn - 4 \times (n-1) \) is written back to \( Rn \).

The PUSH and POP instructions can be expressed in this form. See “PUSH and POP” on page 48 for details.

2.6.3 Restrictions

In these instructions:

- \( Rn \) must not be PC.
- reglist must not contain SP.
- In any STM instruction, reglist must not contain PC.
- In any LDM instruction, reglist must not contain PC if it contains LR.
- reglist must not contain \( Rn \) if you specify the writeback suffix.

When PC is in reglist in an LDM instruction:

- Bit[0] of the value loaded to the PC must be 1 for correct execution, and a branch occurs to this halfword-aligned address.
- If the instruction is conditional, it must be the last instruction in the IT block.

2.6.4 Condition Flags

These instructions do not change the flags.

2.6.5 Examples

LDM R8, {R0,R2,R9} ; LDMIA is a synonym for LDM.
STM DB R1!, {R3-R6,R11,R12}

2.6.6 Incorrect Examples

STM R5!, {R5,R4,R9} ; Value stored for R5 is unpredictable.
LDM R2, {} ; There must be at least one register in the list.
2.7  **PUSH and POP**

Push registers on and pop registers off a full-descending stack.

<table>
<thead>
<tr>
<th>Applies to...</th>
<th>M3</th>
<th>M4</th>
<th>M4F</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

### 2.7.1 Syntax

**PUSH**{cond} reglist

**POP**{cond} reglist

where:

cod

Is an optional condition code. See Table 1-2 on page 33.

reglist

Is a non-empty list of registers, enclosed in braces. It can contain register ranges. It must be comma separated if it contains more than one register or register range.

**PUSH** and **POP** are synonyms for **STMDB** and **LDM** (or **LDMIA**) with the memory addresses for the access based on SP, and with the final address for the access written back to the SP. **PUSH** and **POP** are the preferred mnemonics in these cases.

### 2.7.2 Operation

**PUSH** stores registers on the stack in order of decreasing register numbers, with the highest numbered register using the highest memory address and the lowest numbered register using the lowest memory address.

**POP** loads registers from the stack in order of increasing register numbers, with the lowest numbered register using the lowest memory address and the highest numbered register using the highest memory address.

See “LDM and STM” on page 46 for more information.

### 2.7.3 Restrictions

In these instructions:

- reglist must not contain SP.
- For the **PUSH** instruction, reglist must not contain PC.
- For the **POP** instruction, reglist must not contain PC if it contains LR.

When PC is in reglist in a **POP** instruction:

- Bit[0] of the value loaded to the PC must be 1 for correct execution, and a branch occurs to this halfword-aligned address.
- If the instruction is conditional, it must be the last instruction in the IT block.
2.7.4 Condition Flags

These instructions do not change the flags.

2.7.5 Examples

PUSH   {R0,R4–R7}
PUSH   {R2,LR}
POP    {R0,R10,PC}
2.8 LDREX and STREX
Load and Store Register Exclusive.

<table>
<thead>
<tr>
<th>Applies to...</th>
<th>M3</th>
<th>M4</th>
<th>M4F</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

2.8.1 Syntax

LDREX\(\text{cond}\) \(Rt, [Rn \{, \#\text{offset}\}]\)  
STREX\(\text{cond}\) \(Rd, Rt, [Rn \{, \#\text{offset}\}]\)  
LDREXB\(\text{cond}\) \(Rt, [Rn]\)  
STREXB\(\text{cond}\) \(Rd, Rt, [Rn]\)  
LDREXH\(\text{cond}\) \(Rt, [Rn]\)  
STREXH\(\text{cond}\) \(Rd, Rt, [Rn]\)

where:

\(\text{cond}\)  
Is an optional condition code. See Table 1-2 on page 33.

\(Rd\)  
Is the destination register for the returned status.

\(Rt\)  
Is the register to load or store.

\(Rn\)  
Is the register on which the memory address is based.

\(\text{offset}\)  
Is an optional offset applied to the value in \(Rn\). If \(\text{offset}\) is omitted, the address is the value in \(Rn\).

2.8.2 Operation

LDREX, LDREXB, and LDREXH load a word, byte, and halfword respectively from a memory address.  
STREX, STREXB, and STREXH attempt to store a word, byte, and halfword respectively to a memory address. The address used in any Store-Exclusive instruction must be the same as the address in the most recently executed Load-exclusive instruction. The value stored by the Store-Exclusive instruction must also have the same data size as the value loaded by the preceding Load-exclusive instruction. This means software must always use a Load-exclusive instruction and a matching Store-Exclusive instruction to perform a synchronization operation (see "Synchronization Primitives" in the Stellaris® Data Sheet).

If a Store-Exclusive instruction performs the store, it writes 0 to its destination register. If it does not perform the store, it writes 1 to its destination register. If the Store-Exclusive instruction writes 0 to the destination register, it is guaranteed that no other process in the system has accessed the memory location between the Load-exclusive and Store-Exclusive instructions.
For reasons of performance, keep the number of instructions between corresponding Load-Exclusive and Store-Exclusive instruction to a minimum.

**Important:** The result of executing a Store-Exclusive instruction to an address that is different from that used in the preceding Load-Exclusive instruction is unpredictable.

### 2.8.3 Restrictions

In these instructions:

- Do not use PC.
- Do not use SP for \(Rd\) and \(Rt\).
- For STREX, \(Rd\) must be different from both \(Rt\) and \(Rn\).
- The value of \(offset\) must be a multiple of four in the range 0-1020.

### 2.8.4 Condition Flags

These instructions do not change the flags.

### 2.8.5 Examples

```
MOV R1, #0x1 ; Initialize the 'lock taken' value.
try
LDREX R0, [LockAddr] ; Load the lock value.
CMP R0, #0 ; Is the lock free?
ITT EQ ; IT instruction for STREXEQ and CMPEQ.
STREXEQ R0, R1, [LockAddr] ; Try and claim the lock.
CMPEQ R0, #0 ; Did this succeed?
BNE try ; No - try again.
.... ; Yes - we have the lock.
```
2.9 CLREX

Clear Exclusive.

<table>
<thead>
<tr>
<th>Applies to...</th>
<th>M3</th>
<th>M4</th>
<th>M4F</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

2.9.1 Syntax

CLREX (cond)

where:

cond

Is an optional condition code. See Table 1-2 on page 33.

2.9.2 Operation

Use CLREX to make the next STREX, STREXB, or STREXH instruction write 1 to its destination register and fail to perform the store. It is useful in exception handler code to force the failure of the store exclusive if the exception occurs between a load exclusive instruction and the matching store exclusive instruction in a synchronization operation (see "Synchronization Primitives" in the Stellaris® Data Sheet).

2.9.3 Condition Flags

This instruction does not change the flags.

2.9.4 Examples

CLREX
3 General Data Processing Instructions

Table 3-1 on page 53 shows the data processing instructions:

Table 3-1. General Data Processing Instructions

<table>
<thead>
<tr>
<th>Mnemonic</th>
<th>Brief Description</th>
<th>See Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>ADC</td>
<td>Add with carry</td>
<td>55</td>
</tr>
<tr>
<td>ADD</td>
<td>Add</td>
<td>55</td>
</tr>
<tr>
<td>ADDW</td>
<td>Add</td>
<td>55</td>
</tr>
<tr>
<td>AND</td>
<td>Logical AND</td>
<td>58</td>
</tr>
<tr>
<td>ASR</td>
<td>Arithmetic shift right</td>
<td>60</td>
</tr>
<tr>
<td>BIC</td>
<td>Bit clear</td>
<td>58</td>
</tr>
<tr>
<td>CLZ</td>
<td>Count leading zeros</td>
<td>63</td>
</tr>
<tr>
<td>CMN</td>
<td>Compare negative</td>
<td>64</td>
</tr>
<tr>
<td>CMP</td>
<td>Compare</td>
<td>64</td>
</tr>
<tr>
<td>EOR</td>
<td>Exclusive OR</td>
<td>58</td>
</tr>
<tr>
<td>LSL</td>
<td>Logical shift left</td>
<td>60</td>
</tr>
<tr>
<td>LSR</td>
<td>Logical shift right</td>
<td>60</td>
</tr>
<tr>
<td>MOV</td>
<td>Move</td>
<td>65</td>
</tr>
<tr>
<td>MOVT</td>
<td>Move top</td>
<td>67</td>
</tr>
<tr>
<td>MOVW</td>
<td>Move 16-bit constant</td>
<td>65</td>
</tr>
<tr>
<td>MVN</td>
<td>Move NOT</td>
<td>65</td>
</tr>
<tr>
<td>ORN</td>
<td>Logical OR NOT</td>
<td>58</td>
</tr>
<tr>
<td>ORR</td>
<td>Logical OR</td>
<td>58</td>
</tr>
<tr>
<td>RBIT</td>
<td>Reverse bits</td>
<td>68</td>
</tr>
<tr>
<td>REV</td>
<td>Reverse byte order in a word</td>
<td>68</td>
</tr>
<tr>
<td>REV16</td>
<td>Reverse byte order in each halfword</td>
<td>68</td>
</tr>
<tr>
<td>REVSH</td>
<td>Reverse byte order in bottom halfword and sign extend</td>
<td>68</td>
</tr>
<tr>
<td>ROR</td>
<td>Rotate right</td>
<td>60</td>
</tr>
<tr>
<td>RRX</td>
<td>Rotate right with extend</td>
<td>60</td>
</tr>
<tr>
<td>RSB</td>
<td>Reverse subtract</td>
<td>55</td>
</tr>
<tr>
<td>SADD16</td>
<td>Signed add 16</td>
<td>70</td>
</tr>
<tr>
<td>SADD8</td>
<td>Signed add 8</td>
<td>70</td>
</tr>
<tr>
<td>SASX</td>
<td>Signed add and subtract with exchange</td>
<td>81</td>
</tr>
<tr>
<td>SSAX</td>
<td>Signed subtract and add with exchange</td>
<td>81</td>
</tr>
<tr>
<td>SBC</td>
<td>Subtract with carry</td>
<td>55</td>
</tr>
<tr>
<td>SEL</td>
<td>Select bytes</td>
<td>98</td>
</tr>
<tr>
<td>SHADD16</td>
<td>Signed halving add 16</td>
<td>72</td>
</tr>
<tr>
<td>SHADD8</td>
<td>Signed halving add 8</td>
<td>72</td>
</tr>
<tr>
<td>SHASX</td>
<td>Signed halving add and subtract with exchange</td>
<td>74</td>
</tr>
<tr>
<td>SHSAX</td>
<td>Signed halving subtract and add with exchange</td>
<td>74</td>
</tr>
<tr>
<td>SHSUB16</td>
<td>Signed halving subtract 16</td>
<td>77</td>
</tr>
<tr>
<td>SHSUB8</td>
<td>Signed halving subtract 8</td>
<td>77</td>
</tr>
</tbody>
</table>
Table 3-1. General Data Processing Instructions (continued)

<table>
<thead>
<tr>
<th>Mnemonic</th>
<th>Brief Description</th>
<th>See Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>SSUB16</td>
<td>Signed subtract 16</td>
<td>79</td>
</tr>
<tr>
<td>SSUB8</td>
<td>Signed subtract 8</td>
<td>79</td>
</tr>
<tr>
<td>SUB</td>
<td>Subtract</td>
<td>55</td>
</tr>
<tr>
<td>SUBW</td>
<td>Subtract</td>
<td>55</td>
</tr>
<tr>
<td>TEQ</td>
<td>Test equivalence</td>
<td>84</td>
</tr>
<tr>
<td>TST</td>
<td>Test</td>
<td>84</td>
</tr>
<tr>
<td>UADD16</td>
<td>Unsigned add 16</td>
<td>86</td>
</tr>
<tr>
<td>UADD8</td>
<td>Unsigned add 8</td>
<td>86</td>
</tr>
<tr>
<td>UASX</td>
<td>Unsigned add and subtract with exchange</td>
<td>88</td>
</tr>
<tr>
<td>USAX</td>
<td>Unsigned subtract and add with exchange</td>
<td>88</td>
</tr>
<tr>
<td>UHADD16</td>
<td>Unsigned halving add 16</td>
<td>91</td>
</tr>
<tr>
<td>UHADD8</td>
<td>Unsigned halving add 8</td>
<td>91</td>
</tr>
<tr>
<td>UHASX</td>
<td>Unsigned halving add and subtract with exchange</td>
<td>93</td>
</tr>
<tr>
<td>UHSAX</td>
<td>Unsigned halving subtract and add with exchange</td>
<td>93</td>
</tr>
<tr>
<td>UHSUB16</td>
<td>Unsigned halving subtract 16</td>
<td>96</td>
</tr>
<tr>
<td>UHSUB8</td>
<td>Unsigned halving subtract 8</td>
<td>96</td>
</tr>
<tr>
<td>USAD8</td>
<td>Unsigned sum of absolute differences</td>
<td>99</td>
</tr>
<tr>
<td>USADA8</td>
<td>Unsigned sum of absolute differences and accumulate</td>
<td>101</td>
</tr>
<tr>
<td>USUB16</td>
<td>Unsigned subtract 16</td>
<td>103</td>
</tr>
<tr>
<td>USUB8</td>
<td>Unsigned subtract 8</td>
<td>103</td>
</tr>
</tbody>
</table>
3.1 ADD, ADC, SUB, SBC, and RSB

Add, Add with carry, Subtract, Subtract with carry, and Reverse Subtract.

<table>
<thead>
<tr>
<th>Applies to...</th>
<th>M3</th>
<th>M4</th>
<th>M4F</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

3.1.1 Syntax

\[
\text{op}(S)\{\text{cond}\} \{Rd,\} \ Rn, \ \text{Operand2} \\
\text{op}\{\text{cond}\} \{Rd,\} \ Rn, \ #\text{imm12} \quad ; \text{ADD and SUB only}
\]

where:

- **op**
  - Is one of:
    - **ADD**
      - Add.
    - **ADC**
      - Add with Carry.
    - **SUB**
      - Subtract.
    - **SBC**
      - Subtract with Carry.
    - **RSB**
      - Reverse Subtract.

- **S**
  - Is an optional suffix. If S is specified, the condition code flags are updated on the result of the operation. See 32.

- **cond**
  - Is an optional condition code. See Table 1-2 on page 33.

- **Rd**
  - Is the destination register. If Rd is omitted, the destination register is Rn.

- **Rn**
  - Is the register holding the first operand.

- **Operand2**
  - Is a flexible second operand. See "Flexible Second Operand" on page 27 for details of the options.

- **imm12**
  - Is any value in the range 0-4095.
3.1.2 Operation
The **ADD** instruction adds the value of **Operand2** or **imm12** to the value in **Rn**.
The **ADC** instruction adds the values in **Rn** and **Operand2**, together with the carry flag.
The **SUB** instruction subtracts the value of **Operand2** or **imm12** from the value in **Rn**.
The **SBC** instruction subtracts the value of **Operand2** from the value in **Rn**. If the carry flag is clear, the result is reduced by one.
The **RSB** instruction subtracts the value in **Rn** from the value of **Operand2**. This is useful because of the wide range of options for **Operand2**.

Use **ADC** and **SBC** to synthesize multiword arithmetic. See 57.

See also 36.

**Note:** **ADDW** is equivalent to the **ADD** syntax that uses the **imm12** operand. **SUBW** is equivalent to the **SUB** syntax that uses the **imm12** operand.

3.1.3 Restrictions
In these instructions:

- **Operand2** must not be **SP** and must not be **PC**.

- **Rd** can be **SP** only in **ADD** and **SUB**, and only with the additional restrictions:
  - **Rn** must also be **SP**.
  - any shift in **Operand2** must be limited to a maximum of 3 bits using **LSL**.

- **Rn** can be **SP** only in **ADD** and **SUB**.

- **Rd** can be **PC** only in the **ADD{cond} PC, PC, Rm** instruction where:
  - You must not specify the S suffix.
  - **Rm** must not be **PC** and must not be **SP**.
  - If the instruction is conditional, it must be the last instruction in the **IT** block.

- With the exception of the **ADD{cond} PC, PC, Rm** instruction, **Rn** can be **PC** only in **ADD** and **SUB**, and only with the additional restrictions:
  - You must not specify the S suffix.
  - The second operand must be a constant in the range 0 to 4095.

**Note:**
- When using the **PC** for an addition or a subtraction, bits[1:0] of the **PC** are rounded to b00 before performing the calculation, making the base address for the calculation word-aligned.
- If you want to generate the address of an instruction, you have to adjust the constant based on the value of the PC. ARM recommends that you use the **ADR** instruction instead of **ADD** or **SUB** with **Rn** equal to the PC, because your assembler automatically calculates the correct constant for the **ADR** instruction.
When \emph{Rd is PC} in the \texttt{ADD\{cond\} PC, PC, Rm} instruction:

- Bit[0] of the value written to the \emph{PC} is ignored.
- A branch occurs to the address created by forcing bit[0] of that value to 0.

### 3.1.4 Condition Flags

If \emph{S} is specified, these instructions update the \emph{N}, \emph{Z}, \emph{C} and \emph{V} flags according to the result.

### 3.1.5 Examples

\begin{verbatim}
ADD    R2, R1, R3
SUBS   R8, R6, #240 ; Sets the flags on the result.
RSB    R4, R4, #1280 ; Subtracts contents of R4 from 1280.
ADCHI  R11, R0, R3 ; Only executed if C flag set and Z flag clear.
\end{verbatim}

### 3.1.6 Multiword Arithmetic Examples

Example 3-1, “64-Bit Addition” on page 57 shows two instructions that add a 64-bit integer contained in \emph{R2} and \emph{R3} to another 64-bit integer contained in \emph{R0} and \emph{R1}, and place the result in \emph{R4} and \emph{R5}.

**Example 3-1. 64-Bit Addition**

\begin{verbatim}
ADDS   R4, R0, R2 ; Add the least significant words.
ADC    R5, R1, R3 ; Add the most significant words with carry.
\end{verbatim}

Multiword values do not have to use consecutive registers. Example 3-2, “96-Bit Subtraction” on page 57 shows instructions that subtract a 96-bit integer contained in \emph{R9}, \emph{R1}, and \emph{R11} from another contained in \emph{R6}, \emph{R2}, and \emph{R8}. The example stores the result in \emph{R6}, \emph{R9}, and \emph{R2}.

**Example 3-2. 96-Bit Subtraction**

\begin{verbatim}
SUBS   R6, R6, R9 ; Subtract the least significant words.
SBCS   R9, R2, R1 ; Subtract the middle words with carry.
SBC    R2, R8, R11 ; Subtract the most significant words with carry.
\end{verbatim}
3.2 AND, ORR, EOR, BIC, and ORN

Logical AND, OR, Exclusive OR, Bit Clear, and OR NOT.

<table>
<thead>
<tr>
<th>Applies to...</th>
<th>M3</th>
<th>M4</th>
<th>M4F</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

3.2.1 Syntax

\[ op(S)\{cond\} \{Rd,\} Rn, \text{Operand2} \]

where:

\( op \)

Is one of:

- **AND**
  Logical AND.

- **ORR**
  Logical OR, or bit set.

- **EOR**
  Logical Exclusive OR.

- **BIC**
  Logical AND NOT, or bit clear.

- **ORN**
  Logical OR NOT.

\( S \)

Is an optional suffix. If \( S \) is specified, the condition code flags are updated on the result of the operation. See 32.

\( cond \)

Is an optional condition code. See Table 1-2 on page 33.

\( Rd \)

Is the destination register.

\( Rn \)

Is the register holding the first operand.

\( \text{Operand2} \)

Is a flexible second operand. See “Flexible Second Operand” on page 27 for details of the options.

3.2.2 Operation

The **AND**, **EOR**, and **ORR** instructions perform bitwise AND, Exclusive OR, and OR operations on the values in \( Rn \) and \( \text{Operand2} \).

The **BIC** instruction performs an AND operation on the bits in \( Rn \) with the complements of the corresponding bits in the value of \( \text{Operand2} \).
The ORN instruction performs an OR operation on the bits in \( Rn \) with the complements of the corresponding bits in the value of Operand2.

### 3.2.3 Restrictions
Do not use SP and do not use PC.

### 3.2.4 Condition Flags
If S is specified, these instructions:
- Update the \( N \) and \( Z \) flags according to the result.
- Can update the \( C \) flag during the calculation of Operand2. See “Flexible Second Operand” on page 27.
- Do not affect the \( V \) flag.

### 3.2.5 Examples

AND R9, R2, #0xFF00
ORREQ R2, R0, R5
ANDS R9, R8, #0x19
EORS R7, R11, #0x18181818
BIC R0, R1, #0xab
ORN R7, R11, R14, ROR #4
ORNS R7, R11, R14, ASR #32
3.3 **ASR, LSL, LSR, ROR, and RRX**

Arithmetic Shift Right, Logical Shift Left, Logical Shift Right, Rotate Right, and Rotate Right with Extend.

<table>
<thead>
<tr>
<th>Applies to</th>
<th>M3</th>
<th>M4</th>
<th>M4F</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

### 3.3.1 Syntax

\[ op(S)(cond) \text{ Rd, Rm, Rs} \]

\[ op(S)(cond) \text{ Rd, Rm, \#n} \]

\[ RRX(S)(cond) \text{ Rd, Rm} \]

**where:**

- **op**
  - Is one of:
    - **ASR**
      - Arithmetic Shift Right.
    - **LSL**
      - Logical Shift Left.
    - **LSR**
      - Logical Shift Right.
    - **ROR**
      - Rotate Right.

- **S**
  - Is an optional suffix. If S is specified, the condition code flags are updated on the result of the operation. See 32.

- **Rd**
  - Is the destination register.

- **Rm**
  - Is the register holding the value to be shifted.

- **Rs**
  - Is the register holding the shift length to apply to the value in \( Rm \). Only the least significant byte is used and can be in the range 0 to 255.

- **n**
  - Is the shift length. The range of shift length depends on the instruction:
    - **ASR**
      - Shift length from 1 to 32.
    - **LSL**
      - Shift length from 0 to 31.
LSR
Shift length from 1 to 32.

ROR
Shift length from 1 to 31.

**Note:** MOV(S){cond} Rd, Rm is the preferred syntax for LSL(S){cond} Rd, Rm, #0.
3.3.2 Operation

ASR, LSL, LSR, and ROR move the bits in the register $Rm$ to the left or right by the number of places specified by constant $n$ or register $Rs$.

RRX moves the bits in register $Rm$ to the right by 1.

In all these instructions, the result is written to $Rd$, but the value in register $Rm$ remains unchanged. For details on what result is generated by the different instructions, see “Shift Operations” on page 28.

3.3.3 Restrictions

Do not use SP and do not use PC.

3.3.4 Condition Flags

If S is specified:

- These instructions update the $N$ and $Z$ flags according to the result.
- The $C$ flag is updated to the last bit shifted out, except when the shift length is 0. See “Shift Operations” on page 28.

3.3.5 Examples

ASR R7, R8, #9 ; Arithmetic shift right by 9 bits.
LSLS R1, R2, #3 ; Logical shift left by 3 bits with flag update.
LSR R4, R5, #6 ; Logical shift right by 6 bits.
ROR R4, R5, R6 ; Rotate right by the value in the bottom byte of R6.
RRX R4, R5 ; Rotate right with extend.
3.4 CLZ
Count Leading Zeros.

<table>
<thead>
<tr>
<th>Applies to...</th>
<th>M3</th>
<th>M4</th>
<th>M4F</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

3.4.1 Syntax

CLZ (cond) Rd, Rm

where:

cond
Is an optional condition code. See Table 1-2 on page 33.

Rd
Is the destination register.

Rm
Is the operand register.

3.4.2 Operation

The CLZ instruction counts the number of leading zeros in the value in Rm and returns the result in Rd. The result value is 32 if no bits are set in the source register, and zero if bit[31] is set.

3.4.3 Restrictions

Do not use SP and do not use PC.

3.4.4 Condition Flags

This instruction does not change the flags.

3.4.5 Examples

CLZ R4, R9
CLZNE R2, R3
3.5  CMP and CMN

Compare and Compare Negative.

<table>
<thead>
<tr>
<th>Applies to...</th>
<th>M3</th>
<th>M4</th>
<th>M4F</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

3.5.1  Syntax

\[
\text{CMP} \{\text{cond}\} \ Rn, \ \text{Operand2} \\
\text{CMN} \{\text{cond}\} \ Rn, \ \text{Operand2}
\]

where:

\text{cond}  
Is an optional condition code. See Table 1-2 on page 33.

\text{Rn}  
Is the register holding the first operand.

\text{Operand2}  
Is a flexible second operand. See “Flexible Second Operand” on page 27 for details of the options.

3.5.2  Operation

These instructions compare the value in a register with \text{Operand2}. They update the condition flags on the result, but do not write the result to a register.

The \text{CMP} instruction subtracts the value of \text{Operand2} from the value in \text{Rn}. This is the same as a \text{SUBS} instruction, except that the result is discarded.

The \text{CMN} instruction adds the value of \text{Operand2} to the value in \text{Rn}. This is the same as an \text{ADDS} instruction, except that the result is discarded.

3.5.3  Restrictions

In these instructions:

- Do not use \text{PC}.

- \text{Operand2} must not be \text{SP}.

3.5.4  Condition Flags

These instructions update the \text{N}, \text{Z}, \text{C} and \text{V} flags according to the result.

3.5.5  Examples

\[
\begin{align*}
\text{CMP} & \quad \text{R2}, \text{R9} \\
\text{CMN} & \quad \text{R0}, \ #6400 \\
\text{CMPGT} & \quad \text{SP}, \text{R7}, \text{LSL} \ #2
\end{align*}
\]
3.6 MOV and MVN

Move and Move NOT.

<table>
<thead>
<tr>
<th>Applies to...</th>
<th>M3</th>
<th>M4</th>
<th>M4F</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

3.6.1 Syntax

\[
\text{MOV(S)}\{\text{cond}\} \ R_d, \ \text{Operand2} \\
\text{MOV}\{\text{cond}\} \ R_d, \ #\text{imm16} \\
\text{MVN(S)}\{\text{cond}\} \ R_d, \ \text{Operand2}
\]

where:

- **S**
  - Is an optional suffix. If S is specified, the condition code flags are updated on the result of the operation. See 32.

- **cond**
  - Is an optional condition code. See Table 1-2 on page 33.

- **Rd**
  - Is the destination register.

- **Operand2**
  - Is a flexible second operand. See “Flexible Second Operand” on page 27 for details of the options.

- **imm16**
  - Is any value in the range 0-65535.

3.6.2 Operation

The MOV instruction copies the value of Operand2 into Rd.

When Operand2 in a MOV instruction is a register with a shift other than LSL #0, the preferred syntax is the corresponding shift instruction:

<table>
<thead>
<tr>
<th>MOV Instruction</th>
<th>Preferred Syntax using Shift Instruction</th>
</tr>
</thead>
<tbody>
<tr>
<td>MOV(S){cond} Rd, Rm, ASR #n</td>
<td>ASR(S){cond} Rd, Rm, #n</td>
</tr>
<tr>
<td>MOV(S){cond} Rd, Rm, LSL #n (if n != 0)</td>
<td>LSL(S){cond} Rd, Rm, #n</td>
</tr>
<tr>
<td>MOV(S){cond} Rd, Rm, LSR #n</td>
<td>LSR(S){cond} Rd, Rm, #n</td>
</tr>
<tr>
<td>MOV(S){cond} Rd, Rm, ROR #n</td>
<td>ROR(S){cond} Rd, Rm, #n</td>
</tr>
<tr>
<td>MOV(S){cond} Rd, Rm, RRX</td>
<td>RRX(S){cond} Rd, Rm</td>
</tr>
</tbody>
</table>

Also, the MOV instruction permits additional forms of Operand2 as synonyms for shift instructions. See “ASR, LSL, LSR, ROR, and RRX” on page 60.

<table>
<thead>
<tr>
<th>Shift Instruction</th>
<th>MOV Instruction Synonym</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASR(S){cond} Rd, Rm, Rs</td>
<td>MOV(S){cond} Rd, Rm, ASR Rs</td>
</tr>
</tbody>
</table>
The \texttt{MVN} instruction takes the value of \textit{Operand2}, performs a bitwise logical NOT operation on the value, and places the result into \textit{Rd}.

\textbf{Note:} The \texttt{MOVW} instruction provides the same function as \texttt{MOV}, but is restricted to using the \textit{imm16} operand.

### 3.6.3 Restrictions

You can use \texttt{SP} and \texttt{PC} only in the \texttt{MOV} instruction, with the following restrictions:

- The second operand must be a register without shift
- You must not specify the S suffix.

When \textit{Rd} is \texttt{PC} in a \texttt{MOV} instruction:

- Bit[0] of the value written to the \texttt{PC} is ignored
- A branch occurs to the address created by forcing bit[0] of that value to 0.

\textbf{Note:} Though it is possible to use \texttt{MOV} as a branch instruction, Texas Instruments strongly recommends the use of a \texttt{BX} or \texttt{BLX} instruction to branch for software portability to the ARM Cortex-M3/M4F instruction set.

### 3.6.4 Condition Flags

If \textit{S} is specified, these instructions:

- Update the \texttt{N} and \texttt{Z} flags according to the result.
- Can update the \texttt{C} flag during the calculation of \textit{Operand2}. See "Flexible Second Operand" on page 27.
- Do not affect the \texttt{V} flag.

### 3.6.5 Example

- \texttt{MOVS R11, #0x000B} \quad ; Write value of 0x000B to R11, flags get updated.
- \texttt{MOV R1, #0xFA05} \quad ; Write value of 0xFA05 to R1, flags are not updated.
- \texttt{MOVS R10, R12} \quad ; Write value in R12 to R10, flags get updated.
- \texttt{MOV R3, #23} \quad ; Write value of 23 to R3.
- \texttt{MOV R8, SP} \quad ; Write value of stack pointer to R8.
- \texttt{MVNS R2, #0xF} \quad ; Write value of 0xFFFFFFFF0 (bitwise inverse of 0xF) to R2 and update flags.
3.7 MOVT

Move Top.

<table>
<thead>
<tr>
<th>Applies to...</th>
<th>M3</th>
<th>M4</th>
<th>M4F</th>
</tr>
</thead>
</table>

3.7.1 Syntax

MOVT\{cond\} Rd, #imm16

where:

cond
  Is an optional condition code. See Table 1-2 on page 33.

Rd
  Is the destination register.

imm16
  Is a 16-bit immediate constant.

3.7.2 Operation

MOVT writes a 16-bit immediate value, imm16, to the top halfword, Rd[31:16], of its destination register. The write does not affect Rd[15:0].

The MOV, MOVT instruction pair enables you to generate any 32-bit constant.

3.7.3 Restrictions

Rd must not be SP and must not be PC.

3.7.4 Condition Flags

This instruction does not change the flags.

3.7.5 Examples

MOVT R3, #0xF123 ; Write 0xF123 to upper halfword of R3, lower halfword ; and APSR are unchanged.
3.8 REV, REV16, REVSH, and RBIT

Reverse bytes and Reverse bits.

3.8.1 Syntax

\[
op(\text{cond}) \ R_d, \ R_n
\]

where:

- **op**
  - Is any of:
    - REV
      - Reverse byte order in a word.
    - REV16
      - Reverse byte order in each halfword independently.
    - REVSH
      - Reverse byte order in the bottom halfword, and sign extend to 32 bits.
    - RBIT
      - Reverse the bit order in a 32-bit word.
  
- **cond**
  - Is an optional condition code. See Table 1-2 on page 33.

- **Rd**
  - Is the destination register.

- **Rn**
  - Is the register holding the operand.

3.8.2 Operation

Use these instructions to change endianness of data:

- **REV**
  - Converts 32-bit big-endian data into little-endian data or 32-bit little-endian data into big-endian data.

- **REV16**
  - Converts 16-bit big-endian data into little-endian data or 16-bit little-endian data into big-endian data.

- **REVSH**
  - Converts either:
    - 16-bit signed big-endian data into 32-bit signed little-endian data.
    - 16-bit signed little-endian data into 32-bit signed big-endian data.
3.8.3 **Restrictions**

Do not use SP and do not use PC.

3.8.4 **Condition Flags**

These instructions do not change the flags.

3.8.5 **Examples**

- `REV    R3, R7    ; Reverse byte order of value in R7 and write it to R3.
- `REV16  R0, R0    ; Reverse byte order of each 16-bit halfword in R0.
- `REVSH  R0, R5    ; Reverse Signed Halfword.
- `REVHS  R3, R7    ; Reverse with Higher or Same condition.
- `RBIT   R7, R8    ; Reverse bit order of value in R8 and write the result to R7.`
3.9 **SADD16 and SADD8**

Signed Add 16 and Signed Add 8.

<table>
<thead>
<tr>
<th>Applies to...</th>
<th>M3</th>
<th>M4</th>
<th>M4F</th>
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<tbody>
<tr>
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<td>✓</td>
</tr>
</tbody>
</table>

### 3.9.1 Syntax

\[ \text{op} \{ \text{cond} \} \{ \text{Rd} \} \ Rn, \ Rm \]

where:

- \textit{op} is any of:
  - \texttt{SADD16} Performs two 16-bit signed integer additions.
  - \texttt{SADD8} Performs four 8-bit signed integer additions.

- \textit{cond} is an optional condition code, see 33.

- \textit{Rd} is the destination register.

- \textit{Rn} is the first register holding the operand.

- \textit{Rm} is the second register holding the operand.

### 3.9.2 Operation

Use these instructions to perform a halfword or byte add in parallel:

The \texttt{SADD16} instruction:

1. Adds each halfword from the first operand to the corresponding halfword of the second operand.
2. Writes the result in the corresponding halfwords of the destination register.

The \texttt{SADD8} instruction:

1. Adds each byte of the first operand to the corresponding byte of the second operand.
2. Writes the result in the corresponding bytes of the destination register.

### 3.9.3 Restrictions

Do not use SP and do not use PC.
3.9.4 Condition flags

These instructions do not change the flags.

3.9.5 Examples

SADD16 R1, R0 ; Adds the halfwords in R0 to the corresponding halfwords of R1 and writes to corresponding halfword of R1.

SADD8 R4, R0, R5 ; Adds bytes of R0 to the corresponding byte in R5 and writes to the corresponding byte in R4.
3.10 SHADD16 and SHADD8
Signed Halving Add 16 and Signed Halving Add 8.

<table>
<thead>
<tr>
<th>Applies to...</th>
<th>M3</th>
<th>M4</th>
<th>M4F</th>
</tr>
</thead>
<tbody>
<tr>
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</tr>
</tbody>
</table>

3.10.1 Syntax

\[ op\{cond\}\{Rd, \} \ Rn, \ Rm \]

where:

- \( op \) is any of:
  - SHADD16
    - Signed Halving Add 16
  - SHADD8
    - Signed Halving Add 8

- \( cond \) is an optional condition code, see 33.

- \( Rd \) is the destination register.

- \( Rn \) is the first operand register.

- \( Rm \) is the second operand register.

3.10.2 Operation

Use these instructions to add 16-bit and 8-bit data and then to halve the result before writing the result to the destination register:

The \texttt{SHADD16} instruction:

1. Adds each halfword from the first operand to the corresponding halfword of the second operand.
2. Shuffles the result by one bit to the right, halving the data.
3. Writes the halfword results in the destination register.

The \texttt{SHADD8} instruction:

1. Adds each byte of the first operand to the corresponding byte of the second operand.
2. Shuffles the result by one bit to the right, halving the data.
3. Writes the byte results in the destination register.

3.10.3 Restrictions
Do not use SP and do not use PC.

3.10.4 Condition flags
These instructions do not change the flags.

3.10.5 Examples

SHADD16 R1, R0 ; Adds halfwords in R0 to corresponding halfword of R1 and
; writes halved result to corresponding halfword in R1

SHADD8 R4, R0, R5 ; Adds bytes of R0 to corresponding byte in R5 and
; writes halved result to corresponding byte in R4
3.11 **SHASX and SHSAX**

Signed Halving Add and Subtract with Exchange and Signed Halving Subtract and Add with Exchange.

<table>
<thead>
<tr>
<th>Applies to...</th>
<th>M3</th>
<th>M4</th>
<th>M4F</th>
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</table>

3.11.1 **Syntax**

\[
\text{op}(\text{cond}) \ (Rd), \ Rn, \ Rm
\]

where:

*op* is any of:

- **SHASX**
  Add and Subtract with Exchange and Halving.

- **SHSAX**
  Subtract and Add with Exchange and Halving.

*cond* is an optional condition code, see 33.

*Rd* is the destination register.

*Rn, Rm* are registers holding the first and second operands.

3.11.2 **Operation**

The **SHASX** instruction:

1. Adds the top halfword of the first operand with the bottom halfword of the second operand.
2. Writes the halfword result of the addition to the top halfword of the destination register, shifted by one bit to the right causing a divide by two, or halving.
3. Subtracts the top halfword of the second operand from the bottom highword of the first operand.
4. Writes the halfword result of the division in the bottom halfword of the destination register, shifted by one bit to the right causing a divide by two, or halving.

The **SHSAX** instruction:

1. Subtracts the bottom halfword of the second operand from the top highword of the first operand.
2. Writes the halfword result of the addition to the bottom halfword of the destination register, shifted by one bit to the right causing a divide by two, or halving.
3. Adds the bottom halfword of the first operand with the top halfword of the second operand.
4. Writes the halfword result of the division in the top halfword of the destination register, shifted by one bit to the right causing a divide by two, or halving.

3.11.3 Restrictions
Do not use SP and do not use PC.

3.11.4 Condition flags
These instructions do not affect the condition code flags.
3.11.5 Examples

SHASX   R7, R4, R2 ; Adds top halfword of R4 to bottom halfword of R2
               ; and writes halved result to top halfword of R7
               ; Subtracts top halfword of R2 from bottom halfword of
               ; R4 and writes halved result to bottom halfword of R7

SHSAX   R0, R3, R5 ; Subtracts bottom halfword of R5 from top halfword
               ; of R3 and writes halved result to top halfword of R0
               ; Adds top halfword of R5 to bottom halfword of R3 and
               ; writes halved result to bottom halfword of R0
3.12  SHSUB16 and SHSUB8

Signed Halving Subtract 16 and Signed Halving Subtract 8.

<table>
<thead>
<tr>
<th>Applies to</th>
<th>M3</th>
<th>M4</th>
<th>M4F</th>
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</table>

3.12.1 Syntax

\[ op(\text{cond})\{Rd,\} \ Rn, \ Rm \]

where:

- \( op \) is any of:
  - SHSUB16
    - Signed Halving Subtract 16
  - SHSUB8
    - Signed Halving Subtract 8

- \( \text{cond} \) is an optional condition code, see 33.

- \( Rd \) is the destination register.

- \( Rn \) is the first operand register.

- \( Rm \) is the second operand register.

3.12.2 Operation

Use these instructions to add 16-bit and 8-bit data and then to halve the result before writing the result to the destination register:

The \texttt{SHSUB16} instruction:

1. Subtracts each halfword of the second operand from the corresponding halfwords of the first operand.
2. Shuffles the result by one bit to the right, halving the data.
3. Writes the halved halfword results in the destination register.

The \texttt{SHSUBB8} instruction:

1. Subtracts each byte of the second operand from the corresponding byte of the first operand,
2. Shuffles the result by one bit to the right, halving the data,
3. Writes the corresponding signed byte results in the destination register.

3.12.3 Restrictions
Do not use SP and do not use PC.

3.12.4 Condition flags
These instructions do not change the flags.

3.12.5 Examples

```
SHSUB16 R1, R0 ; Subtracts halfwords in R0 from corresponding halfword
               ; of R1 and writes to corresponding halfword of R1

SHSUB8  R4, R0, R5 ; Subtracts bytes of R0 from corresponding byte in R5,
                    ; and writes to corresponding byte in R4
```
3.13 SSUB16 and SSUB8

Signed Subtract 16 and Signed Subtract 8.

<table>
<thead>
<tr>
<th>Applies to</th>
<th>M3</th>
<th>M4</th>
<th>M4F</th>
</tr>
</thead>
</table>

3.13.1 Syntax

\[ op \{ cond \} \{ Rd, \} \ Rn, \ Rm \]

where:

- \( op \) is any of:
  - SSUB16
    - Performs two 16-bit signed integer subtractions.
  - SSUB8
    - Performs four 8-bit signed integer subtractions.

- \( cond \) is an optional condition code, see 33.

- \( Rd \) is the destination register.

- \( Rn \) is the first operand register.

- \( Rm \) is the second operand register.

3.13.2 Operation

Use these instructions to change endianness of data:

The SSUB16 instruction:

1. Subtracts each halfword from the second operand from the corresponding halfword of the first operand

2. Writes the difference result of two signed halfwords in the corresponding halfword of the destination register.

The SSUB8 instruction:

1. Subtracts each byte of the second operand from the corresponding byte of the first operand

2. Writes the difference result of four signed bytes in the corresponding byte of the destination register.
3.13.3 Restrictions

Do not use SP and do not use PC.

3.13.4 Condition flags

These instructions do not change the flags.

3.13.5 Examples

SSUB16 R1, R0 ; Subtracts halfwords in R0 from corresponding halfword of R1
; and writes to corresponding halfword of R1

SSUB8 R4, R0, R5 ; Subtracts bytes of R5 from corresponding byte in
; R0, and writes to corresponding byte of R4
3.14 **SASX and SSAX**

Signed Add and Subtract with Exchange and Signed Subtract and Add with Exchange.

<table>
<thead>
<tr>
<th>Applies to:</th>
<th>M3</th>
<th>M4</th>
<th>M4F</th>
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</table>

### 3.14.1 Syntax

\[
\text{op}\{\text{cond}\}(\text{Rd}), \text{Rm}, \text{Rn}
\]

\[
\text{op}\{\text{cond}\}(\text{Rd}), \text{Rm}, \text{Rn}
\]

where:

- **op**
  - is any of:
    - **SASX**
      - Signed Add and Subtract with Exchange.
    - **SSAX**
      - Signed Subtract and Add with Exchange.

- **cond**
  - is an optional condition code, see 33.

- **Rd**
  - is the destination register.

- **Rn, Rm**
  - are registers holding the first and second operands.

### 3.14.2 Operation

The **SASX** instruction:

1. Adds the signed top halfword of the first operand with the signed bottom halfword of the second operand.
2. Writes the signed result of the addition to the top halfword of the destination register.
3. Subtracts the signed bottom halfword of the second operand from the top signed highword of the first operand.
4. Writes the signed result of the subtraction to the bottom halfword of the destination register.

The **SSAX** instruction:

1. Subtracts the signed bottom halfword of the second operand from the top signed highword of the first operand.
2. Writes the signed result of the addition to the bottom halfword of the destination register.
3. Adds the signed top halfword of the first operand with the signed bottom halfword of the second operand.

4. Writes the signed result of the subtraction to the top halfword of the destination register.

3.14.3 Restrictions

Do not use SP and do not use PC.

3.14.4 Condition flags

These instructions do not affect the condition code flags.
3.14.5 Examples

SASX R0, R4, R5 ; Adds top halfword of R4 to bottom halfword of R5 and
; writes to top halfword of R0

; Subtracts bottom halfword of R5 from top halfword of R4

; and writes to bottom halfword of R0

SSAX R7, R3, R2 ; Subtracts top halfword of R2 from bottom halfword of R3

; and writes to bottom halfword of R7

; Adds top halfword of R3 with bottom halfword of R2 and

; writes to top halfword of R7
3.15 TST and TEQ

Test bits and Test Equivalence.

<table>
<thead>
<tr>
<th>Applies to...</th>
<th>M3</th>
<th>M4</th>
<th>M4F</th>
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</table>

3.15.1 Syntax

TST\(\{\text{cond}\}\) \(Rn\), \(\text{Operand2}\)

TEQ\(\{\text{cond}\}\) \(Rn\), \(\text{Operand2}\)

where:

\(\text{cond}\)

Is an optional condition code. See Table 1-2 on page 33.

\(Rn\)

Is the register holding the first operand.

\(\text{Operand2}\)

Is a flexible second operand. See “Flexible Second Operand” on page 27 for details of the options.

3.15.2 Operation

These instructions test the value in a register against \(\text{Operand2}\). They update the condition flags based on the result, but do not write the result to a register.

The TST instruction performs a bitwise AND operation on the value in \(Rn\) and the value of \(\text{Operand2}\). This is the same as the ANDS instruction, except that it discards the result.

To test whether a bit of \(Rn\) is 0 or 1, use the TST instruction with an \(\text{Operand2}\) constant that has that bit set to 1 and all other bits cleared to 0.

The TEQ instruction performs a bitwise Exclusive OR operation on the value in \(Rn\) and the value of \(\text{Operand2}\). This is the same as the EORS instruction, except that it discards the result.

Use the TEQ instruction to test if two values are equal without affecting the V or C flags.

TEQ is also useful for testing the sign of a value. After the comparison, the n flag is the logical Exclusive OR of the sign bits of the two operands.

3.15.3 Restrictions

Do not use \(\text{SP}\) and do not use \(\text{PC}\).
3.15.4 Condition Flags

These instructions:

- Update the \( N \) and \( Z \) flags according to the result.

- Can update the \( C \) flag during the calculation of Operand2. See “Flexible Second Operand” on page 27.

- Do not affect the \( V \) flag.

3.15.5 Examples

```
TST    R0, #0x3F8 ; Perform bitwise AND of R0 value to 0x3F8;
        ; APSR is updated but result is discarded.
TEQEQ  R10, R9  ; Conditionally test if value in R10 is equal to
        ; value in R9; APSR is updated but result is discarded.
```
3.16 **UADD16 and UADD8**

Unsigned Add 16 and Unsigned Add 8.

<table>
<thead>
<tr>
<th>Applies to...</th>
<th>M3</th>
<th>M4</th>
<th>M4F</th>
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</table>

### Syntax

\[ \text{op}(\text{cond})\{Rd,\} \text{ } Rn, \text{ } Rm \]

where:

- \( \text{op} \)
  - is any of:
    - **UADD16**
      - Performs two 16-bit unsigned integer additions.
    - **UADD8**
      - Performs four 8-bit unsigned integer additions.
  - \( \text{cond} \)
    - is an optional condition code, see 33.
  - \( \text{Rd} \)
    - is the destination register.
  - \( \text{Rn} \)
    - is the first register holding the operand.
  - \( \text{Rm} \)
    - is the second register holding the operand.

### Operation

Use these instructions to add 16- and 8-bit unsigned data:

**The UADD16 instruction:**

1. adds each halfword from the first operand to the corresponding halfword of the second operand.
2. writes the unsigned result in the corresponding halfwords of the destination register.

**The UADD8 instruction:**

1. adds each byte of the first operand to the corresponding byte of the second operand.
2. writes the unsigned result in the corresponding byte of the destination register.

### Restrictions

Do not use SP and do not use PC.
3.16.4 Condition flags

These instructions do not change the flags.

3.16.5 Examples

```
UADD16 R1, R0 ; Adds halfwords in R0 to corresponding halfword of R1,
               ; writes to corresponding halfword of R1

UADD8  R4, R0, R5 ; Adds bytes of R0 to corresponding byte in R5 and writes
                    ; to corresponding byte in R4
```
3.17 **UASX and USAX**
Add and Subtract with Exchange and Subtract and Add with Exchange.

<table>
<thead>
<tr>
<th>Applies to...</th>
<th>M3</th>
<th>M4</th>
<th>M4F</th>
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</thead>
<tbody>
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</tr>
</tbody>
</table>

3.17.1 **Syntax**

\[
\text{op}\{\text{cond}\} (Rd), Rn, Rm
\]

where:

- \(\text{op}\) is one of:
  - **UASX**
    - Add and Subtract with Exchange.
  - **USAX**
    - Subtract and Add with Exchange.
- \(\text{cond}\) is an optional condition code, see 33.
- \(Rd\) is the destination register.
- \(Rn, Rm\) are registers holding the first and second operands.

3.17.2 **Operation**

The **UASX** instruction:

1. Subtracts the top halfword of the second operand from the bottom halfword of the first operand.
2. Writes the unsigned result from the subtraction to the bottom halfword of the destination register.
3. Adds the top halfword of the first operand with the bottom halfword of the second operand.
4. Writes the unsigned result of the addition to the top halfword of the destination register.

The **USAX** instruction:

1. Adds the bottom halfword of the first operand with the top halfword of the second operand.
2. Writes the unsigned result of the addition to the bottom halfword of the destination register.
3. Subtracts the bottom halfword of the second operand from the top halfword of the first operand.
4. Writes the unsigned result from the subtraction to the top halfword of the destination register.
3.17.3 Restrictions
Do not use SP and do not use PC.

3.17.4 Condition flags
These instructions do not affect the condition code flags.
3.17.5 Examples

UASX R0, R4, R5 ; Adds top halfword of R4 to bottom halfword of R5 and
                  ; writes to top halfword of R0
                  ; Subtracts bottom halfword of R5 from top halfword of R0
                  ; and writes to bottom halfword of R0

USAX R7, R3, R2 ; Subtracts top halfword of R2 from bottom halfword of R3
                  ; and writes to bottom halfword of R7
                  ; Adds top halfword of R3 to bottom halfword of R2 and
                  ; writes to top halfword of R7
3.18 UHADD16 and UHADD8

Unsigned Halving Add 16 and Unsigned Halving Add 8.

<table>
<thead>
<tr>
<th>Applies to...</th>
<th>M3</th>
<th>M4</th>
<th>M4F</th>
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</thead>
</table>

3.18.1 Syntax

\[
\textit{op}\{\textit{cond}\}\{\textit{Rd}\_s\} \text{ } \textit{Rn}, \textit{Rm}
\]

where:

\textit{op}

is any of:

\textbf{UHADD16}

Unsigned Halving Add 16.

\textbf{UHADD8}

Unsigned Halving Add 8.

\textit{cond}

is an optional condition code, see 33.

\textit{Rd}

is the destination register.

\textit{Rn}

is the register holding the first operand.

\textit{Rm}

is the register holding the second operand.

3.18.2 Operation

Use these instructions to add 16- and 8-bit data and then to halve the result before writing the result to the destination register:

The \textbf{UHADD16} instruction:

1. Adds each halfword from the first operand to the corresponding halfword of the second operand.
2. Shuffles the halfword result by one bit to the right, halving the data.
3. Writes the unsigned results to the corresponding halfword in the destination register.

The \textbf{UHADD8} instruction:

1. Adds each byte of the first operand to the corresponding byte of the second operand.
2. Shuffles the byte result by one bit to the right, halving the data.
3. Writes the unsigned results in the corresponding byte in the destination register.
3.18.3 Restrictions
Do not use SP and do not use PC.

3.18.4 Condition flags
These instructions do not change the flags.

3.18.5 Examples

UHADD16 R7, R3 ; Adds halfwords in R7 to corresponding halfword of R3
; and writes halved result to corresponding halfword in R7

UHADD8 R4, R0, R5 ; Adds bytes of R0 to corresponding byte in R5 and writes
; halved result to corresponding byte in R4
3.19 UHASX and UHSAX

Unsigned Halving Add and Subtract with Exchange and Unsigned Halving Subtract and Add with Exchange.

<table>
<thead>
<tr>
<th>Applies to...</th>
<th>M3</th>
<th>M4</th>
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</tbody>
</table>

3.19.1 Syntax

\[ \text{op}(\text{cond}) \{\text{Rd}\}, \text{Rn}, \text{Rm} \]

where:

\( \text{op} \)

is one of:

- \text{UHASX}
  - Add and Subtract with Exchange and Halving.
- \text{UHSAX}
  - Subtract and Add with Exchange and Halving.

\( \text{cond} \)

is an optional condition code, see 33.

\( \text{Rd} \)

is the destination register.

\( \text{Rn}, \text{Rm} \)

are registers holding the first and second operands.

3.19.2 Operation

The \text{UHASX} instruction:

1. Adds the top halfword of the first operand with the bottom halfword of the second operand.
2. Shifts the result by one bit to the right causing a divide by two, or halving.
3. Writes the halfword result of the addition to the top halfword of the destination register.
4. Subtracts the top halfword of the second operand from the bottom highword of the first operand.
5. Shifts the result by one bit to the right causing a divide by two, or halving.
6. Writes the halfword result of the division in the bottom halfword of the destination register.

The \text{UHSAX} instruction:

1. Subtracts the bottom halfword of the second operand from the top highword of the first operand.
2. Shifts the result by one bit to the right causing a divide by two, or halving.
3. Writes the halfword result of the subtraction in the top halfword of the destination register.
4. Adds the bottom halfword of the first operand with the top halfword of the second operand.
5. Shifts the result by one bit to the right causing a divide by two, or halving.
6. Writes the halfword result of the addition to the bottom halfword of the destination register.

3.19.3 Restrictions
Do not use SP and do not use PC.

3.19.4 Condition flags
These instructions do not affect the condition code flags.
3.19.5 Examples

UHASX R7, R4, R2 ; Adds top halfword of R4 with bottom halfword of R2
; and writes halved result to top halfword of R7
; Subtracts top halfword of R2 from bottom halfword of R7
; R7 and writes halved result to bottom halfword of R7

UHSAX R0, R3, R5 ; Subtracts bottom halfword of R5 from top halfword of R3
; Adds top halfword of R5 to bottom halfword of R3 and
; writes halved result to bottom halfword of R0
3.20 **UHSUB16 and UHSUB8**

Unsigned Halving Subtract 16 and Unsigned Halving Subtract 8.

<table>
<thead>
<tr>
<th>Applies to...</th>
<th>M3</th>
<th>M4</th>
<th>M4F</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

### 3.20.1 Syntax

\[
\text{op}\{\text{cond}\}\{\text{Rd},\}\ Rn,\ Rm
\]

where:

- \text{op} is any of:
  - **UHSUB16**: Performs two unsigned 16-bit integer additions, halves the results, and writes the results to the destination register.
  - **UHSUB8**: Performs four unsigned 8-bit integer additions, halves the results, and writes the results to the destination register.

- \text{cond} is an optional condition code, see 33.

- \text{Rd} is the destination register.

- \text{Rn} is the first register holding the operand.

- \text{Rm} is the second register holding the operand.

### 3.20.2 Operation

Use these instructions to add 16-bit and 8-bit data and then to halve the result before writing the result to the destination register:

**The UHSUB16 instruction:**

1. Subtracts each halfword of the second operand from the corresponding halfword of the first operand.
2. Shuffles each halfword result to the right by one bit, halving the data.
3. Writes each unsigned halfword result to the corresponding halfwords in the destination register.

**The UHSUB8 instruction:**

1. Subtracts each byte of second operand from the corresponding byte of the first operand.
2. Shuffles each byte result by one bit to the right, halving the data.
3. Writes the unsigned byte results to the corresponding byte of the destination register.

3.20.3 Restrictions
Do not use SP and do not use PC.

3.20.4 Condition flags
These instructions do not change the flags.

3.20.5 Examples

```
UHSUB16   R1, R0 ; Subtracts halfwords in R0 from corresponding halfword of
                 ; R1 and writes halved result to corresponding halfword in
                 ; R1

UHSUB8    R4, R0, R5 ; Subtracts bytes of R5 from corresponding byte in R0 and
                 ; writes halved result to corresponding byte in R4
```
3.21 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.

<table>
<thead>
<tr>
<th>Applies to...</th>
<th>M3</th>
<th>M4</th>
<th>M4F</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
</tbody>
</table>

3.21.1 Syntax

SEL{<c>}{<q>} {<Rd>,} <Rn>, <Rm>

where:

- `<c>, <q>` is a standard assembler syntax fields.
- `<Rd>` is the destination register.
- `<Rn>` is the first operand register.
- `<Rm>` is the second operand register.

3.21.2 Operation

The `SEL` instruction:

1. Reads the value of each bit of APSR.GE.
2. Depending on the value of APSR.GE, assigns the destination register the value of either the first or second operand register.

3.21.3 Restrictions

None.

3.21.4 Condition flags

These instructions do not change the flags.

3.21.5 Examples

SADD16 R0, R1, R2 ; Set GE bits based on result

SEL R0, R0, R3 ; Select bytes from R0 or R3, based on GE
3.22 **USAD8**

Unsigned Sum of Absolute Differences.

<table>
<thead>
<tr>
<th>Applies to...</th>
<th>M3</th>
<th>M4</th>
<th>M4F</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

3.22.1 **Syntax**

\[
\text{USAD8}\{\text{cond}\}\{\text{Rd},\}\ \text{Rn},\ \text{Rm}
\]

where:

- \textit{cond} is an optional condition code, see 33.
- \textit{Rd} is the destination register.
- \textit{Rn} is the first operand register.
- \textit{Rm} is the second operand register.

3.22.2 **Operation**

The \text{USAD8} instruction:

1. Subtracts each byte of the second operand register from the corresponding byte of the first operand register.
2. Adds the absolute values of the differences together.
3. Writes the result to the destination register.

3.22.3 **Restrictions**

Do not use SP and do not use PC.

3.22.4 **Condition flags**

These instructions do not change the flags.

3.22.5 **Examples**

\[
\text{USAD8\ R1,\ R4,\ R0}\quad;\quad\text{Subtracts each byte in R0 from corresponding byte of R4}
\]

\[
\qquad;\quad\text{adds the differences and writes to R1}
\]

\[
\text{USAD8\ R0,\ R5}\quad;\quad\text{Subtracts bytes of R5 from corresponding byte in R0,}
\]

\[
\qquad;\quad\text{adds the differences and writes to R0}
\]
3.23 **USADA8**

Unsigned Sum of Absolute Differences and Accumulate.

<table>
<thead>
<tr>
<th>Applies to</th>
<th>M3</th>
<th>M4</th>
<th>M4F</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
</tbody>
</table>

### 3.23.1 Syntax

USADA8\{(cond)\} Rd, Rn, Rm, Ra

where:

- **cond** is an optional condition code, see 33.
- **Rd** is the destination register.
- **Rn** is the first operand register.
- **Rm** is the second operand register.
- **Ra** is the register that contains the accumulation value.

### 3.23.2 Operation

The **USADA8** instruction:

1. Subtracts each byte of the second operand register from the corresponding byte of the first operand register.
2. Adds the unsigned absolute differences together.
3. Adds the accumulation value to the sum of the absolute differences.
4. Writes the result to the destination register.

### 3.23.3 Restrictions

Do not use SP and do not use PC.

### 3.23.4 Condition flags

These instructions do not change the flags.

### 3.23.5 Examples

- USADA8 R1, R0, R6 ; Subtracts bytes in R0 from corresponding halfword of R1
- ; adds differences, adds value of R6, writes to R1
USADA8  R4, R0, R5, R2 ; Subtracts bytes of R5 from corresponding byte in R0

; adds differences, adds value of R2 writes to R4
3.24 USUB16 and USUB8

Unsigned Subtract 16 and Unsigned Subtract 8.

<table>
<thead>
<tr>
<th>Applies to...</th>
<th>M3</th>
<th>M4</th>
<th>M4F</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

3.24.1 Syntax

\[ op\{cond\}\{Rd,\} Rn, Rm \]

where:

- **op**
  - is any of:
    - **USUB16**
      - Unsigned Subtract 16.
    - **USUB8**
      - Unsigned Subtract 8.
  - is an optional condition code, see 33.

- **Rd**
  - is the destination register.

- **Rn**
  - is the first operand register.

- **Rm**
  - is the second operand register.

3.24.2 Operation

Use these instructions to subtract 16-bit and 8-bit data before writing the result to the destination register:

The **USUB16** instruction:

1. Subtracts each halfword from the second operand register from the corresponding halfword of the first operand register.
2. Writes the unsigned result in the corresponding halfwords of the destination register.

The **USUB8** instruction:

1. Subtracts each byte of the second operand register from the corresponding byte of the first operand register.
2. Writes the unsigned byte result in the corresponding byte of the destination register.
3.24.3 Restrictions
Do not use SP and do not use PC.

3.24.4 Condition flags
These instructions do not change the flags.

3.24.5 Examples

USUB16 R1, R0 ; Subtracts halfwords in R0 from corresponding halfword of R1
; and writes to corresponding halfword in R1
USUB8 R4, R0, R5 ; Subtracts bytes of R5 from corresponding byte in R0 and
; writes to the corresponding byte in R4
## Multiply and Divide Instructions

Table 4-1 on page 105 shows the multiply and divide instructions:

<table>
<thead>
<tr>
<th>Mnemonic</th>
<th>Brief Description</th>
<th>See Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>MLA</td>
<td>Multiply with accumulate, 32-bit result</td>
<td>106</td>
</tr>
<tr>
<td>MLS</td>
<td>Multiply and subtract, 32-bit result</td>
<td>106</td>
</tr>
<tr>
<td>MUL</td>
<td>Multiply, 32-bit result</td>
<td>106</td>
</tr>
<tr>
<td>SDIV</td>
<td>Signed divide</td>
<td>130</td>
</tr>
<tr>
<td>SMLA[B,T]</td>
<td>Signed multiply accumulate (halfwords)</td>
<td>108</td>
</tr>
<tr>
<td>SMLAD, SMLADX</td>
<td>Signed multiply accumulate dual</td>
<td>111</td>
</tr>
<tr>
<td>SMLAL</td>
<td>Signed multiply with accumulate (32x32+64), 64-bit result</td>
<td>128</td>
</tr>
<tr>
<td>SMLAL[B,T]</td>
<td>Signed multiply accumulate long (halfwords)</td>
<td>113</td>
</tr>
<tr>
<td>SMLADLD, SMLALDX</td>
<td>Signed multiply accumulate long dual</td>
<td>113</td>
</tr>
<tr>
<td>SMLAW[B,T]</td>
<td>Signed multiply accumulate (word by halfword)</td>
<td>108</td>
</tr>
<tr>
<td>SMLSD</td>
<td>Signed multiply subtract</td>
<td>116</td>
</tr>
<tr>
<td>SMLSLD</td>
<td>Signed multiply subtract long</td>
<td>116</td>
</tr>
<tr>
<td>SMMLA</td>
<td>Signed most significant word multiply accumulate</td>
<td>119</td>
</tr>
<tr>
<td>SMMLS, SMMLSR</td>
<td>Signed most significant word multiply subtract</td>
<td>119</td>
</tr>
<tr>
<td>SMUAD, SMUADX</td>
<td>Signed dual multiply add</td>
<td>123</td>
</tr>
<tr>
<td>SMUL[B,T]</td>
<td>Signed multiply (word by halfword)</td>
<td>125</td>
</tr>
<tr>
<td>SMMUL, SMMULR</td>
<td>Signed most significant word multiply</td>
<td>121</td>
</tr>
<tr>
<td>SMULL</td>
<td>Signed multiply (32x32), 64-bit result</td>
<td>128</td>
</tr>
<tr>
<td>SMULWB, SMULWT</td>
<td>Signed multiply (word by halfword)</td>
<td>125</td>
</tr>
<tr>
<td>SMUSD, SMUSDX</td>
<td>Signed dual multiply subtract</td>
<td>123</td>
</tr>
<tr>
<td>UDIV</td>
<td>Unsigned divide</td>
<td>130</td>
</tr>
<tr>
<td>UMAAL</td>
<td>Unsigned multiply accumulate accumulate long (32x32+32+32), 64-bit result</td>
<td>128</td>
</tr>
<tr>
<td>UMLAL</td>
<td>Unsigned multiply with accumulate (32x32+64), 64-bit result</td>
<td>128</td>
</tr>
<tr>
<td>UMULL</td>
<td>Unsigned multiply (32x32), 64-bit result</td>
<td>128</td>
</tr>
</tbody>
</table>
4.1 MUL, MLA, and MLS

Multiply, Multiply with Accumulate, and Multiply with Subtract, using 32-bit operands, and producing a 32-bit result.

<table>
<thead>
<tr>
<th>Applies to...</th>
<th>M3</th>
<th>M4</th>
<th>M4F</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

4.1.1 Syntax

MUL{S}{cond}{Rd,} Rn, Rm ; Multiply
MLA{cond} Rd, Rn, Rm, Ra ; Multiply with accumulate
MLS{cond} Rd, Rn, Rm, Ra ; Multiply with subtract

where:

cond
Is an optional condition code. See Table 1-2 on page 33.

S
Is an optional suffix. If S is specified, the condition code flags are updated on the result of the operation. See 33.

Rd
Is the destination register. If Rd is omitted, the destination register is Rn.

Rn, Rm
Are registers holding the values to be multiplied.

Ra
Is a register holding the value to be added or subtracted from.

4.1.2 Operation

The MUL instruction multiplies the values from Rn and Rm, and places the least-significant 32 bits of the result in Rd.

The MLA instruction multiplies the values from Rn and Rm, adds the value from Ra, and places the least-significant 32 bits of the result in Rd.

The MLS instruction multiplies the values from Rn and Rm, subtracts the product from Ra, and places the least-significant 32 bits of the result in Rd.

The results of these instructions do not depend on whether the operands are signed or unsigned.

4.1.3 Restrictions

In these instructions, do not use SP and do not use PC.

If you use the S suffix with the MUL instruction:

- Rd, Rn, and Rm must all be in the range R0 to R7.
- Rd must be the same as Rm.
■ You must not use the cond suffix.

### 4.1.4 Condition Flags

If S is specified, the MUL instruction:

■ Updates the N and Z flags according to the result.
■ Does not affect the C and V flags.

### 4.1.5 Examples

<table>
<thead>
<tr>
<th>Instruction</th>
<th>Description</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>MUL R10, R2, R5</td>
<td>Multiply, R10 = R2 x R5.</td>
<td>MUL R10, R2, R5 ; Multiply, R10 = R2 x R5.</td>
</tr>
<tr>
<td>MLA R10, R2, R1, R5</td>
<td>Multiply with accumulate, R10 = (R2 x R1) + R5.</td>
<td>MLA R10, R2, R1, R5 ; Multiply with accumulate, R10 = (R2 x R1) + R5.</td>
</tr>
<tr>
<td>MULS R0, R2, R2</td>
<td>Multiply with flag update, R0 = R2 x R2.</td>
<td>MULS R0, R2, R2 ; Multiply with flag update, R0 = R2 x R2.</td>
</tr>
<tr>
<td>MULLT R2, R3, R2</td>
<td>Conditionally multiply, R2 = R3 x R2.</td>
<td>MULLT R2, R3, R2 ; Conditionally multiply, R2 = R3 x R2.</td>
</tr>
<tr>
<td>MLS R4, R5, R6, R7</td>
<td>Multiply with subtract, R4 = R7 - (R5 x R6).</td>
<td>MLS R4, R5, R6, R7 ; Multiply with subtract, R4 = R7 - (R5 x R6).</td>
</tr>
</tbody>
</table>
4.2 SMLA and SMLAW

Signed Multiply Accumulate (halfwords).

<table>
<thead>
<tr>
<th>Applies to</th>
<th>M3</th>
<th>M4</th>
<th>M4F</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
</tbody>
</table>

4.2.1 Syntax

\[
\text{op}(X)\{Y\}\{\text{cond}\} \ Rd, \ Rn, \ Rm \\
\text{op}(Y)\{\text{cond}\} \ Rd, \ Rn, \ Rm, \ Ra
\]

where

\text{op}

is one of:

- \text{SMLAXY}
  
  Signed Multiply Accumulate Long (halfwords)
  
  \(X\) and \(Y\) specifies which half of the source registers \(Rn\) and \(Rm\) are used as the first and second multiply operand.
  
  If \(X\) is B, then the bottom halfword, bits [15:0], of \(Rn\) is used. If \(X\) is T, then the top halfword, bits [31:16], of \(Rn\) is used.
  
  If \(Y\) is B, then the bottom halfword, bits [15:0], of \(Rm\) is used. If \(Y\) is T, then the top halfword, bits [31:16], of \(Rm\) is used.

- \text{SMLAWY}
  
  Signed Multiply Accumulate (word by halfword)
  
  \(Y\) specifies which half of the source register \(Rm\) is used as the second multiply operand.
  
  If \(Y\) is T, then the top halfword, bits [31:16] of \(Rm\) is used.
  
  If \(Y\) is B, then the bottom halfword, bits [15:0] of \(Rm\) is used.

\text{cond}

is an optional condition code, see Table 1-2 on page 33.

\text{Rd}

is the destination register. If \(Rd\) is omitted, the destination register is \(Rn\).

\text{Rn}, \text{Rm}

are registers holding the values to be multiplied.

\text{Ra}

is a register holding the value to be added or subtracted from.

4.2.2 Operation

The SMALBB, SMLBTT, SMLATB, SMLATT instructions:
- Multiplies the specified signed halfword, top or bottom, values from $R_n$ and $R_m$.
- Adds the value in $R_a$ to the resulting 32-bit product.
- Writes the result of the multiplication and addition in $R_d$.

The non-specified halfwords of the source registers are ignored.

The $SMLAWB$ and $SMLAWT$ instructions:

- Multiply the 32-bit signed values in $R_n$ with:
  - The top signed halfword of $R_m$, $T$ instruction suffix.
  - The bottom signed halfword of $R_m$, $B$ instruction suffix.
- Add the 32-bit signed value in $R_a$ to the top 32 bits of the 48-bit product
- Writes the result of the multiplication and addition in $R_d$.

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 APSR. No overflow can occur during the multiplication.

### 4.2.3 Restrictions

In these instructions, do not use SP and do not use PC.

### 4.2.4 Condition flags

If an overflow is detected, the $Q$ flag is set.

### 4.2.5 Examples

```
SMLABB R5, R6, R4, R1 ; Multiplies bottom halfwords of R6 and R4, adds
; R1 and writes to R5

SMLATB R5, R6, R4, R1 ; Multiplies top halfword of R6 with bottom halfword
; of R4, adds R1 and writes to R5

SMLATT R5, R6, R4, R1 ; Multiplies top halfwords of R6 and R4, adds
; R1 and writes the sum to R5

SMLABT R5, R6, R4, R1 ; Multiplies bottom halfword of R6 with top halfword
; of R4, adds R1 and writes to R5
```
Multiply and Divide Instructions

SMLABT R4, R3, R2 ; Multiplies bottom halfword of R4 with top halfword of R3, adds R2 and writes to R4

SMLAWB R10, R2, R5, R3 ; Multiplies R2 with bottom halfword of R5, adds R3 to the result and writes top 32-bits to R10

SMLAWT R10, R2, R1, R5 ; Multiplies R2 with top halfword of R1, adds R5 and writes top 32-bits to R10
4.3 **SMLAD**

Signed Multiply Accumulate Long Dual.

<table>
<thead>
<tr>
<th>Applies to...</th>
<th>M3</th>
<th>M4</th>
<th>M4F</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

### 4.3.1 Syntax

\[
\text{SMLAD}(X\{\text{cond}\}) \space Rd, \space Rn, \space Rm, \space Ra \space ;
\]

where:

- **SMLAD**
  - Signed Multiply Accumulate Dual
- **SMLADX**
  - Signed Multiply Accumulate Dual Reverse

- **X**
  - Specifies which halfword of the source register \(Rn\) is used as the multiply operand. If \(X\) is omitted, the multiplications are bottom \(\times\) bottom and top \(\times\) top. If \(X\) is present, the multiplications are bottom \(\times\) top and top \(\times\) bottom.

- **cond**
  - is an optional condition code, see Table 1-2 on page 33.

- **Rd**
  - is the destination register.

- **Rn**
  - is the first operand register holding the values to be multiplied.

- **Rm**
  - the second operand register.

- **Ra**
  - is the accumulate value.

### 4.3.2 Operation

The **SMLAD** and **SMLADX** instructions regard the two operands as four halfword 16-bit values. The **SMLAD** and **SMLADX** instructions:

- If \(X\) is not present, multiply the top signed halfword value in \(Rn\) with the top signed halfword of \(Rm\) and the bottom signed halfword values in \(Rn\) with the bottom signed halfword of \(Rm\).
- Or if \(X\) is present, multiply the top signed halfword value in \(Rn\) with the bottom signed halfword of \(Rm\) and the bottom signed halfword values in \(Rn\) with the top signed halfword of \(Rm\).
- Add both multiplication results to the signed 32-bit value in \(Ra\).
- Writes the 32-bit signed result of the multiplication and addition to \(Rd\).

### 4.3.3 Restrictions

Do not use SP and do not use PC.
4.3.4 Condition flags

These instructions do not change the flags.

4.3.5 Examples

SMLAD R10, R2, R1, R5 ; Multiplies two halfword values in R2 with
; corresponding halfwords in R1, adds R5 and writes to
; R10

SMLALDX R0, R2, R4, R6 ; Multiplies top halfword of R2 with bottom halfword
; of R4, multiplies bottom halfword of R2 with top
; halfword of R4, adds R6 and writes to R0
4.4 SMLAL and SMLALD

Signed Multiply Accumulate Long and Signed Multiply Accumulate Long Dual and Signed Multiply Accumulate Long (halfwords).

<table>
<thead>
<tr>
<th>Applies to...</th>
<th>SMLAL</th>
<th>SMLALD</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M3</td>
<td>M4</td>
</tr>
<tr>
<td></td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

4.4.1 Syntax

\[
\text{SMLAL} \{\text{cond}\} \ RdLo, \ RdHi, \ Rn, \ Rm
\]

\[
\text{SMLAL} \{X\} \{Y\} \{\text{cond}\} \ RdLo, \ RdHi, \ Rn, \ Rm
\]

\[
\text{SMLALD} \{X\} \{\text{cond}\} \ RdLo, \ RdHi, \ Rn, \ Rm
\]

where:

SMLAL
Signed Multiply Accumulate Long

SMLAL\{X\}\{Y\}
Signed Multiply Accumulate Long (halfwords, X and Y)

\{X\}\{Y\}
Specifies which halfword of the source registers \(Rn\) and \(Rm\) are used as the first and second multiply operand:

- If \(X\) is \(B\), then the bottom halfword, bits [15:0], of \(Rn\) is used. If \(X\) is \(T\), then the top halfword, bits [31:16], of \(Rn\) is used.
- If \(Y\) is \(B\), then the bottom halfword, bits [15:0], of \(Rm\) is used. If \(Y\) is \(T\), then the top halfword, bits [31:16], of \(Rm\) is used.

SMLALD
Signed Multiply Accumulate Long Dual

SMLALDX
Signed Multiply Accumulate Long Dual Reversed

- If the \(X\) is omitted, the multiplications are bottom × bottom and top × top.
- If \(X\) is present, the multiplications are bottom × top and top × bottom.

\text{cond}
is an optional condition code, see Table 1-2 on page 33.

\(RdHi, \ RdLo\)
are the destination registers. \(RdLo\) is the lower 32 bits and \(RdHi\) is the upper 32 bits of the 64-bit integer. For SMLAL, SMLALBB, SMLALBT, SMLALTB, SMLALTT, SMLALD and SMLALDX, they also hold the accumulating value.
Rn, Rm
are registers holding the first and second operands.

4.4.2 Operation
The SMLAL instruction:
- Multiplies the two's complement signed word values from Rn and Rm.
- Adds the 64-bit value in RdLo and RdHi to the resulting 64-bit product.
- Writes the 64-bit result of the multiplication and addition in RdLo and RdHi.

The SMLALBB, SMLALBT, SMLALTB and SMLALTT instructions:
- Multiplies the specified signed halfword, Top or Bottom, values from Rn and Rm.
- Adds the resulting sign-extended 32-bit product to the 64-bit value in RdLo and RdHi.
- Writes the 64-bit result of the multiplication and addition in RdLo and RdHi.

The non-specified halfwords of the source registers are ignored.

The SMLALD and SMLALDX instructions interpret the values from Rn and Rm as four halfword two's complement signed 16-bit integers. These instructions:
- if X is not present, multiply the top signed halfword value of Rn with the top signed halfword of Rm and the bottom signed halfword values of Rn with the bottom signed halfword of Rm.
- Or if X is present, multiply the top signed halfword value of Rn with the bottom signed halfword of Rm and the bottom signed halfword values of Rn with the top signed halfword of Rm.
- Add the two multiplication results to the signed 64-bit value in RdLo and RdHi to create the resulting 64-bit product.
- Write the 64-bit product in RdLo and RdHi.

4.4.3 Restrictions
In these instructions:
- do not use SP and do not use PC.
- RdHi and RdLo must be different registers.

4.4.4 Condition flags
These instructions do not affect the condition code flags.

4.4.5 Examples

SMLAL R4, R5, R3, R8 ; Multiplies R3 and R8, adds R5:R4 and writes to
 ; R5:R4

SMLALBT R2, R1, R6, R7 ; Multiplies bottom halfword of R6 with top
 ; halfword of R7, sign extends to 32-bit, adds

Multiply and Divide Instructions

Texas Instruments Incorporated
SMLALTB R2, R1, R6, R7 ; Multiplies top halfword of R6 with bottom halfword of R7, sign extends to 32-bit, adds R1:R2 and writes to R1:R2

SMLALD R6, R8, R5, R1 ; Multiplies top halfwords in R5 and R1 and bottom halfwords of R5 and R1, adds R8:R6 and writes to R8:R6

SMLALDX R6, R8, R5, R1 ; Multiplies top halfword in R5 with bottom halfword of R1, and bottom halfword of R5 with top halfword of R1, adds R8:R6 and writes to R8:R6
### 4.5 SMLSD and SMLSLD

Signed Multiply Subtract Dual and Signed Multiply Subtract Long Dual.

<table>
<thead>
<tr>
<th>Applies to...</th>
<th>M3</th>
<th>M4</th>
<th>M4F</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
</tbody>
</table>

#### 4.5.1 Syntax

\[ \text{op}(X)\{\text{cond}\} \text{ Rd, Rn, Rm, Ra} \]

where:

- **op** is one of:
  - **SMLSD**
    - Signed Multiply Subtract Dual.
  - **SMLSLD**
    - Signed Multiply Subtract Long Dual.
- **X**
  - If \( X \) is present, the multiplications are bottom \( \times \) top and top \( \times \) bottom. If the \( X \) is omitted, the multiplications are bottom \( \times \) bottom and top \( \times \) top.
- **cond**
  - is an optional condition code, see Table 1-2 on page 33.
- **Rd**
  - is the destination register.
- **Rn, Rm**
  - are registers holding the first and second operands.
- **Ra**
  - is the register holding the accumulate value.

#### 4.5.2 Operation

The **SMLSD** instruction interprets the values from the first and second operands as four signed halfwords. This instruction:

- Optionally rotates the halfwords of the second operand.
- Performs two signed 16 \( \times \) 16-bit halfword multiplications.
- Subtracts the result of the upper halfword multiplication from the result of the lower halfword multiplication.
- Adds the signed accumulate value to the result of the subtraction.
- Writes the result of the addition to the destination register.

The **SMLSLD** instruction interprets the values from \( Rn \) and \( Rm \) as four signed halfwords. This instruction:

- Optionally rotates the halfwords of the second operand.
- Performs two signed 16 × 16-bit halfword multiplications.
- Subtracts the result of the upper halfword multiplication from the result of the lower halfword multiplication.
- Adds the 64-bit value in \(RdHi\) and \(RdLo\) to the result of the subtraction.
- Writes the 64-bit result of the addition to the \(RdHi\) and \(RdLo\).

### 4.5.3 Restrictions

In these instructions:

- Do not use SP and do not use PC.

### 4.5.4 Condition flags

This instruction sets the Q flag if the accumulate operation overflows. Overflow cannot occur during the multiplications or subtraction.

For the Thumb instruction set, these instructions do not affect the condition code flags.

### 4.5.5 Examples

SMLSD \( R0, R4, R5, R6 \) ; Multiplies bottom halfword of R4 with bottom

; halfword of R5, multiplies top halfword of R4

; with top halfword of R5, subtracts second from

; first, adds R6, writes to R0

SMLSDX \( R1, R3, R2, R0 \) ; Multiplies bottom halfword of R3 with top

; halfword of R2, multiplies top halfword of R3

; with bottom halfword of R2, subtracts second from

; first, adds R0, writes to R1

SMLSLD \( R3, R6, R2, R7 \) ; Multiplies bottom halfword of R6 with bottom

; halfword of R2, multiplies top halfword of R6

; with top halfword of R2, subtracts second from

; first, adds R6:R3, writes to R6:R3
SMLSLDX   R3, R6, R2, R7 ; Multiplies bottom halfword of R6 with top
   ; halfword of R2, multiplies top halfword of R6
   ; with bottom halfword of R2, subtracts second from
   ; first, adds R6:R3, writes to R6:R3
4.6 SMMLA and SMMLS

Signed Most Significant Word Multiply Accumulate and Signed Most Significant Word Multiply Subtract.

<table>
<thead>
<tr>
<th>Applies to...</th>
<th>M3</th>
<th>M4</th>
<th>M4F</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
</tbody>
</table>

4.6.1 Syntax

\[ \text{op}(R)\{\text{cond}\} \ R_d, \ R_n, \ R_m, \ R_a \]

where:

\text{op} 

is one of:

- \text{SMMLA} 
  Signed Most Significant Word Multiply Accumulate.

- \text{SMMLS} 
  Signed Most Significant Word Multiply Subtract.

\text{R} 

is a rounding error flag. If \text{R} is specified, the result is rounded instead of being truncated. In this case the constant \text{0x80000000} is added to the product before the high word is extracted.

\text{cond} 

is an optional condition code, see Table 1-2 on page 33.

\text{Rd} 

is the destination register.

\text{Rn, Rm} 

are registers holding the first and second multiply operands.

\text{Ra} 

is the register holding the accumulate value.

4.6.2 Operation

The \text{SMMLA} instruction interprets the values from \text{Rn} and \text{Rm} as signed 32-bit words.

The \text{SMMLA} instruction:

\begin{itemize}
  \item Multiplies the values in \text{Rn} and \text{Rm}.
  \item Optionally rounds the result by adding \text{0x80000000}.
  \item Extracts the most significant 32 bits of the result.
  \item Adds the value of \text{Ra} to the signed extracted value.
  \item Writes the result of the addition in \text{Rd}.
\end{itemize}

The \text{SMMLS} instruction interprets the values from \text{Rn} and \text{Rm} as signed 32-bit words.

The \text{SMMLS} instruction:
Multiply and Divide Instructions

- Multiplies the values in \( R_n \) and \( R_m \).
- Optionally rounds the result by adding \( 0x80000000 \).
- Extracts the most significant 32 bits of the result.
- Subtracts the extracted value of the result from the value in \( R_a \).
- Writes the result of the subtraction in \( R_d \).

4.6.3 Restrictions

In these instructions:
- Do not use SP and do not use PC.

4.6.4 Condition flags

These instructions do not affect the condition code flags.

4.6.5 Examples

\[ \text{SMMLA} \quad R_0, R_4, R_5, R_6 \quad ; \text{Multiplies } R_4 \text{ and } R_5, \text{ extracts top 32 bits, adds } \]
\[ \quad \quad R_6, \text{ truncates and writes to } R_0 \]

\[ \text{SMMLAR} \quad R_6, R_2, R_1, R_4 \quad ; \text{Multiplies } R_2 \text{ and } R_1, \text{ extracts top 32 bits, adds } \]
\[ \quad \quad R_4, \text{ rounds and writes to } R_6 \]

\[ \text{SMMLSR} \quad R_3, R_6, R_2, R_7 \quad ; \text{Multiplies } R_6 \text{ and } R_2, \text{ extracts top 32 bits, } \]
\[ \quad \quad \text{subtracts } R_7, \text{ rounds and writes to } R_3 \]

\[ \text{SMMLS} \quad R_4, R_5, R_3, R_8 \quad ; \text{Multiplies } R_5 \text{ and } R_3, \text{ extracts top 32 bits, } \]
\[ \quad \quad \text{subtracts } R_8, \text{ truncates and writes to } R_4 \]
4.7 SMMUL
Signed Most Significant Word Multiply.

<table>
<thead>
<tr>
<th>Applies to...</th>
<th>M3</th>
<th>M4</th>
<th>M4F</th>
</tr>
</thead>
</table>

4.7.1 Syntax

\[ \text{op}(R)(\text{cond}) \quad Rd, \ Rn, \ Rm \]

where:

\( \text{op} \)

is one of:

SMMUL
Signed Most Significant Word Multiply

\( R \)

is a rounding error flag. If \( R \) is specified, 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.

\( \text{cond} \)

is an optional condition code, see Table 1-2 on page 33.

\( Rd \)

is the destination register.

\( Rn, \ Rm \)

are registers holding the first and second operands.

4.7.2 Operation

The SMMUL instruction interprets the values from \( Rn \) and \( Rm \) as two's complement 32-bit signed integers. The SMMUL instruction:

- Multiplies the values from \( Rn \) and \( Rm \).
- Optionally rounds the result, otherwise truncates the result.
- Writes the most significant signed 32 bits of the result in \( Rd \).

4.7.3 Restrictions

In this instruction:

- do not use SP and do not use PC.

4.7.4 Condition flags

This instruction does not affect the condition code flags.
4.7.5 Examples

```
SMULL   R0, R4, R5 ; Multiplies R4 and R5, truncates top 32 bits
                 ; and writes to R0

SMULLR  R6, R2  ; Multiplies R6 and R2, rounds the top 32 bits
                 ; and writes to R6
```
4.8 SMUAD and SMUSD

Signed Dual Multiply Add and Signed Dual Multiply Subtract.

<table>
<thead>
<tr>
<th>Applies to...</th>
<th>M3</th>
<th>M4</th>
<th>M4F</th>
</tr>
</thead>
</table>

4.8.1 Syntax

\[
\text{op}\{X\}\{\text{cond}\}\ Rd, \ Rn, \ Rm
\]

where:

\text{op}

is one of:

\text{SMUAD}

Signed Dual Multiply Add.

\text{SMUSD}

Signed Dual Multiply Subtract.

\text{X}

If \text{X} is present, the multiplications are bottom × top and top × bottom. If the \text{X} is omitted, the multiplications are bottom × bottom and top × top.

\text{cond}

is an optional condition code, see Table 1-2 on page 33.

\text{Rd}

is the destination register.

\text{Rn, Rm}

are registers holding the first and the second operands.

4.8.2 Operation

The \text{SMUAD} instruction interprets the values from the first and second operands as two signed halfwords in each operand. This instruction:

- Optionally rotates the halfwords of the second operand.
- Performs two signed 16 × 16-bit multiplications.
- Adds the two multiplication results together.
- Writes the result of the addition to the destination register.

The \text{SMUSD} instruction interprets the values from the first and second operands as two’s complement signed integers. This instruction:

- Optionally rotates the halfwords of the second operand.
- Performs two signed 16 × 16-bit multiplications.
- Subtracts the result of the top halfword multiplication from the result of the bottom halfword multiplication.
- Writes the result of the subtraction to the destination register.
4.8.3 Restrictions
In these instructions:
- Do not use SP and do not use PC.

4.8.4 Condition flags
Sets the Q flag if the addition overflows. The multiplications cannot overflow.

4.8.5 Examples

SMUAD R0, R4, R5 ; Multiplies bottom halfword of R4 with the bottom
; halfword of R5, adds multiplication of top halfword
; of R4 with top halfword of R5, writes to R0

SMUADX R3, R7, R4 ; Multiplies bottom halfword of R7 with top halfword
; of R4, adds multiplication of top halfword of R7
; with bottom halfword of R4, writes to R3

SMUSD R3, R6, R2 ; Multiplies bottom halfword of R4 with bottom halfword
; of R6, subtracts multiplication of top halfword of R6
; with top halfword of R3, writes to R3

SMUSDX R4, R5, R3 ; Multiplies bottom halfword of R5 with top halfword of
; R3, subtracts multiplication of top halfword of R5
; with bottom halfword of R3, writes to R4
4.9 SMUL and SMULW

Signed Multiply (halfwords) and Signed Multiply (word by halfword).

<table>
<thead>
<tr>
<th>Applies to...</th>
<th>M3</th>
<th>M4</th>
<th>M4F</th>
</tr>
</thead>
</table>

4.9.1 Syntax

$$\text{SMUL}(X)\{Y\} \{\text{cond}\} \ Rd, \ Rn, \ Rm$$

$$\text{SMULW}(Y) \{\text{cond}\} \ Rd. \ Rn, \ Rm$$

For $\text{SMULXY}$ only:

\[ \text{op} \]

is one of:

- $\text{SMUL}(X)\{Y\}$ Signed Multiply (halfwords)
  
  $X$ and $Y$ specify which halfword of the source registers $Rn$ and $Rm$ is used as the first and second multiply operand. If $X$ is $B$, then the bottom halfword, bits [15:0] of $Rn$ is used. If $X$ is $T$, then the top halfword, bits [31:16] of $Rn$ is used. If $Y$ is $B$, then the bottom halfword, bits [15:0], of $Rm$ is used. If $Y$ is $T$, then the top halfword, bits [31:16], of $Rm$ is used.

- $\text{SMULW}(Y)$ Signed Multiply (word by halfword)
  
  $Y$ specifies which halfword of the source register $Rn$ is used as the second multiply operand. If $Y$ is $B$, then the bottom halfword (bits [15:0]) of $Rm$ is used. If $Y$ is $T$, then the top halfword (bits [31:16]) of $Rm$ is used.

$\text{cond}$

is an optional condition code, see Table 1-2 on page 33.

$Rd$

is the destination register.

$Rn, Rm$

are registers holding the first and second operands.

4.9.2 Operation

The $\text{SMULBB}$, $\text{SMULTB}$, $\text{SMULTT}$ and $\text{SMULTT}$ instructions interprets the values from $Rn$ and $Rm$ as four signed 16-bit integers. These instructions:

- Multiplies the specified signed halfword, Top or Bottom, values from $Rn$ and $Rm$.
- Writes the 32-bit result of the multiplication in $Rd$.

The $\text{SMULWT}$ and $\text{SMULWB}$ instructions interprets the values from $Rn$ as a 32-bit signed integer and $Rm$ as two halfword 16-bit signed integers. These instructions:

- Multiplies the first operand and the top, T suffix, or the bottom, B suffix, halfword of the second operand.
Writes the signed most significant 32 bits of the 48-bit result in the destination register.

### 4.9.3 Restrictions

In these instructions:

- Do not use SP and do not use PC.
- RdHi and RdLo must be different registers.

### 4.9.4 Examples

- **SMULBT**  
  R0, R4, R5  
  ; Multiplies the bottom halfword of R4 with the  
  ; top halfword of R5, multiplies results and  
  ; writes to R0

- **SMULBB**  
  R0, R4, R5  
  ; Multiplies the bottom halfword of R4 with the  
  ; bottom halfword of R5, multiplies results and  
  ; writes to R0

- **SMULTT**  
  R0, R4, R5  
  ; Multiplies the top halfword of R4 with the top  
  ; halfword of R5, multiplies results and writes  
  ; to R0

- **SMULTB**  
  R0, R4, R5  
  ; Multiplies the top halfword of R4 with the  
  ; bottom halfword of R5, multiplies results and  
  ; and writes to R0

- **SMULWT**  
  R4, R5, R3  
  ; Multiplies R5 with the top halfword of R3,  
  ; extracts top 32 bits and writes to R4

- **SMULWB**  
  R4, R5, R3  
  ; Multiplies R5 with the bottom halfword of R3,
; extracts top 32 bits and writes to R4
4.10 UMULL, UMAAL, UMLAL, SMULL, and SMLAL

Signed and Unsigned Long Multiply, with optional Accumulate, using 32-bit operands and producing a 64-bit result.

<table>
<thead>
<tr>
<th>Applies to...</th>
<th>UMULL, UMLAL, SMLL, SMLAL</th>
<th>UMAAL</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M3</td>
<td>M4</td>
</tr>
<tr>
<td></td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

4.10.1 Syntax

{(cond) RdLo, RdHi, Rn, Rm}

where:

\( op \)

is one of:

- **UMULL**
  - Unsigned Long Multiply.

- **UMAAL**
  - Unsigned Long Multiply with Accumulate.

- **UMLAL**
  - Unsigned Long Multiply, with Accumulate.

- **SMULL**
  - Signed Long Multiply.

- **SMLAL**
  - Signed Long Multiply, with Accumulate.

\( cond \)

is an optional condition code, see Table 1-2 on page 33.

\( RdHi, RdLo \)

are the destination registers. For **UMLAL** and **SMLAL** they also hold the accumulating value.

\( Rn, Rm \)

are registers holding the operands.

4.10.2 Operation

The **UMULL** instruction interprets the values from \( Rn \) and \( Rm \) as unsigned integers. It multiplies these integers and places the least significant 32 bits of the result in \( RdLo \), and the most significant 32 bits of the result in \( RdHi \).

The **UMAAL** instruction interprets the values from \( Rn \) and \( Rm \) as unsigned integers. It multiplies the two unsigned integers in the first and second operands and adds the unsigned 32-bit integer in \( RdHi \) to the 64-bit result of the multiplication. It adds the unsigned 32-bit integer in \( RdLo \) to the 64-bit result of the addition, writes the top 32-bits of the result to \( RdHi \), and writes the lower 32-bits of the result to \( RdLo \).
The UMLAL instruction interprets the values from \( R_n \) and \( R_m \) as unsigned integers. It multiplies these integers, adds the 64-bit result to the 64-bit unsigned integer contained in \( R_{dHi} \) and \( R_{dLo} \), and writes the result back to \( R_{dHi} \) and \( R_{dLo} \).

The SMULL instruction interprets the values from \( R_n \) and \( R_m \) as two’s complement signed integers. It multiplies these integers and places the least significant 32 bits of the result in \( R_{dLo} \), and the most significant 32 bits of the result in \( R_{dHi} \).

The SMLAL instruction interprets the values from \( R_n \) and \( R_m \) as two’s complement signed integers. It multiplies these integers, adds the 64-bit result to the 64-bit signed integer contained in \( R_{dHi} \) and \( R_{dLo} \), and writes the result back to \( R_{dHi} \) and \( R_{dLo} \).

### 4.10.3 Restrictions

In these instructions:

- do not use \( SP \) and do not use \( PC \)
- \( R_{dHi} \) and \( R_{dLo} \) must be different registers.

### 4.10.4 Condition flags

These instructions do not affect the condition code flags.

### 4.10.5 Examples

```plaintext
UMULL R0, R4, R5, R6 ; Unsigned (R4,R0) = R5 x R6
SMLAL R4, R5, R3, R8 ; Signed (R5,R4) = (R5,R4) + R3 x R8
UMAAL R3, R6, R2, R7 ; Multiplies R2 and R7, adds R6, adds R3, writes top 32 bits to R6, and the bottom 32 bits to R3.
```
4.11 SDIV and UDIV

Signed Divide and Unsigned Divide.

<table>
<thead>
<tr>
<th>Applies to...</th>
<th>M3</th>
<th>M4</th>
<th>M4F</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

4.11.1 Syntax

SDIV\(\text{cond}\) \(\{Rd,\}\) \(Rn, Rm\)

UDIV\(\text{cond}\) \(\{Rd,\}\) \(Rn, Rm\)

where:

\textit{cond}

Is an optional condition code. See Table 1-2 on page 33.

\textit{Rd}

Is the destination register. If \textit{Rd} is omitted, the destination register is \textit{Rn}.

\textit{Rn}

Is the register holding the value to be divided.

\textit{Rm}

Is a register holding the divisor.

4.11.2 Operation

\texttt{SDIV} performs a signed integer division of the value in \textit{Rn} by the value in \textit{Rm}.

\texttt{UDIV} performs an unsigned integer division of the value in \textit{Rn} by the value in \textit{Rm}.

For both instructions, if the value in \textit{Rn} is not divisible by the value in \textit{Rm}, the result is rounded towards zero.

4.11.3 Restrictions

Do not use \texttt{SP} and do not use \texttt{PC}.

4.11.4 Condition Flags

These instructions do not change the flags.

4.11.5 Examples

\texttt{SDIV R0, R2, R4 ; Signed divide, R0 = R2/R4.}

\texttt{UDIV R8, R8, R1 ; Unsigned divide, R8 = R8/R1.}
# Saturating Instructions

Table 5-1 on page 131 shows the saturating instructions:

## Table 5-1. Saturating Instructions

<table>
<thead>
<tr>
<th>Mnemonic</th>
<th>Brief Description</th>
<th>See Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>SSAT</td>
<td>Signed saturate</td>
<td>132</td>
</tr>
<tr>
<td>SSAT16</td>
<td>Signed saturate halfword</td>
<td>134</td>
</tr>
<tr>
<td>USAT</td>
<td>Unsigned saturate</td>
<td>132</td>
</tr>
<tr>
<td>USAT16</td>
<td>Unsigned saturate halfword</td>
<td>134</td>
</tr>
<tr>
<td>QADD</td>
<td>Saturating add</td>
<td>136</td>
</tr>
<tr>
<td>QADD8</td>
<td>Saturating add 8</td>
<td>136</td>
</tr>
<tr>
<td>QADD16</td>
<td>Saturating add 16</td>
<td>136</td>
</tr>
<tr>
<td>QSUB</td>
<td>Saturating subtract</td>
<td>136</td>
</tr>
<tr>
<td>QSUB8</td>
<td>Saturating subtract 8</td>
<td>136</td>
</tr>
<tr>
<td>QSUB16</td>
<td>Saturating subtract 16</td>
<td>136</td>
</tr>
<tr>
<td>QASX</td>
<td>Saturating add and subtract with exchange</td>
<td>138</td>
</tr>
<tr>
<td>QSAX</td>
<td>Saturating subtract and add with exchange</td>
<td>138</td>
</tr>
<tr>
<td>QDADD</td>
<td>Saturating double and add</td>
<td>140</td>
</tr>
<tr>
<td>QDSUB</td>
<td>Saturating double and subtract</td>
<td>140</td>
</tr>
<tr>
<td>UQADD16</td>
<td>Unsigned saturating add 16</td>
<td>144</td>
</tr>
<tr>
<td>UQADD8</td>
<td>Unsigned saturating add 8</td>
<td>144</td>
</tr>
<tr>
<td>UQASX</td>
<td>Unsigned saturating add and subtract with exchange</td>
<td>142</td>
</tr>
<tr>
<td>UQSAX</td>
<td>Unsigned saturating subtract and add with exchange</td>
<td>142</td>
</tr>
<tr>
<td>UQSUB16</td>
<td>Unsigned saturating subtract 16</td>
<td>144</td>
</tr>
<tr>
<td>UQSUB8</td>
<td>Unsigned saturating subtract 8</td>
<td>144</td>
</tr>
</tbody>
</table>
5.1 SSAT and USAT

Signed Saturate and Unsigned Saturate to any bit position, with optional shift before saturating.

<table>
<thead>
<tr>
<th>Applies to...</th>
<th>M3</th>
<th>M4</th>
<th>M4F</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

5.1.1 Syntax

\[ op\{cond\} \ Rd, \ #n, \ Rm \{, \ shift \ #s\} \]

where:

- \( op \)
  Is one of:
  
  - **SSAT**
    Saturates a signed value to a signed range.
  
  - **USAT**
    Saturates a signed value to an unsigned range.

- \( cond \)
  Is an optional condition code. See Table 1-2 on page 33.

- \( Rd \)
  Is the destination register.

- \( n \)
  Specifies the bit position to saturate to:
  - \( n \) ranges from 1 to 32 for **SSAT**
  - \( n \) ranges from 0 to 31 for **USAT**

- \( Rm \)
  Is the register containing the value to saturate.

- \( shift \ #s \)
  Is an optional shift applied to \( Rm \) before saturating. It must be one of the following:

  - **ASR \ #s**
    Where \( s \) is in the range 1 to 31.

  - **LSL \ #s**
    Where \( s \) is in the range 0 to 31.

5.1.2 Operation

These instructions saturate to a signed or unsigned \( n \)-bit value.

The **SSAT** instruction applies the specified shift, then saturates to the signed range \( -2^{n-1} \leq x \leq 2^{n-1}-1 \).

The **USAT** instruction applies the specified shift, then saturates to the unsigned range \( 0 \leq x \leq 2^n-1 \).

For signed \( n \)-bit saturation using **SSAT**, this means that:

- If the value to be saturated is less than \(-2^{n-1}\), the result returned is \(-2^{n-1}\).
If the value to be saturated is greater than $2^{n-1}-1$, the result returned is $2^{n-1}-1$.

Otherwise, the result returned is the same as the value to be saturated.

For unsigned $n$-bit saturation using USAT, this means that:

- If the value to be saturated is less than 0, the result returned is 0.
- If the value to be saturated is greater than $2^n-1$, the result returned is $2^n-1$.
- Otherwise, the result returned is the same as the value to be saturated.

If the returned result is different from the value to be saturated, it is called saturation. If saturation occurs, the instruction sets the $Q$ flag to 1 in the APSR. Otherwise, it leaves the $Q$ flag unchanged. To clear the $Q$ flag to 0, you must use the MSR instruction. See “MSR” on page 215.

To read the state of the $Q$ flag, use the MRS instruction. See “MRS” on page 214.

### 5.1.3 Restrictions

Do not use SP and do not use PC.

### 5.1.4 Condition Flags

These instructions do not affect the condition code flags.

If saturation occurs, these instructions set the $Q$ flag to 1.

### 5.1.5 Examples

```
SSAT  R7, #16, R7, LSL #4 ; Logical shift left value in R7 by 4, then
                       ; saturate it as a signed 16-bit value and
                       ; write it back to R7.

USATNE R0, #7, R5     ; Conditionally saturate value in R5 as an
                       ; unsigned 7 bit value and write it to R0.
```
5.2 SSAT16 and USAT16

Signed Saturate and Unsigned Saturate to any bit position for two halfwords.

### 5.2.1 Syntax

\[ \text{op} \{ \text{cond} \} \text{ Rd, \#n, Rm} \]

where:

- **op** is one of:
  - **SSAT16**
    - Saturates a signed halfword value to a signed range.
  - **USAT16**
    - Saturates a signed halfword value to an unsigned range.

- **cond** is an optional condition code, see Table 1-2 on page 33.

- **Rd** is the destination register.

- **n** specifies the bit position to saturate to:
  - **n** ranges from 1 to 16 for **SSAT**.
  - **n** ranges from 0 to 15 for **USAT**.

- **Rm** is the register containing the value to saturate.

### 5.2.2 Operation

The **SSAT16** instruction:

1. Saturates two signed 16-bit halfword values of the register with the value to saturate from selected by the bit position in \( n \).
2. Writes the results as two signed 16-bit halfwords to the destination register.

The **USAT16** instruction:

1. Saturates two unsigned 16-bit halfword values of the register with the value to saturate from selected by the bit position in \( n \).
2. Writes the results as two unsigned halfwords in the destination register.

### 5.2.3 Restrictions

Do not use SP and do not use PC.
5.2.4 Condition flags

These instructions do not affect the condition code flags.
If saturation occurs, these instructions set the Q flag to 1.

5.2.5 Examples

SSAT16 R7, #9, R2 ; Saturates the top and bottom highwords of R2
; as 9-bit values, writes to corresponding halfword
; of R7

USAT16NE R0, #13, R5 ; Conditionally saturates the top and bottom
; halfwords of R5 as 13-bit values, writes to
; corresponding halfword of R0
5.3 **QADD and QSUB**

Saturating Add and Saturating Subtract, signed.

<table>
<thead>
<tr>
<th>Applies to...</th>
<th>M3</th>
<th>M4</th>
<th>M4F</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

5.3.1 **Syntax**

\[
\text{op} \{\text{cond}\} \ (\text{Rd}, \ \text{Rn}, \ \text{Rm})
\]

\[
\text{op} \{\text{cond}\} \ (\text{Rd}, \ \text{Rn}, \ \text{Rm})
\]

where:

- \(\text{op}\) is one of:
  - **QADD** Saturating 32-bit add.
  - **QADD8** Saturating four 8-bit integer additions.
  - **QADD16** Saturating two 16-bit integer additions.
  - **QSUB** Saturating 32-bit subtraction.
  - **QSUB8** Saturating four 8-bit integer subtraction.
  - **QSUB16** Saturating two 16-bit integer subtraction.

- \(\text{cond}\) is an optional condition code, see Table 1-2 on page 33.

- \(\text{Rd}\) is the destination register.

- \(\text{Rn}, \ \text{Rm}\) are registers holding the first and second operands.

5.3.2 **Operation**

These instructions add or subtract two, four or eight values from the first and second operands and then writes a signed saturated value in the destination register.

The **QADD** and **QSUB** instructions apply the specified add or subtract, and then saturate the result to the signed range \(-2^{n-1} \leq x \leq 2^{n-1}-1\), where \(x\) is given by the number of bits applied in the instruction, 32, 16 or 8.
If the returned result is different from the value to be saturated, it is called saturation. If saturation occurs, the QADD and QSUB instructions set the Q flag to 1 in the APSR. Otherwise, it leaves the Q flag unchanged. The 8-bit and 16-bit QADD and QSUB instructions always leave the Q flag unchanged.

To clear the Q flag to 0, you must use the MSR instruction, see 215.

To read the state of the Q flag, use the MRS instruction, see 214.

5.3.3 Restrictions

Do not use SP and do not use PC.

5.3.4 Condition flags

These instructions do not affect the condition code flags.

If saturation occurs, these instructions set the Q flag to 1.

5.3.5 Examples

QADD16 R7, R4, R2 ; Adds halfwords of R4 with corresponding halfword of
    ; R2, saturates to 16 bits and writes to corresponding
    ; halfword of R7

QADD8 R3, R1, R6 ; Adds bytes of R1 to the corresponding bytes of R6,;
    ; saturates to 8 bits and writes to corresponding byte of
    ; R3

QSUB16 R4, R2, R3 ; Subtracts halfwords of R3 from corresponding halfword
    ; of R2, saturates to 16 bits, writes to corresponding
    ; halfword of R4

QSUB8 R4, R2, R5 ; Subtracts bytes of R5 from the corresponding byte in
    ; R2, saturates to 8 bits, writes to corresponding byte of
    ; R4
5.4 QASX and QSAX

Saturating Add and Subtract with Exchange and Saturating Subtract and Add with Exchange, signed.

<table>
<thead>
<tr>
<th>Applies to...</th>
<th>M3</th>
<th>M4</th>
<th>M4F</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

5.4.1 Syntax

\[
\text{op}\{\text{cond}\} \ (Rd), \ Rm, \ Rn
\]

where:

- **op** is one of:
  - QASX: Add and Subtract with Exchange and Saturate.
  - QSAX: Subtract and Add with Exchange and Saturate.

- **cond** is an optional condition code, see Table 1-2 on page 33.

- **Rd** is the destination register.

- **Rn, Rm** are registers holding the first and second operands.

5.4.2 Operation

The QASX instruction:

1. Adds the top halfword of the source operand with the bottom halfword of the second operand.
2. Subtracts the top halfword of the second operand from the bottom highword of the first operand.
3. Saturates the result of the subtraction and writes a 16-bit signed integer in the range \(-2^{15} \leq x \leq 2^{15} - 1\), where \(x\) equals 16, to the bottom halfword of the destination register.
4. Saturates the results of the sum and writes a 16-bit signed integer in the range \(-2^{15} \leq x \leq 2^{15} - 1\), where \(x\) equals 16, to the top halfword of the destination register.

The QSAX instruction:

1. Subtracts the bottom halfword of the second operand from the top highword of the first operand.
2. Adds the bottom halfword of the source operand with the top halfword of the second operand.
3. Saturates the results of the sum and writes a 16-bit signed integer in the range \(-2^{15} \leq x \leq 2^{15} - 1\), where \(x\) equals 16, to the bottom halfword of the destination register.
4. Saturates the result of the subtraction and writes a 16-bit signed integer in the range \(-2^{15} \leq x \leq 2^{15} - 1\), where \(x\) equals 16, to the top halfword of the destination register.

5.4.3 Restrictions

Do not use SP and do not use PC.
5.4.4  **Condition flags**

These instructions do not affect the condition code flags.

5.4.5  **Examples**

QASX  R7, R4, R2  ; Adds top halfword of R4 to bottom halfword of R2,
             ; saturates to 16 bits, writes to top halfword of R7
             ; Subtracts top highword of R2 from bottom halfword of
             ; R4, saturates to 16 bits and writes to bottom halfword
             ; of R7

QSAX  R0, R3, R5  ; Subtracts bottom halfword of R5 from top halfword of
             ; R3, saturates to 16 bits, writes to top halfword of R0
             ; Adds bottom halfword of R3 to top halfword of R5,
             ; saturates to 16 bits, writes to bottom halfword of R0
5.5 **QDADD and QDSUB**

Saturating Double and Add and Saturating Double and Subtract, signed.

<table>
<thead>
<tr>
<th>Applies to...</th>
<th>M3</th>
<th>M4</th>
<th>M4F</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
</tbody>
</table>

### 5.5.1 Syntax

\[ op(\text{cond}) \ (Rd), \ Rm, \ Rn \]

where:

- **op** is one of:
  - **QDADD**
    - Saturating Double and Add.
  - **QDSUB**
    - Saturating Double and Subtract.
- **cond** is an optional condition code, see Table 1-2 on page 33.
- **Rd** is the destination register.
- **Rm**, **Rn** are registers holding the first and second operands.

### 5.5.2 Operation

The **QDADD** instruction:

- Doubles the second operand value.
- Adds the result of the doubling to the signed saturated value in the first operand.
- Writes the result to the destination register.

The **QDSUB** instruction:

- Doubles the second operand value.
- Subtracts the doubled value from the signed saturated value in the first operand.
- Writes the result to the destination register.

Both the doubling and the addition or subtraction 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 APSR.

### 5.5.3 Restrictions

Do not use SP and do not use PC.
5.5.4 Condition flags

If saturation occurs, these instructions set the Q flag to 1.

5.5.5 Examples

QDADD  R7, R4, R2 ; Doubles and saturates R4 to 32 bits, adds R2,

; saturates to 32 bits, writes to R7.

QDSUB  R0, R3, R5 ; Subtracts R3 doubled and saturated to 32 bits

; from R5, saturates to 32 bits, writes to R0.
5.6 **UQASX and UQSAAX**

Saturating Add and Subtract with Exchange and Saturating Subtract and Add with Exchange, unsigned.

<table>
<thead>
<tr>
<th>Applies to...</th>
<th>M3</th>
<th>M4</th>
<th>M4F</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

### 5.6.1 Syntax

\[
\text{op}\{\text{cond}\}\{Rd\},\ Rm,\ Rn
\]

where:

- **type** is one of:
  - **UQASX**
    - Add and Subtract with Exchange and Saturate.
  - **UQSAAX**
    - Subtract and Add with Exchange and Saturate.

- **cond** is an optional condition code, see Table 1-2 on page 33.

- **Rd** is the destination register.

- **Rn, Rm** are registers holding the first and second operands.

### 5.6.2 Operation

The **UQASX** instruction:

1. Adds the bottom halfword of the source operand with the top halfword of the second operand.
2. Subtracts the bottom halfword of the second operand from the top highword of the first operand.
3. Saturates the results of the sum and writes a 16-bit unsigned integer in the range \(0 \leq x \leq 216 - 1\), where \(x\) equals 16, to the top halfword of the destination register.
4. Saturates the result of the subtraction and writes a 16-bit unsigned integer in the range \(0 \leq x \leq 216 - 1\), where \(x\) equals 16, to the bottom halfword of the destination register.

The **UQSAAX** instruction:

1. Subtracts the bottom halfword of the second operand from the top highword of the first operand.
2. Adds the bottom halfword of the first operand with the top halfword of the second operand.
3. Saturates the result of the subtraction and writes a 16-bit unsigned integer in the range \(0 \leq x \leq 216 - 1\), where \(x\) equals 16, to the top halfword of the destination register.
4. Saturates the results of the addition and writes a 16-bit unsigned integer in the range \(0 \leq x \leq 216 - 1\), where \(x\) equals 16, to the bottom halfword of the destination register.
5.6.3 Restrictions
Do not use SP and do not use PC.

5.6.4 Condition flags
These instructions do not affect the condition code flags.

5.6.5 Examples

UQASX   R7, R4, R2 ; Adds top halfword of R4 with bottom halfword of R2,
; saturates to 16 bits, writes to top halfword of R7
; Subtracts top halfword of R2 from bottom halfword of
; R4, saturates to 16 bits, writes to bottom halfword of R7

UQASX   R0, R3, R5 ; Subtracts bottom halfword of R5 from top halfword of R3,
; saturates to 16 bits, writes to top halfword of R0
; Adds bottom halfword of R4 to top halfword of R5
; saturates to 16 bits, writes to bottom halfword of R0.
5.7 **UQADD and UQSUB**

Saturating Add and Saturating Subtract Unsigned.

<table>
<thead>
<tr>
<th>Applies to...</th>
<th>M3</th>
<th>M4</th>
<th>M4F</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

5.7.1 **Syntax**

```plaintext
op{cond} {Rd}, Rn, Rm
```

```plaintext
op{cond} {Rd}, Rn, Rm
```

where:

- `op` is one of:
  - **UQADD8**
    - Saturating four unsigned 8-bit integer additions.
  - **UQADD16**
    - Saturating two unsigned 16-bit integer additions.
  - **UDSUB8**
    - Saturating four unsigned 8-bit integer subtractions.
  - **UQSUB16**
    - Saturating two unsigned 16-bit integer subtractions.

- **cond** is an optional condition code, see Table 1-2 on page 33.

- **Rd** is the destination register.

- **Rn, Rm** are registers holding the first and second operands.

5.7.2 **Operation**

These instructions add or subtract two or four values and then writes an unsigned saturated value in the destination register.

The **UQADD16** instruction:

- Adds the respective top and bottom halfwords of the first and second operands.
- Saturates the result of the additions for each halfword in the destination register to the unsigned range $0 \leq x \leq 2^{16} - 1$, where $x$ is 16.

The **UQADD8** instruction:

- Adds each respective byte of the first and second operands.
Saturates the result of the addition for each byte in the destination register to the unsigned range \(0 \leq x \leq 2^{8}\)−1, where \(x\) is 8.

The **UQSUB16** instruction:

- Subtracts both halfwords of the second operand from the respective halfwords of the first operand.
- Saturates the result of the differences in the destination register to the unsigned range \(0 \leq x \leq 2^{16}\)−1, where \(x\) is 16.

The **UQSUB8** instructions:

- Subtracts the respective bytes of the second operand from the respective bytes of the first operand.
- Saturates the results of the differences for each byte in the destination register to the unsigned range \(0 \leq x \leq 2^{8}\)−1, where \(x\) is 8.

### 5.7.3 Restrictions

Do not use SP and do not use PC.

### 5.7.4 Condition flags

These instructions do not affect the condition code flags.

### 5.7.5 Examples

```
UQADD16 R7, R4, R2 ; Adds halfwords in R4 to corresponding halfword in R2,
; saturates to 16 bits, writes to corresponding halfword
; of R7

UQADD8 R4, R2, R5 ; Adds bytes of R2 to corresponding byte of R5, saturates
; to 8 bits, writes to corresponding bytes of R4

UQSUB16 R6, R3, R0 ; Subtracts halfwords in R0 from corresponding halfword
; in R3, saturates to 16 bits, writes to corresponding
; halfword in R6

UQSUB8 R1, R5, R6 ; Subtracts bytes in R6 from corresponding byte of R5,
; saturates to 8 bits, writes to corresponding byte of R1
```
Packing and Unpacking Instructions

Table 6-1 on page 147 shows the packing and unpacking instructions:

Table 6-1. Packing and Unpacking Instructions

<table>
<thead>
<tr>
<th>Mnemonic</th>
<th>Brief Description</th>
<th>See Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>PKH</td>
<td>Pack halfword</td>
<td>148</td>
</tr>
<tr>
<td>SXTAB</td>
<td>Extend 8 bits to 32 and add</td>
<td>154</td>
</tr>
<tr>
<td>SXTAB16</td>
<td>Dual extend 8 bits to 16 and add</td>
<td>154</td>
</tr>
<tr>
<td>SXTAH</td>
<td>Extend 16 bits to 32 and add</td>
<td>154</td>
</tr>
<tr>
<td>SXTB</td>
<td>Sign extend a byte</td>
<td>150</td>
</tr>
<tr>
<td>SXTB16</td>
<td>Dual extend 8 bits to 16 and add</td>
<td>150</td>
</tr>
<tr>
<td>SXTH</td>
<td>Sign extend a halfword</td>
<td>150</td>
</tr>
<tr>
<td>UXTAB</td>
<td>Extend 8 bits to 32 and add</td>
<td>154</td>
</tr>
<tr>
<td>UXTAB16</td>
<td>Dual extend 8 bits to 16 and add</td>
<td>154</td>
</tr>
<tr>
<td>UXTAH</td>
<td>Extend 16 bits to 32 and add</td>
<td>154</td>
</tr>
<tr>
<td>UXTB</td>
<td>Zero extend a byte</td>
<td>150</td>
</tr>
<tr>
<td>UXTB16</td>
<td>Dual zero extend 8 bits to 16 and add</td>
<td>150</td>
</tr>
<tr>
<td>UXTH</td>
<td>Zero extend a halfword</td>
<td>150</td>
</tr>
</tbody>
</table>
6.1 PKHBT and PKHTB
Pack Halfword.

<table>
<thead>
<tr>
<th>Applies to...</th>
<th>M3</th>
<th>M4</th>
<th>M4F</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

6.1.1 Syntax

\[
\text{op}\{\text{cond}\} (\text{Rd}), \text{Rn}, \text{Rm} (, \text{LSL} \ #\text{imm})
\]

\[
\text{op}\{\text{cond}\} (\text{Rd}), \text{Rn}, \text{Rm} (, \text{ASR} \ #\text{imm})
\]

where:

\[
\text{op}
\]
is one of:

PKHBT
Pack Halfword, bottom and top with shift.

PKHTB
Pack Halfword, top and bottom with shift.

\[
\text{cond}
\]
is an optional condition code, see 33.

\[
\text{Rd}
\]
is the destination register.

\[
\text{Rn}
\]
is the first operand register.

\[
\text{Rm}
\]
is the second operand register holding the value to be optionally shifted.

\[
\text{imm}
\]
is the shift length. The type of shift length depends on the instruction: For PKHBT:

\[
\text{LSL}
\]
a left shift with a shift length from 1 to 31, 0 means no shift.

For PKHTB:

\[
\text{ASR}
\]
an arithmetic shift right with a shift length from 1 to 32, a shift of 32-bits is encoded as \(0b00000\).

6.1.2 Operation

The PKHBT instruction:
1. Writes the value of the bottom halfword of the first operand to the bottom halfword of the destination register.
2. If shifted, the shifted value of the second operand is written to the top halfword of the destination register.

The PKHTB instruction:
1. Writes the value of the top halfword of the first operand to the top halfword of the destination register.
2. If shifted, the shifted value of the second operand is written to the bottom halfword of the destination register.

6.1.3 Restrictions

Rd must not be SP and must not be PC.

6.1.4 Condition flags

This instruction does not change the flags.

6.1.5 Examples

PKHBT R3, R4, R5 LSL #0 ; Writes bottom halfword of R4 to bottom halfword of
; R3, writes top halfword of R5, unshifted, to top halfword of R3

PKHTB R4, R0, R2 ASR #1 ; Writes R2 shifted right by 1 bit to bottom halfword
; of R4, and writes top halfword of R0 to top halfword of R4
6.2 **SXT and UXT**

Sign extend and Zero extend.

<table>
<thead>
<tr>
<th>Applies to...</th>
<th>M3</th>
<th>M4</th>
<th>M4F</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

### 6.2.1 Syntax

\[
\text{op}\{\text{cond}\} (Rd,) \; Rm \; (, \; \text{ROR \#} n)
\]

\[
\text{op}\{\text{cond}\} (Rd), \; Rm \; (, \; \text{ROR \#} n)
\]

where:

*op* is one of:

- **SXTB**
  
  Sign extends an 8-bit value to a 32-bit value.

- **SXTH**
  
  Sign extends a 16-bit value to a 32-bit value.

- **SXTB16**
  
  Sign extends two 8-bit values to two 16-bit values.

- **UXTB**
  
  Zero extends an 8-bit value to a 32-bit value.

- **UXTH**
  
  Zero extends a 16-bit value to a 32-bit value.

- **UXTB16**
  
  Zero extends two 8-bit values to two 16-bit values.

*cond* is an optional condition code, see 33.

*Rd* is the destination register.

*Rm* is the register holding the value to extend.

*ROR \#n* is one of:

- **ROR \#8**
  
  Value from *Rm* is rotated right 8 bits.

- **ROR \#16**
  
  Value from *Rm* is rotated right 16 bits.
ROR #24

Value from $R_m$ is rotated right 24 bits.

If ROR #n is omitted, no rotation is performed.

### 6.2.2 Operation

These instructions do the following:

1. Rotate the value from $R_m$ right by 0, 8, 16 or 24 bits.

2. Extract bits from the resulting value:
   - **SXTB** extracts bits[7:0] and sign extends to 32 bits.
   - **UXTB** extracts bits[7:0] and zero extends to 32 bits.
   - **SXTH** extracts bits[15:0] and sign extends to 32 bits.
   - **UXTH** extracts bits[15:0] and zero extends to 32 bits.
   - **SXTB16** extracts bits[7:0] and sign extends to 16 bits, and extracts bits [23:16] and sign extends to 16 bits.
   - **UXTB16** extracts bits[7:0] and zero extends to 16 bits, and extracts bits [23:16] and zero extends to 16 bits.

### 6.2.3 Restrictions

Do not use SP and do not use PC.

### 6.2.4 Condition flags

These instructions do not affect the flags.

### 6.2.5 Examples

```
SXTB R4, R6, ROR #16 ; Rotates R6 right by 16 bits, obtains bottom halfword of
; of result, sign extends to 32 bits and writes to R4
UXTB R3, R10 ; Extracts lowest byte of value in R10, zero extends, and
; writes to R3
```
6.3  **SXTB16 and UXTB16**

Sign extend and Zero extend byte 16.

<table>
<thead>
<tr>
<th>Applies to...</th>
<th>M3</th>
<th>M4</th>
<th>M4F</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

### 6.3.1 Syntax

\[
\text{op}\{\text{cond}\} \ (Rd,) \ Rm \ \{, \ ROR \ #n\}
\]

\[
\text{op}\{\text{cond}\} \ (Rd), \ Rm \ \{, \ ROR \ #n\}
\]

where:

- **op**
  - is one of:
    - **SXTB16**
      - Sign extends two 8-bit values to two 16-bit values.
    - **UXTB16**
      - Zero extends two 8-bit values to two 16-bit values.
  - is the destination register.

- **Rm**
  - is the register holding the value to extend.

- **ROR \ #n**
  - is one of:
    - **ROR \ #8**
      - Value from \(Rm\) is rotated right 8 bits.
    - **ROR \ #16**
      - Value from \(Rm\) is rotated right 16 bits.
    - **ROR \ #24**
      - Value from \(Rm\) is rotated right 24 bits.

If **ROR \ #n** is omitted, no rotation is performed.

### 6.3.2 Operation

These instructions do the following:

1. Rotate the value from \(Rm\) right by 0, 8, 16 or 24 bits.
2. Extract bits from the resulting value:
   - **SXTB16** extracts bits[7:0] and sign extends to 16 bits, and extracts bits [23:16] and sign extends to 16 bits.
   - **UXTB16** extracts bits[7:0] and zero extends to 16 bits, and extracts bits [23:16] and zero extends to 16 bits.

6.3.3 Restrictions
Do not use SP and do not use PC.

6.3.4 Condition flags
These instructions do not affect the flags.

6.3.5 Examples

```
SXTH R4, R6, ROR #16 ; Rotates R6 right by 16 bits, obtains bottom halfword of
                      ; of result, sign extends to 32 bits and writes to R4
UXTB R3, R10 ; Extracts lowest byte of value in R10, zero extends, and
              ; writes to R3
```
6.4 **SXTA and UXTA**

Signed and Unsigned Extend and Add.

<table>
<thead>
<tr>
<th>Applies to...</th>
<th>M3</th>
<th>M4</th>
<th>M4F</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
</tbody>
</table>

6.4.1 **Syntax**

\[
\text{op\{cond\}}\ (\text{Rd,} \) \ Rn, \ Rm \ (, \ \text{ROR \#n})
\]

\[
\text{op\{cond\}}\ (\text{Rd,} \) \ Rn, \ Rm \ (, \ \text{ROR \#n})
\]

where:

\text{op}

is one of:

- **SXTAB**
  
  Sign extends an 8-bit value to a 32-bit value and add.

- **SXTAH**
  
  Sign extends a 16-bit value to a 32-bit value and add.

- **SXTAB16**
  
  Sign extends two 8-bit values to two 16-bit values and add.

- **UXTAB**
  
  Zero extends an 8-bit value to a 32-bit value and add.

- **UXTAH**
  
  Zero extends a 16-bit value to a 32-bit value and add.

- **UXTAB16**
  
  Zero extends two 8-bit values to two 16-bit values and add.

\text{cond}

is an optional condition code, see 33.

\text{Rd}

is the destination register.

\text{Rn}

is the first operand register.

\text{Rm}

is the register holding the value to rotate and extend.

\text{ROR \#n}

is one of:

- \text{ROR \#8}
  
  Value from \text{Rm} is rotated right 8 bits.
ROR #16
   Value from Rm is rotated right 16 bits.

ROR #24
   Value from Rm is rotated right 24 bits.

If ROR #n is omitted, no rotation is performed.

6.4.2 Operation

These instructions do the following:

1. Rotate the value from Rm right by 0, 8, 16 or 24 bits.

2. Extract bits from the resulting value:
   - SXTAB extracts bits[7:0] from Rm and sign extends to 32 bits.
   - UXTAB extracts bits[7:0] from Rm and zero extends to 32 bits.
   - SXTAH extracts bits[15:0] from Rm and sign extends to 32 bits.
   - UXTAH extracts bits[15:0] from Rm and zero extends to 32 bits.
   - SXTAB16 extracts bits[7:0] from Rm and sign extends to 16 bits, and extracts bits [23:16] from Rm and sign extends to 16 bits.
   - UXTAB16 extracts bits[7:0] from Rm and zero extends to 16 bits, and extracts bits [23:16] from Rm and zero extends to 16 bits.

3. Adds the signed or zero extended value to the word or corresponding halfword of Rn and writes the result in Rd.

6.4.3 Restrictions

Do not use SP and do not use PC.

6.4.4 Condition flags

These instructions do not affect the flags.

6.4.5 Examples

SXTAH R4, R8, R6, ROR #16 ; Rotates R6 right by 16 bits, obtains bottom halfword, sign extends to 32 bits, adds R8, and writes to R4

UXTAB R3, R4, R10 ; Extracts bottom byte of R10 and zero extends to 32 bits, adds R4, and writes to R3
7 Bitfield Instructions

Table 7-1 on page 156 shows the instructions that operate on adjacent sets of bits in registers or bitfields:

Table 7-1. Bitfield Instructions

<table>
<thead>
<tr>
<th>Mnemonic</th>
<th>Brief Description</th>
<th>See Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>BFC</td>
<td>Bit field clear</td>
<td>157</td>
</tr>
<tr>
<td>BFI</td>
<td>Bit field insert</td>
<td>157</td>
</tr>
<tr>
<td>SBFX</td>
<td>Signed bit field extract</td>
<td>158</td>
</tr>
<tr>
<td>UBFX</td>
<td>Unsigned bit field extract</td>
<td>158</td>
</tr>
</tbody>
</table>
7.1 **BFC and BFI**

Bit Field Clear and Bit Field Insert.

<table>
<thead>
<tr>
<th>Applies to...</th>
<th>M3</th>
<th>M4</th>
<th>M4F</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

### 7.1.1 Syntax

**BFC**(cond) Rd, #lsb, #width

**BFI**(cond) Rd, Rn, #lsb, #width

where:

- **cond**
  
  Is an optional condition code. See Table 1-2 on page 33.

- **Rd**
  
  Is the destination register.

- **Rn**
  
  Is the source register.

- **lsb**
  
  Is the position of the least-significant bit of the bitfield. **lsb** must be in the range 0 to 31.

- **width**
  
  Is the width of the bitfield and must be in the range 1 to 32 - **lsb**.

### 7.1.2 Operation

**BFC** clears a bitfield in a register. It clears **width** bits in **Rd**, starting at the low bit position **lsb**. Other bits in **Rd** are unchanged.

**BFI** copies a bitfield into one register from another register. It replaces **width** bits in **Rd** starting at the low bit position **lsb**, with **width** bits from **Rn** starting at bit[0]. Other bits in **Rd** are unchanged.

### 7.1.3 Restrictions

Do not use **SP** and do not use **PC**.

### 7.1.4 Condition Flags

These instructions do not affect the flags.

### 7.1.5 Examples

- **BFC** R4, #8, #12 ; Clear bit 8 to bit 19 (12 bits) of R4 to 0.
- **BFI** R9, R2, #8, #12 ; Replace bit 8 to bit 19 (12 bits) of R9 with bit 0 to bit 11 from R2.
7.2  **SBFX and UBFX**

Signed Bit Field Extract and Unsigned Bit Field Extract.

<table>
<thead>
<tr>
<th>Applies to...</th>
<th>M3</th>
<th>M4</th>
<th>M4F</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

### 7.2.1 Syntax

\[
\text{SBFX}\{\text{cond}\} \ Rd, \ Rn, \ #\text{lsb}, \ #\text{width} \\
\text{UBFX}\{\text{cond}\} \ Rd, \ Rn, \ #\text{lsb}, \ #\text{width}
\]

where:

- **cond**
  
  Is an optional condition code. See Table 1-2 on page 33.

- **Rd**
  
  Is the destination register.

- **Rn**
  
  Is the source register.

- **lsb**
  
  Is the position of the least-significant bit of the bitfield. \(\text{lsb}\) must be in the range 0 to 31.

- **width**
  
  Is the width of the bitfield and must be in the range 1 to \(32 \div \text{lsb}\).

### 7.2.2 Operation

- **SBFX** extracts a bitfield from one register, sign extends it to 32 bits, and writes the result to the destination register.

- **UBFX** extracts a bitfield from one register, zero extends it to 32 bits, and writes the result to the destination register.

### 7.2.3 Restrictions

Do not use **SP** and do not use **PC**.

### 7.2.4 Condition Flags

These instructions do not affect the flags.

### 7.2.5 Examples

- **SBFX**  
  
  \[ \text{R0, R1, #20, #4} \] ; Extract bit 20 to bit 23 (4 bits) from R1 and sign extend to 32 bits and then write the result to R0.

- **UBFX**  
  
  \[ \text{R8, R11, #9, #10} \] ; Extract bit 9 to bit 18 (10 bits) from R11 and zero extend to 32 bits and then write the result to R8.
8 Floating-Point

Table 8-1 on page 159 shows the floating-point instructions.¹

<table>
<thead>
<tr>
<th>Mnemonic</th>
<th>Brief Description</th>
<th>See Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>VABS</td>
<td>Floating-point absolute</td>
<td>161</td>
</tr>
<tr>
<td>VADD</td>
<td>Floating-point add</td>
<td>162</td>
</tr>
<tr>
<td>VCMP</td>
<td>Compare two floating-point registers, or one floating-point register and zero</td>
<td>163</td>
</tr>
<tr>
<td>VCMPF</td>
<td>Compare two floating-point registers, or one floating-point register and zero with Invalid Operation check</td>
<td>163</td>
</tr>
<tr>
<td>VCVT</td>
<td>Convert between floating-point and integer</td>
<td>167</td>
</tr>
<tr>
<td>VCVT</td>
<td>Convert between floating-point and fixed point</td>
<td>167</td>
</tr>
<tr>
<td>VCVTR</td>
<td>Convert between floating-point and integer with rounding</td>
<td>167</td>
</tr>
<tr>
<td>VCVTB</td>
<td>Converts half-precision value to single-precision</td>
<td>169</td>
</tr>
<tr>
<td>VCVTT</td>
<td>Converts single-precision register to half-precision</td>
<td>169</td>
</tr>
<tr>
<td>VDIV</td>
<td>Floating-point divide</td>
<td>171</td>
</tr>
<tr>
<td>VFMA</td>
<td>Floating-point fused multiply accumulate</td>
<td>172</td>
</tr>
<tr>
<td>VFNMA</td>
<td>Floating-point fused negate multiply accumulate</td>
<td>173</td>
</tr>
<tr>
<td>VFMN</td>
<td>Floating-point fused multiply subtract</td>
<td>172</td>
</tr>
<tr>
<td>VFNMS</td>
<td>Floating-point fused negate multiply subtract</td>
<td>173</td>
</tr>
<tr>
<td>VLD</td>
<td>Load multiple extension registers</td>
<td>174</td>
</tr>
<tr>
<td>VLDR</td>
<td>Loads an extension register from memory</td>
<td>176</td>
</tr>
<tr>
<td>VLMA</td>
<td>Floating-point multiply accumulate</td>
<td>178</td>
</tr>
<tr>
<td>VLMS</td>
<td>Floating-point multiply subtract</td>
<td>178</td>
</tr>
<tr>
<td>VMOV</td>
<td>Floating-point move immediate</td>
<td>179</td>
</tr>
<tr>
<td>VMOV</td>
<td>Floating-point move register</td>
<td>180</td>
</tr>
<tr>
<td>VMOV</td>
<td>Copy ARM core register to single precision</td>
<td>182</td>
</tr>
<tr>
<td>VMOV</td>
<td>Copy 2 ARM core registers to 2 single precision</td>
<td>183</td>
</tr>
<tr>
<td>VMOV</td>
<td>Copies between ARM core register to scalar</td>
<td>182</td>
</tr>
<tr>
<td>VMOV</td>
<td>Copies between scalar to ARM core register</td>
<td>182</td>
</tr>
<tr>
<td>VMRS</td>
<td>Move to ARM core register from floating-point system register</td>
<td>185</td>
</tr>
<tr>
<td>VMSR</td>
<td>Move to ARM core register from floating-point system register from ARM Core register</td>
<td>186</td>
</tr>
<tr>
<td>VMUL</td>
<td>Multiply floating-point</td>
<td>187</td>
</tr>
<tr>
<td>VNEG</td>
<td>Floating-point negate</td>
<td>188</td>
</tr>
<tr>
<td>VPNLA</td>
<td>Floating-point multiply and add</td>
<td>189</td>
</tr>
<tr>
<td>VPNLS</td>
<td>Floating-point multiply and subtract</td>
<td>189</td>
</tr>
<tr>
<td>VNMUL</td>
<td>Floating-point multiply</td>
<td>189</td>
</tr>
<tr>
<td>VPPOP</td>
<td>Pop extension registers</td>
<td>191</td>
</tr>
<tr>
<td>VPUSH</td>
<td>Push extension registers</td>
<td>192</td>
</tr>
<tr>
<td>VSQRT</td>
<td>Floating-point square root</td>
<td>193</td>
</tr>
</tbody>
</table>

¹These instructions are only available if the FPU is included, and enabled, in the system.
Table 8-1. Floating-Point Instructions (continued)

<table>
<thead>
<tr>
<th>Mnemonic</th>
<th>Brief Description</th>
<th>See Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>VSTM</td>
<td>Store multiple extension registers</td>
<td>194</td>
</tr>
<tr>
<td>VSTR</td>
<td>Stores an extension register to memory</td>
<td>196</td>
</tr>
<tr>
<td>VSUB</td>
<td>Floating-point subtract</td>
<td>197</td>
</tr>
</tbody>
</table>
8.1 VABS

Floating-point Absolute.

<table>
<thead>
<tr>
<th>Applies to...</th>
<th>M3</th>
<th>M4</th>
<th>M4F</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>✓</td>
</tr>
</tbody>
</table>

8.1.1 Syntax

\[
\text{VABS}\{\text{cond}\}.\text{F32} \ Sd, Sm
\]

where:

\(\text{cond}\)

is an optional condition code, see “Conditional Execution” on page 32.

\(Sd, Sm\)

destiny the destination floating-point value and the operand floating-point value.

8.1.2 Operation

This instruction:

1. Takes the absolute value of the operand floating-point register.
2. Places the results in the destination floating-point register.

8.1.3 Restrictions

There are no restrictions.

8.1.4 Condition flags

The floating-point instruction clears the sign bit.

8.1.5 Examples

\[
\text{VABS.F32} \ S4, S6
\]
8.2 VADD

Floating-point Add.

<table>
<thead>
<tr>
<th>Applies to...</th>
<th>M3</th>
<th>M4</th>
<th>M4F</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>✓</td>
<td></td>
</tr>
</tbody>
</table>

8.2.1 Syntax

\[ VADD\{ cond\}.F32 \{ Sd, \} S_n, S_m \]

where:

- \( cond \) is an optional condition code, see “Conditional Execution” on page 32.
- \( S_d \) is the destination floating-point value.
- \( S_n, S_m \) are the operand floating-point values.

8.2.2 Operation

This instruction:

1. Adds the values in the two floating-point operand registers.
2. Places the results in the destination floating-point register.

8.2.3 Restrictions

There are no restrictions.

8.2.4 Condition flags

This instruction does not change the flags.

8.2.5 Examples

\[ VADD.F32 S_4, S_6, S_7 \]
8.3 VCMP, VCMPE

Compares two floating-point registers, or one floating-point register and zero.

<table>
<thead>
<tr>
<th>Applies to...</th>
<th>M3</th>
<th>M4</th>
<th>M4F</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>✓</td>
</tr>
</tbody>
</table>

8.3.1 Syntax

VCMP{E}{cond}.F32  Sd, Sm

VCMP{E}{cond}.F32  Sd, #0.0

where:

cond
is an optional condition code, see “Conditional Execution” on page 32.

E
If present, any NaN operand causes an Invalid Operation exception. Otherwise, only a signaling NaN causes the exception.

Sd
is the floating-point operand to compare.

Sm
is the floating-point operand that is compared with.

8.3.2 Operation

This instruction:

1. Compares:
   - Two floating-point registers.
   - One floating-point register and zero.

2. Writes the result to the FPSCR flags.

8.3.3 Restrictions

This instruction can optionally raise an Invalid Operation exception if either operand is any type of NaN. It always raises an Invalid Operation exception if either operand is a signaling NaN.

8.3.4 Condition flags

When this instruction writes the result to the FPSCR flags, the values are normally transferred to the ARM flags by a subsequent VMRS instruction, see “VMRS” on page 185.
8.3.5 Examples

VCMP.F32 S4, #0.0
VCMP.F32 S4, S2
8.4 **VCVT, VCVTR between floating-point and integer**

Converts a value in a register from floating-point to a 32-bit integer.

<table>
<thead>
<tr>
<th>Applies to...</th>
<th>M3</th>
<th>M4</th>
<th>M4F</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>✓</td>
</tr>
</tbody>
</table>

### 8.4.1 Syntax

\[
\text{VCVT}\{R\}\{\text{cond}\}.\text{Tm}.\text{F32} \; \text{Sd}, \; \text{Sm}
\]

\[
\text{VCVT}\{\text{cond}\}.\text{F32}.\text{Tm} \; \text{Sd}, \; \text{Sm}
\]

where:

- **R**
  - If \( R \) is specified, the operation uses the rounding mode specified by the \( \text{FPSCR} \). If \( R \) is omitted, the operation uses the \textit{Round towards Zero} rounding mode.

- **cond**
  - is an optional condition code, see “Conditional Execution” on page 32.

- **Tm**
  - is the data type for the operand. It must be one of:
    - \textbf{S32} signed 32-bit value.
    - \textbf{U32} unsigned 32-bit value.

- **Sd, Sm**
  - are the destination register and the operand register.

### 8.4.2 Operation

These instructions:

1. Either
   - Converts a value in a register from floating-point value to a 32-bit integer.
   - Converts from a 32-bit integer to floating-point value.

2. Places the result in a second register.

   The floating-point to integer operation normally uses the \textit{Round towards Zero} rounding mode, but can optionally use the rounding mode specified by the \( \text{FPSCR} \).

   The integer to floating-point operation uses the rounding mode specified by the \( \text{FPSCR} \).

### 8.4.3 Restrictions

There are no restrictions.
8.4.4 Condition flags

These instructions do not change the flags.
8.5 **VCVT between floating-point and fixed-point**
Converts a value in a register from floating-point to and from fixed-point.

<table>
<thead>
<tr>
<th>Applies to...</th>
<th>M3</th>
<th>M4</th>
<th>M4F</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>✓</td>
</tr>
</tbody>
</table>

### 8.5.1 Syntax

\[
\text{VCVT}\{\text{cond}\}.Td.F32 \text{ Sd, Sd, \#fbits}
\]

\[
\text{VCVT}\{\text{cond}\}.F32.Td \text{ Sd, Sd, \#fbits}
\]

where:

- **cond**
  is an optional condition code, see “Conditional Execution” on page 32.

- **Td**
  is the data type for the fixed-point number. It must be one of:
  - S16 signed 16-bit value.
  - U16 unsigned 16-bit value.
  - S32 signed 32-bit value.
  - U32 unsigned 32-bit value.

- **Sd**
  is the destination register and the operand register.

- **fbits**
  is the number of fraction bits in the fixed-point number:
  - If **Td** is S16 or U16, **fbits** must be in the range 0-16.
  - If **Td** is S32 or U32, **fbits** must be in the range 1-32.

### 8.5.2 Operation

These instructions:

1. Either
   - Converts a value in a register from floating-point to fixed-point.
   - Converts a value in a register from fixed-point to floating-point.

2. Places the result in a second register.

The floating-point values are single-precision.
The fixed-point value can be 16-bit or 32-bit. Conversions from fixed-point values take their operand from the low-order bits of the source register and ignore any remaining bits.

Signed conversions to fixed-point values sign-extend the result value to the destination register width.

Unsigned conversions to fixed-point values zero-extend the result value to the destination register width.

The floating-point to fixed-point operation uses the Round towards Zero rounding mode. The fixed-point to floating-point operation uses the Round to Nearest rounding mode.

8.5.3 Restrictions
There are no restrictions.

8.5.4 Condition flags
These instructions do not change the flags.
8.6 VCVTB, VCVTT

Converts between a half-precision value and a single-precision value.

<table>
<thead>
<tr>
<th>Applies to...</th>
<th>M3</th>
<th>M4</th>
<th>M4F</th>
</tr>
</thead>
<tbody>
<tr>
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<td>✔️</td>
</tr>
</tbody>
</table>

8.6.1 Syntax

VCVT\{y\}\{cond\}.F32.F16  Sd, Sm

VCVT\{y\}\{cond\}.F16.F32  Sd, Sm

where:

\(y\)

Specifies which half of the operand register \(Sm\) or destination register \(Sd\) is used for the operand or destination:

- If \(y\) is \(B\), then the bottom half, bits \([15:0]\), of \(Sm\) or \(Sd\) is used.
- If \(y\) is \(T\), then the top half, bits \([31:16]\), of \(Sm\) or \(Sd\) is used.

\(cond\)

is an optional condition code, see “Conditional Execution” on page 32.

\(Sd\)

is the destination register.

\(Sm\)

is the operand register.

8.6.2 Operation

This instruction with the .F16.32 suffix:

1. Converts the half-precision value in the top or bottom half of a single-precision register to single-precision.
2. Writes the result to a single-precision register.

This instruction with the .F32.F16 suffix:

1. Converts the value in a single-precision register to half-precision.
2. Writes the result into the top or bottom half of a single-precision register, preserving the other half of the target register.

8.6.3 Restrictions

There are no restrictions.
8.6.4 Condition flags

These instructions do not change the flags.
8.7 VDIV
Divides floating-point values.

<table>
<thead>
<tr>
<th>Applies to...</th>
<th>M3</th>
<th>M4</th>
<th>M4F</th>
</tr>
</thead>
<tbody>
<tr>
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<td></td>
<td>✓</td>
</tr>
</tbody>
</table>

8.7.1 Syntax

VDIV{cond}.F32 {Sd,} Sn, Sm

where:

cond
is an optional condition code, see “Conditional Execution” on page 32.

Sd
is the destination register.

Sn, Sm
are the operand registers.

8.7.2 Operation
This instruction:

1. Divides one floating-point value by another floating-point value.
2. Writes the result to the floating-point destination register.

8.7.3 Restrictions
There are no restrictions.

8.7.4 Condition flags
These instructions do not change the flags.
8.8  **VFMA, VFMS**

Floating-point Fused Multiply Accumulate and Subtract.

<table>
<thead>
<tr>
<th>Applies to...</th>
<th>M3</th>
<th>M4</th>
<th>M4F</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>✓</td>
</tr>
</tbody>
</table>

### 8.8.1 Syntax

\[
\text{VFMA}(\text{cond})\cdot\text{F32}\ (Sd,)\ Sn,\ Sm
\]

\[
\text{VFMS}(\text{cond})\cdot\text{F32}\ (Sd,)\ Sn,\ Sm
\]

where:

- *cond* is an optional condition code, see “Conditional Execution” on page 32.

- *Sd* is the destination register.

- *Sn, Sm* are the operand registers.

### 8.8.2 Operation

The **VFMA** instruction:

1. Multiplies the floating-point values in the operand registers.
2. Accumulates the results into the destination register.

The result of the multiply is not rounded before the accumulation.

The **VFMS** instruction:

1. Negates the first operand register.
2. Multiplies the floating-point values of the first and second operand registers.
3. Adds the products to the destination register.
4. Places the results in the destination register.

The result of the multiply is not rounded before the addition.

### 8.8.3 Restrictions

There are no restrictions.

### 8.8.4 Condition flags

These instructions do not change the flags.
8.9 VFNMA, VFNMS

Floating-point Fused Negate Multiply Accumulate and Subtract.

### 8.9.1 Syntax

\[
\begin{align*}
\text{VFNMA} & (\text{cond}) \cdot \text{F32} \ (Sd,) \ Sn, \ Sm \\
\text{VFNMS} & (\text{cond}) \cdot \text{F32} \ (Sd,) \ Sn, \ Sm
\end{align*}
\]

where:

\text{cond} is an optional condition code, see “Conditional Execution” on page 32.

\text{Sd} is the destination register.

\text{Sn, Sm} are the operand registers.

### 8.9.2 Operation

The VFNMA instruction:

1. Negates the first floating-point operand register.
2. Multiplies the first floating-point operand with second floating-point operand.
3. Adds the negation of the floating-point destination register to the product.
4. Places the result into the destination register.

The result of the multiply is not rounded before the addition.

The VFNMS instruction:

1. Multiplies the first floating-point operand with second floating-point operand.
2. Adds the negation of the floating-point value in the destination register to the product.
3. Places the result in the destination register.

The result of the multiply is not rounded before the addition.

### 8.9.3 Restrictions

There are no restrictions.

### 8.9.4 Condition flags

These instructions do not change the flags.
8.10 **VLDM**  
Floating-point Load Multiple.

<table>
<thead>
<tr>
<th>Applies to...</th>
<th>M3</th>
<th>M4</th>
<th>M4F</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<td>✓</td>
</tr>
</tbody>
</table>

### 8.10.1 Syntax

VLDM\(\text{mode}\{\text{cond}\}{.\text{size}}\) \text{Rn(!), list}

where:

- **mode** is the addressing mode:
  - **IA** Increment After. The consecutive addresses start at the address specified in \(Rn\).
  - **DB** Decrement Before. The consecutive addresses end just before the address specified in \(Rn\).
- **cond** is an optional condition code, see "Conditional Execution" on page 32.
- **size** is an optional data size specifier.
- **Rn** is the base register. The \(SP\) can be used.
- **!** is the command to the instruction to write a modified value back to \(Rn\). This is required if \(\text{mode} == DB\), and is optional if \(\text{mode} == IA\).
- **list** is the list of extension registers to be loaded, as a list of consecutively numbered doubleword or singleword registers, separated by commas and surrounded by brackets.

### 8.10.2 Operation

This instruction loads:

- Multiple extension registers from consecutive memory locations using an address from an ARM core register as the base address.

### 8.10.3 Restrictions

The restrictions are:

- If **size** is present, it must be equal to the size in bits, 32 or 64, of the registers in **list**.
- For the base address, the \(SP\) can be used. In the ARM instruction set, if **!** is not specified the \(PC\) can be used.
- \textit{list} must contain at least one register. If it contains doubleword registers, it must not contain more than 16 registers.

- If using the Decrement Before addressing mode, the write back flag, !, must be appended to the base register specification.

### 8.10.4 Condition flags

These instructions do not change the flags.
8.11 VLDR

Loads a single extension register from memory.

<table>
<thead>
<tr>
<th>Applies to...</th>
<th>M3</th>
<th>M4</th>
<th>M4F</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<td></td>
<td>✓</td>
</tr>
</tbody>
</table>

### 8.11.1 Syntax

VLDR{cond}{.64} Dd, [Rn#{imm}]

VLDR{cond}{.64} Dd, label

VLDR{cond}{.64} Dd, [PC, #imm]

VLDR{cond}{.32} Sd, [Rn {, #imm}]

VLDR{cond}{.32} Sd, label

VLDR{cond}{.32} Sd, [PC, #imm]

where:

- **cond** is an optional condition code, see “Conditional Execution” on page 32.
- **64, 32** are the optional data size specifiers.
- **Dd** is the destination register for a doubleword load.
- **Sd** is the destination register for a singleword load.
- **Rn** is the base register. The SP can be used.
- **imm** is the + or - immediate offset used to form the address. Permitted address values are multiples of 4 in the range 0 to 1020.
- **label** is the label of the literal data item to be loaded.

### 8.11.2 Operation

This instruction:
• Loads a single extension register from memory, using a base address from an ARM core register, with an optional offset.

8.11.3 Restrictions

There are no restrictions.

8.11.4 Condition flags

These instructions do not change the flags.
8.12 **VLMA, VLMS**

Multiplies two floating-point values, and accumulates or subtracts the results.

<table>
<thead>
<tr>
<th>Applies to...</th>
<th>M3</th>
<th>M4</th>
<th>M4F</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>✓</td>
</tr>
</tbody>
</table>

### 8.12.1 Syntax

\[
\text{VLMA}\{\text{cond}\}.F32 \quad Sd, \quad Sn, \quad Sm
\]

\[
\text{VLMS}\{\text{cond}\}.F32 \quad Sd, \quad Sn, \quad Sm
\]

where:

- \( cond \) is an optional condition code, see “Conditional Execution” on page 32.
- \( Sd \) is the destination floating-point value.
- \( Sn, Sm \) are the operand floating-point values.

### 8.12.2 Operation

The floating-point Multiply Accumulate instruction:

1. Multiplies two floating-point values.
2. Adds the results to the destination floating-point value.

The floating-point Multiply Subtract instruction:

1. Multiplies two floating-point values.
2. Subtracts the products from the destination floating-point value.
3. Places the results in the destination register.

### 8.12.3 Restrictions

There are no restrictions.

### 8.12.4 Condition flags

These instructions do not change the flags.
8.13 VMOV Immediate

Move floating-point Immediate.

<table>
<thead>
<tr>
<th>Applies to...</th>
<th>M3</th>
<th>M4</th>
<th>M4F</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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</tr>
</tbody>
</table>

8.13.1 Syntax

VMOV{cond}.F32 Sd, #imm

where:

cond
is an optional condition code, see “Conditional Execution” on page 32.

Sd
is the branch destination.

imm
is a floating-point constant.

8.13.2 Operation

This instruction copies a constant value to a floating-point register.

8.13.3 Restrictions

There are no restrictions.

8.13.4 Condition flags

These instructions do not change the flags.
8.14 VMOV Register

Copies the contents of one register to another.

<table>
<thead>
<tr>
<th>Applies to...</th>
<th>M3</th>
<th>M4</th>
<th>M4F</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>✓</td>
</tr>
</tbody>
</table>

8.14.1 Syntax

\[
\text{VMOV}\{\text{cond}\}.F64 \quad \text{Dd, Dm}
\]

\[
\text{VMOV}\{\text{cond}\}.F32 \quad \text{Sd, Sm}
\]

where:

\(\text{cond}\)

is an optional condition code, see “Conditional Execution” on page 32.

\(\text{Dd}\)

is the destination register, for a doubleword operation.

\(\text{Dm}\)

is the source register, for a doubleword operation.

\(\text{Sd}\)

is the destination register, for a singleword operation.

\(\text{Sm}\)

is the source register, for a singleword operation.

8.14.2 Operation

This instruction copies the contents of one floating-point register to another.

8.14.3 Restrictions

There are no restrictions

8.14.4 Condition flags

These instructions do not change the flags.
8.15  **VMOV Scalar to ARM Core register**

Transfers one word of a doubleword floating-point register to an ARM core register.

<table>
<thead>
<tr>
<th>Applies to...</th>
<th>M3</th>
<th>M4</th>
<th>M4F</th>
</tr>
</thead>
<tbody>
<tr>
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<td>✓</td>
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</tbody>
</table>

### 8.15.1 Syntax

\[ \text{VMOV}\{\text{cond}\}\ Rt,\ Dn[x] \]

where:

- **cond** is an optional condition code, see “Conditional Execution” on page 32.

- **Rt** is the destination ARM core register.

- **Dn** is the 64-bit doubleword register.

- **x** Specifies which half of the doubleword register to use:
  - If x is 0, use lower half of doubleword register
  - If x is 1, use upper half of doubleword register.

### 8.15.2 Operation

This instruction transfers:

- one word from the upper or lower half of a doubleword floating-point register to an ARM core register.

### 8.15.3 Restrictions

*Rt* cannot be PC or SP.

### 8.15.4 Condition flags

These instructions do not change the flags.
8.16 VMOV ARM Core register to single precision

Transfers a single-precision register to and from an ARM core register.

<table>
<thead>
<tr>
<th>Applies to...</th>
<th>M3</th>
<th>M4</th>
<th>M4F</th>
</tr>
</thead>
<tbody>
<tr>
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<td></td>
<td>✓</td>
</tr>
</tbody>
</table>

8.16.1 Syntax

\[
\text{VMOV}\{\text{cond}\} \ Sn, \ Rt
\]

\[
\text{VMOV}\{\text{cond}\} \ Rt, \ Sn
\]

where:

\text{cond} \\

is an optional condition code, see “Conditional Execution” on page 32.

\text{Sn} \\

is the single-precision floating-point register.

\text{Rt} \\

is the ARM core register.

8.16.2 Operation

This instruction transfers:

- The contents of a single-precision register to an ARM core register.
- The contents of an ARM core register to a single-precision register.

8.16.3 Restrictions

\text{Rt} cannot be PC or SP.

8.16.4 Condition flags

These instructions do not change the flags.
8.17 **VMOV Two ARM Core registers to two single precision**

Transfers two consecutively numbered single-precision registers to and from two ARM core registers.

<table>
<thead>
<tr>
<th>Applies to...</th>
<th>M3</th>
<th>M4</th>
<th>M4F</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<td></td>
<td>✓</td>
</tr>
</tbody>
</table>

**8.17.1 Syntax**

\[
\text{VMOV}\{\text{cond}\} \hspace{0.5em} \text{Sm, Sm1, Rt, Rt2} \\
\text{VMOV}\{\text{cond}\} \hspace{0.5em} \text{Rt, Rt2, Sm, Sm}
\]

where:

- \(\text{cond}\) is an optional condition code, see “Conditional Execution” on page 32.

- \(\text{Sm}\) is the first single-precision register.

- \(\text{Sm1}\) is the second single-precision register. This is the next single-precision register after \(\text{Sm}\).

- \(\text{Rt}\) is the ARM core register that \(\text{Sm}\) is transferred to or from.

- \(\text{Rt2}\) is the The ARM core register that \(\text{Sm1}\) is transferred to or from.

**8.17.2 Operation**

This instruction transfers:

- The contents of two consecutively numbered single-precision registers to two ARM core registers.

- The contents of two ARM core registers to a pair of single-precision registers.

**8.17.3 Restrictions**

The restrictions are:

- The floating-point registers must be contiguous, one after the other.

- The ARM core registers do not have to be contiguous.

- \(\text{Rt}\) cannot be PC or SP.

**8.17.4 Condition flags**

These instructions do not change the flags.
8.18  VMOV ARM Core register to scalar
Transfers one word to a floating-point register from an ARM core register.

<table>
<thead>
<tr>
<th>Applies to...</th>
<th>M3</th>
<th>M4</th>
<th>M4F</th>
</tr>
</thead>
<tbody>
<tr>
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</tbody>
</table>

8.18.1  Syntax

\[ \text{VMOV}\{\text{cond}\}\{.32\}\ \text{Dd}[x], \ Rt \]

where:

- \text{cond} is an optional condition code, see “Conditional Execution” on page 32.
- \text{32} is an optional data size specifier.
- \text{Dd}[x] is the destination, where [x] defines which half of the doubleword is transferred, as follows:
  - If x is 0, the lower half is extracted
  - If x is 1, the upper half is extracted.
- \text{Rt} is the source ARM core register.

8.18.2  Operation
This instruction transfers one word to the upper or lower half of a doubleword floating-point register from an ARM core register.

8.18.3  Restrictions
\text{Rt} cannot be PC or SP.

8.18.4  Condition flags
These instructions do not change the flags.
8.19 VMRS
Move to ARM Core register from floating-point System Register.

<table>
<thead>
<tr>
<th>Applies to...</th>
<th>M3</th>
<th>M4</th>
<th>M4F</th>
</tr>
</thead>
<tbody>
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</tr>
</tbody>
</table>

8.19.1 Syntax

VMRS{cond} Rt, FPSCR

VMRS{cond} APSR_nzcv, FPSCR

where:

cond
is an optional condition code, see “Conditional Execution” on page 32.

Rt
is the destination ARM core register. This register can be R0-R14.

APSR_nzcv
Transfer floating-point flags to the APSR flags.

8.19.2 Operation
This instruction performs one of the following actions:

- Copies the value of the FPSCR to a general-purpose register.
- Copies the value of the FPSCR flag bits to the APSR N, Z, C, and V flags.

8.19.3 Restrictions
Rt cannot be PC or SP.

8.19.4 Condition flags
These instructions optionally change the flags: N, Z, C, V
8.20 VMSR

Move to floating-point System Register from ARM Core register.

<table>
<thead>
<tr>
<th>Applies to...</th>
<th>M3</th>
<th>M4</th>
<th>M4F</th>
</tr>
</thead>
<tbody>
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</tbody>
</table>

8.20.1 Syntax

VMSR{cond} FPSCR, Rt

where:

cond

is an optional condition code, see “Conditional Execution” on page 32.

Rt

is the general-purpose register to be transferred to the FPSCR.

8.20.2 Operation

This instruction moves the value of a general-purpose register to the FPSCR. See the Floating Point Status Control Register for more information.

8.20.3 Restrictions

The restrictions are:

- Rt cannot be PC or SP.

8.20.4 Condition flags

This instruction updates the FPSCR.
8.21 **VMUL**

Floating-point Multiply.

<table>
<thead>
<tr>
<th>Applies to...</th>
<th>M3</th>
<th>M4</th>
<th>M4F</th>
</tr>
</thead>
<tbody>
<tr>
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</tbody>
</table>

### 8.21.1 Syntax

\[
\text{VMUL} \{\text{cond}\}.\text{F32} \{Sd,\} Sn, Sm
\]

where:

- \(\text{cond}\) is an optional condition code, see “Conditional Execution” on page 32.
- \(Sd\) is the destination floating-point value.
- \(Sn, Sm\) are the operand floating-point values.

### 8.21.2 Operation

This instruction:

1. Multiplies two floating-point values.
2. Places the results in the destination register.

### 8.21.3 Restrictions

There are no restrictions.

### 8.21.4 Condition flags

These instructions do not change the flags.
8.22 VNEG
Floating-point Negate.

<table>
<thead>
<tr>
<th>Applies to...</th>
<th>M3</th>
<th>M4</th>
<th>M4F</th>
</tr>
</thead>
<tbody>
<tr>
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<td>✓</td>
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</tr>
</tbody>
</table>

8.22.1 Syntax

\[ \text{VNEG}\{\text{cond}\}.F32 \text{ Sd, Sm} \]

where:

- \text{cond} is an optional condition code, see “Conditional Execution” on page 32.
- \text{Sd} is the destination floating-point value.
- \text{Sm} is the operand floating-point value.

8.22.2 Operation

This instruction:

1. Negates a floating-point value.
2. Places the results in a second floating-point register.

The floating-point instruction inverts the sign bit.

8.22.3 Restrictions

There are no restrictions.

8.22.4 Condition flags

These instructions do not change the flags.
8.23 **VNMLA, VNMLS, VNMUL**

Floating-point multiply with negation followed by add or subtract.

<table>
<thead>
<tr>
<th>Applies to...</th>
<th>M3</th>
<th>M4</th>
<th>M4F</th>
</tr>
</thead>
<tbody>
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</tr>
</tbody>
</table>

### 8.23.1 Syntax

VNMLA\(\text{\texttt{cond}}\).\texttt{F32} Sd, Sn, Sm

VNMLS\(\text{\texttt{cond}}\).\texttt{F32} Sd, Sn, Sm

VNMUL\(\text{\texttt{cond}}\).\texttt{F32} \{Sd,\} Sn, Sm

where:

- \(\texttt{cond}\) is an optional condition code, see “Conditional Execution” on page 32.
- \(\texttt{Sd}\) is the destination floating-point register.
- \(\texttt{Sn, Sm}\) are the operand floating-point registers.

### 8.23.2 Operation

The **VNMLA** instruction:

1. Multiplies two floating-point register values.
2. Adds the negation of the floating-point value in the destination register to the negation of the product.
3. Writes the result back to the destination register.

The **VNMLS** instruction:

1. Multiplies two floating-point register values.
2. Adds the negation of the floating-point value in the destination register to the product.
3. Writes the result back to the destination register.

The **VNMUL** instruction:

1. Multiplies together two floating-point register values.
2. Writes the negation of the result to the destination register.
8.23.3 Restrictions
There are no restrictions.

8.23.4 Condition flags
These instructions do not change the flags.
8.24 VPOP

Floating-point extension register Pop.

<table>
<thead>
<tr>
<th>Applies to...</th>
<th>M3</th>
<th>M4</th>
<th>M4F</th>
</tr>
</thead>
<tbody>
<tr>
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<td>✓</td>
</tr>
</tbody>
</table>

8.24.1 Syntax

VPOP\{cond\}\{.size\} list

where:

*cond* is an optional condition code, see “Conditional Execution” on page 32.

*size* is an optional data size specifier. If present, it must be equal to the size in bits, 32 or 64, of the registers in *list*.

*list* is a list of extension registers to be loaded, as a list of consecutively numbered doubleword or singleword registers, separated by commas and surrounded by brackets.

8.24.2 Operation

This instruction loads multiple consecutive extension registers from the stack.

8.24.3 Restrictions

The list must contain at least one register, and not more than sixteen registers.

8.24.4 Condition flags

These instructions do not change the flags.
8.25 VPUSH
Floating-point extension register Push.

<table>
<thead>
<tr>
<th>Applies to...</th>
<th>M3</th>
<th>M4</th>
<th>M4F</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<td></td>
<td>✓</td>
</tr>
</tbody>
</table>

8.25.1 Syntax

\[ \text{VPUSH} \{ \text{cond} \} \{ . \text{size} \} \ \text{list} \]

where:

\textit{cond}

is an optional condition code, see “Conditional Execution” on page 32.

\textit{size}

is an optional data size specifier. If present, it must be equal to the size in bits, 32 or 64, of the registers in \textit{list}.

\textit{list}

is a list of the extension registers to be stored, as a list of consecutively numbered doubleword or singleword registers, separated by commas and surrounded by brackets.

8.25.2 Operation

This instruction:

- Stores multiple consecutive extension registers to the stack.

8.25.3 Restrictions

The restrictions are:

- \textit{list} must contain at least one register, and not more than sixteen.

8.25.4 Condition flags

These instructions do not change the flags.
8.26  **VSQRT**  
Floating-point Square Root.

<table>
<thead>
<tr>
<th>Applies to...</th>
<th>M3</th>
<th>M4</th>
<th>M4F</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>✓</td>
</tr>
</tbody>
</table>

### 8.26.1 Syntax

\[ \text{VSQRT} \{ \text{cond} \} .F32 \ Sd, \ Sm \]

where:

- \( \text{cond} \) is an optional condition code, see “Conditional Execution” on page 32.

- \( Sd \) is the destination floating-point value.

- \( Sm \) is the operand floating-point value.

### 8.26.2 Operation

This instruction:

- Calculates the square root of the value in a floating-point register.
- Writes the result to another floating-point register.

### 8.26.3 Restrictions

There are no restrictions.

### 8.26.4 Condition flags

These instructions do not change the flags.
8.27 **VSTM**

Floating-point Store Multiple.

<table>
<thead>
<tr>
<th>Applies to</th>
<th>M3</th>
<th>M4</th>
<th>M4F</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>✓</td>
</tr>
</tbody>
</table>

### 8.27.1 Syntax

VSTM{\(mode\)}{\(cond\)}{\(size\)} \(Rn(!), list\)

where:

- **mode**
  - is the addressing mode:
    - IA *Increment After*. The consecutive addresses start at the address specified in \(Rn\). This is the default and can be omitted.
    - DB *Decrement Before*. The consecutive addresses end just before the address specified in \(Rn\).

- **cond**
  - is an optional condition code, see “Conditional Execution” on page 32.

- **size**
  - is an optional data size specifier. If present, it must be equal to the size in bits, 32 or 64, of the registers in \(list\).

- **Rn**
  - is the base register. The SP can be used.

- **!**
  - is the function that causes the instruction to write a modified value back to \(Rn\). Required if \(mode == DB\).

- **list**
  - is a list of the extension registers to be stored, as a list of consecutively numbered doubleword or singleword registers, separated by commas and surrounded by brackets.

### 8.27.2 Operation

This instruction:

- Stores multiple extension registers to consecutive memory locations using a base address from an ARM core register.

### 8.27.3 Restrictions

The restrictions are:

- **list** must contain at least one register. If it contains doubleword registers it must not contain more than 16 registers.
Use of the PC as $R_n$ is deprecated.

8.27.4 **Condition flags**

These instructions do not change the flags.
8.28 VSTR
Floating-point Store.

<table>
<thead>
<tr>
<th>Applies to…</th>
<th>M3</th>
<th>M4</th>
<th>M4F</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>✓</td>
</tr>
</tbody>
</table>

8.28.1 Syntax

VSTR{cond}{.32} Sd, [Rn{, #imm}]

VSTR{cond}{.64} Dd, [Rn{, #imm}]

where:

- **cond** is an optional condition code, see “Conditional Execution” on page 32.
- **32, 64** are the optional data size specifiers.
- **Sd** is the source register for a singleword store.
- **Dd** is the source register for a doubleword store.
- **Rn** is the base register. The SP can be used.
- **imm** is the + or - immediate offset used to form the address. Values are multiples of 4 in the range 0-1020. **imm** can be omitted, meaning an offset of +0.

8.28.2 Operation
This instruction:

- Stores a single extension register to memory, using an address from an ARM core register, with an optional offset, defined in **imm**.

8.28.3 Restrictions
The restrictions are:

- The use of PC for **Rn** is deprecated.

8.28.4 Condition flags
These instructions do not change the flags.
8.29 **VSUB**

Floating-point Subtract.

<table>
<thead>
<tr>
<th>Applies to...</th>
<th>M3</th>
<th>M4</th>
<th>M4F</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>✓</td>
</tr>
</tbody>
</table>

8.29.1 **Syntax**

\[
\text{VSUB}(\text{cond}).F32(Sd, Sd, Sm)
\]

where:

- \textit{cond} is an optional condition code, see “Conditional Execution” on page 32.
- \textit{Sd} is the destination floating-point value.
- \textit{Sn}, \textit{Sm} are the operand floating-point value.

8.29.2 **Operation**

This instruction:

1. Subtracts one floating-point value from another floating-point value.
2. Places the results in the destination floating-point register.

8.29.3 **Restrictions**

There are no restrictions.

8.29.4 **Condition flags**

These instructions do not change the flags.

8.29.5 **Operation**

\texttt{WFI} is a hint instruction that suspends execution until one of the following events occurs:

- a non-masked interrupt occurs and is taken
- an interrupt masked by \texttt{PRIMASK} becomes pending
- a Debug Entry request.

8.29.6 **Condition flags**

This instruction does not change the flags.
8.29.7 Examples

WFI ; Wait for interrupt
9 Branch and Control Instructions

Table 9-1 on page 199 shows the branch and control instructions:

### Table 9-1. Branch and Control Instructions

<table>
<thead>
<tr>
<th>Mnemonic</th>
<th>Brief Description</th>
<th>See Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>B</td>
<td>Branch</td>
<td>200</td>
</tr>
<tr>
<td>BL</td>
<td>Branch with link</td>
<td>200</td>
</tr>
<tr>
<td>BLX</td>
<td>Branch indirect with link</td>
<td>200</td>
</tr>
<tr>
<td>BX</td>
<td>Branch indirect</td>
<td>200</td>
</tr>
<tr>
<td>CBNZ</td>
<td>Compare and branch if non-zero</td>
<td>202</td>
</tr>
<tr>
<td>CBZ</td>
<td>Compare and branch if zero</td>
<td>202</td>
</tr>
<tr>
<td>IT</td>
<td>If-Then</td>
<td>203</td>
</tr>
<tr>
<td>TBB</td>
<td>Table branch byte</td>
<td>206</td>
</tr>
<tr>
<td>TBH</td>
<td>Table branch halfword</td>
<td>206</td>
</tr>
</tbody>
</table>
9.1 **B, BL, BX, and BLX**

Branch instructions.

<table>
<thead>
<tr>
<th>Applies to...</th>
<th>M3</th>
<th>M4</th>
<th>M4F</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

### 9.1.1 Syntax

- **B**\(_{\text{cond}}\) label
- **BL**\(_{\text{cond}}\) label
- **BX**\(_{\text{cond}}\) \(Rm\)
- **BLX**\(_{\text{cond}}\) \(Rm\)

where:

- **B**
  - Is branch (immediate).
- **BL**
  - Is branch with link (immediate).
- **BX**
  - Is branch indirect (register).
- **BLX**
  - Is branch indirect with link (register).

\(\text{cond}\)

- Is an optional condition code. See Table 1-2 on page 33.

\(\text{label}\)

- Is a PC-relative expression. See “PC-Relative Expressions” on page 32.

\(\text{Rm}\)

- Is a register that indicates an address to branch to. Bit[0] of the value in \(Rm\) must be 1, but the address to branch to is created by changing bit[0] to 0.

### 9.1.2 Operation

All these instructions cause a branch to \(\text{label}\), or to the address indicated in \(Rm\). In addition:

- The **BL** and **BLX** instructions write the address of the next instruction to the **Link Register (LR)**, register R14. See the Stellaris® Data Sheet for more on **LR**.

- The **BX** and **BLX** instructions cause a UsageFault exception if bit[0] of \(Rm\) is 0.

**B** \(_{\text{cond}}\) \(\text{label}\) is the only conditional instruction that can be either inside or outside an **IT** block. All other branch instructions must be conditional inside an **IT** block, and must be unconditional outside the **IT** block. See 203.

Table 9-2 on page 201 shows the ranges for the various branch instructions.
Table 9-2. Branch Ranges

<table>
<thead>
<tr>
<th>Instruction</th>
<th>Branch Rangea</th>
</tr>
</thead>
<tbody>
<tr>
<td>B label</td>
<td>−16 MB to +16 MB</td>
</tr>
<tr>
<td>B(cond) label (outside IT block)</td>
<td>−1 MB to +1 MB</td>
</tr>
<tr>
<td>B(cond) label (inside IT block)</td>
<td>−16 MB to +16 MB</td>
</tr>
<tr>
<td>BL(cond) label</td>
<td>−16 MB to +16 MB</td>
</tr>
<tr>
<td>BX(cond) Rm</td>
<td>Any value in register</td>
</tr>
<tr>
<td>BLX(cond) Rm</td>
<td>Any value in register</td>
</tr>
</tbody>
</table>

a. You might have to use the .W suffix to get the maximum branch range. See “Instruction Width Selection” on page 34.

9.1.3 Restrictions

The restrictions are:

- Do not use PC in the BLX instruction.

- For BX and BLX, bit[0] of Rm must be 1 for correct execution but a branch occurs to the target address created by changing bit[0] to 0.

- When any of these instructions is inside an IT block, it must be the last instruction of the IT block.

Note: B cond is the only conditional instruction that is not required to be inside an IT block. However, it has a longer branch range when it is inside an IT block.

9.1.4 Condition Flags

These instructions do not change the flags.

9.1.5 Examples

B    loopA ; Branch to loopA.
BLE   ng  ; Conditionally branch to label ng.
B.W   target ; Branch to target within 16MB range.
BEQ   target ; Conditionally branch to target.
BEQ.W target ; Conditionally branch to target within 1MB.
BL    funC ; Branch with link (Call) to function funC, return address ; stored in LR.
BX    LR  ; Return from function call.
BXNE  R0  ; Conditionally branch to address stored in R0.
BLX   R0  ; Branch with link and exchange (Call) to a address stored ; in R0.
9.2 CBZ and CBNZ

Compare and Branch if Zero, Compare and Branch if Non-Zero.

<table>
<thead>
<tr>
<th>Applies to...</th>
<th>M3</th>
<th>M4</th>
<th>M4F</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

9.2.1 Syntax

CBZ Rn, label

CBNZ Rn, label

where:

Rn
   Is the register holding the operand.

label
   Is the branch destination.

9.2.2 Operation

Use the CBZ or CBNZ instructions to avoid changing the condition code flags and to reduce the number of instructions.

CBZ Rn, label does not change condition flags but is otherwise equivalent to:

```
CMP   Rn, #0
BEQ   label
```

CBNZ Rn, label does not change condition flags but is otherwise equivalent to:

```
CMP   Rn, #0
BNE   label
```

9.2.3 Restrictions

The restrictions are:

- Rn must be in the range of R0 to R7.
- The branch destination must be within 4 to 130 bytes after the instruction.
- These instructions must not be used inside an IT block.

9.2.4 Condition Flags

These instructions do not change the flags.

9.2.5 Examples

CBZ   R5, target ; Forward branch if R5 is zero.
CBNZ  R0, target ; Forward branch if R0 is not zero.
9.3 IT

If-Then.

<table>
<thead>
<tr>
<th>Applies to...</th>
<th>M3</th>
<th>M4</th>
<th>M4F</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

9.3.1 Syntax

\[ \text{IT}\{x\{y\{z\}\}\} \text{ cond} \]

where:

- \(x\)
  Specifies the condition switch for the second instruction in the IT block.

- \(y\)
  Specifies the condition switch for the third instruction in the IT block.

- \(z\)
  Specifies the condition switch for the fourth instruction in the IT block.

- \(\text{cond}\)
  Specifies the condition for the first instruction in the IT block.

The condition switch for the second, third and fourth instruction in the IT block can be either:

- \(T\)
  Then. Applies the condition \(\text{cond}\) to the instruction.

- \(E\)
  Else. Applies the inverse condition of \(\text{cond}\) to the instruction.

**Note:** It is possible to use \(\text{AL}\) (the always condition) for \(\text{cond}\) in an IT instruction. If this is done, all of the instructions in the IT block must be unconditional, and each of \(x\), \(y\), and \(z\) must be \(T\) or omitted but not \(E\).

9.3.2 Operation

The IT instruction makes up to four following instructions conditional. The conditions can be all the same, or some of them can be the logical inverse of the others. The conditional instructions following the IT instruction form the IT block.

The instructions in the IT block, including any branches, must specify the condition in the \(\{\text{cond}\}\) part of their syntax.

**Note:** Your assembler might be able to generate the required IT instructions for conditional instructions automatically, so that you do not need to write them yourself. See your assembler documentation for details.

A BKPT instruction in an IT block is always executed, even if its condition fails.

Exceptions can be taken between an IT instruction and the corresponding IT block, or within an IT block. Such an exception results in entry to the appropriate exception handler, with suitable return information in LR and stacked PSR. See the PSR register in the Stellaris® Data Sheet for more information.
Instructions designed for use for exception returns can be used as normal to return from the exception, and execution of the IT block resumes correctly. This is the only way that a PC-modifying instruction is permitted to branch to an instruction in an IT block.

### 9.3.3 Restrictions

The following instructions are not permitted in an IT block:

- **IT**
- **CBZ** and **CBNZ**
- **CPSID** and **CPSIE**

Other restrictions when using an IT block are:

- A branch or any instruction that modifies the PC must either be outside an IT block or must be the last instruction inside the IT block. These are:
  - `ADD PC, PC, Rm`
  - `MOV PC, Rm`
  - `B, BL, BX, BLX`
  - any LDM, LDR, or POP instruction that writes to the PC
  - `TBB` and `TBH`
- Do not branch to any instruction inside an IT block, except when returning from an exception handler.
- All conditional instructions except `Bcond` must be inside an IT block. `Bcond` can be either outside or inside an IT block but has a larger branch range if it is inside one.
- Each instruction inside the IT block must specify a condition code suffix that is either the same or the logical inverse.

**Note:** Your assembler might place extra restrictions on the use of IT blocks, such as prohibiting the use of assembler directives within them.

### 9.3.4 Condition Flags

This instruction does not change the flags.

### 9.3.5 Example

```assembly
ITTE NE ; Next 3 instructions are conditional.
ANDNE R0, R0, R1 ; ANDNE does not update condition flags.
ADDSNE R2, R2, #1 ; ADDSNE updates condition flags.
MOVEQ R2, R3 ; Conditional move.

CMP R0, #9 ; Convert R0 hex value (0 to 15) into ASCII
            ; ('0'-'9', 'A'-'F').
ITE GT ; Next 2 instructions are conditional.
ADDG T R1, R0, #55 ; Convert 0xA -> 'A'.
ADDE R1, R0, #48 ; Convert 0x0 -> '0'.
```
IT GT ; IT block with only one conditional instruction.
ADDG T R1, R1, #1 ; Increment R1 conditionally.

ITTEE EQ ; Next 4 instructions are conditional.
MOVEQ R0, R1 ; Conditional move.
ADDEQ R2, R2, #10 ; Conditional add.
ANDNE R3, R3, #1 ; Conditional AND.
BNE.W dloop ; Branch instruction can only be used in the last instruction of an IT block.

IT NE ; Next instruction is conditional.
ADD R0, R0, R1 ; Syntax error: no condition code used in IT block.
9.4 **TBB and TBH**

Table Branch Byte and Table Branch Halfword.

<table>
<thead>
<tr>
<th>Applies to...</th>
<th>M3</th>
<th>M4</th>
<th>M4F</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

### 9.4.1 Syntax

**TBB** \([Rn, \ Rm]\)

**TBH** \([Rn, \ Rm, \ LSL \ #1]\)

**Where:**

\(Rn\)

Is the register containing the address of the table of branch lengths. If \(Rn\) is the **Program Counter (PC)** register, R15, then the address of the table is the address of the byte immediately following the **TBB** or **TBH** instruction.

\(Rm\)

Is the index register. This contains an index into the table. For halfword tables, \(LSL \ #1\) doubles the value in \(Rm\) to form the right offset into the table.

### 9.4.2 Operation

These instructions cause a PC-relative forward branch using a table of single byte offsets for **TBB**, or halfword offsets for **TBH**. \(Rn\) provides a pointer to the table, and \(Rm\) supplies an index into the table. For **TBB** the branch offset is twice the unsigned value of the byte returned from the table. For **TBH**, the branch offset is twice the unsigned value of the halfword returned from the table. The branch occurs to the address at that offset from the address of the byte immediately after the **TBB** or **TBH** instruction.

### 9.4.3 Restrictions

The restrictions are:

- \(Rn\) must not be **SP**.
- \(Rm\) must not be **SP** and must not be **PC**.
- When any of these instructions is used inside an **IT** block, it must be the last instruction of the **IT** block.

### 9.4.4 Condition Flags

These instructions do not change the flags.

### 9.4.5 Examples

ADR.W R0, BranchTable_BYTE  
TBB [R0, R1] ; R1 is the index, R0 is the base address of the ; branch table.
Case1
; an instruction sequence follows
Case2
; an instruction sequence follows
Case3
; an instruction sequence follows

BranchTable_Byte

DCB 0 ; Case1 offset calculation.
DCB ((Case2-Case1)/2) ; Case2 offset calculation.
DCB ((Case3-Case1)/2) ; Case3 offset calculation.

TBH [PC, R1, LSL #1] ; R1 is the index, PC is used as base of the branch table.

BranchTable_H

DCI ((CaseA - BranchTable_H)/2) ; CaseA offset calculation.
DCI ((CaseB - BranchTable_H)/2) ; CaseB offset calculation.
DCI ((CaseC - BranchTable_H)/2) ; CaseC offset calculation.

CaseA
; an instruction sequence follows
CaseB
; an instruction sequence follows
CaseC
; an instruction sequence follows
10 Miscellaneous Instructions

Table 10-1 on page 208 shows the remaining Cortex-M3/M4F instructions:

Table 10-1. Miscellaneous Instructions

<table>
<thead>
<tr>
<th>Mnemonic</th>
<th>Brief Description</th>
<th>See Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>BKPT</td>
<td>Breakpoint</td>
<td>209</td>
</tr>
<tr>
<td>CPSID</td>
<td>Change processor state, disable interrupts</td>
<td>210</td>
</tr>
<tr>
<td>CPSIE</td>
<td>Change processor state, enable interrupts</td>
<td>210</td>
</tr>
<tr>
<td>DMB</td>
<td>Data memory barrier</td>
<td>211</td>
</tr>
<tr>
<td>DSB</td>
<td>Data synchronization barrier</td>
<td>212</td>
</tr>
<tr>
<td>ISB</td>
<td>Instruction synchronization barrier</td>
<td>213</td>
</tr>
<tr>
<td>MRS</td>
<td>Move from special register to register</td>
<td>214</td>
</tr>
<tr>
<td>MSR</td>
<td>Move from register to special register</td>
<td>215</td>
</tr>
<tr>
<td>NOP</td>
<td>No operation</td>
<td>216</td>
</tr>
<tr>
<td>SEV</td>
<td>Send event</td>
<td>217</td>
</tr>
<tr>
<td>SVC</td>
<td>Supervisor call</td>
<td>218</td>
</tr>
<tr>
<td>WFE</td>
<td>Wait for event</td>
<td>219</td>
</tr>
<tr>
<td>WFI</td>
<td>Wait for interrupt</td>
<td>220</td>
</tr>
</tbody>
</table>
10.1 **BKPT**

Breakpoint.

<table>
<thead>
<tr>
<th>Applies to...</th>
<th>M3</th>
<th>M4</th>
<th>M4F</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

### 10.1.1 Syntax


BKPT \#imm

where:

- **imm**
  - Is an expression evaluating to an integer in the range 0-255 (8-bit value).

### 10.1.2 Operation

The **BKPT** instruction causes the processor to enter Debug state. Debug tools can use this to investigate system state when the instruction at a particular address is reached.

- **imm** is ignored by the processor. If required, a debugger can use it to store additional information about the breakpoint.

The **BKPT** instruction can be placed inside an **IT** block, but it executes unconditionally, unaffected by the condition specified by the **IT** instruction.

### 10.1.3 Condition Flags

This instruction does not change the flags.

### 10.1.4 Examples

```plaintext
BKPT 0xAB ; Breakpoint with immediate value set to 0xAB (debugger can; extract the immediate value by locating it using the PC).
```
10.2 CPS
Change Processor State.

<table>
<thead>
<tr>
<th>Applies to</th>
<th>M3</th>
<th>M4</th>
<th>M4F</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

10.2.1 Syntax

CPS effect iflags

where:

effect
Is one of:

IE
Clears the special-purpose register.

ID
Sets the special-purpose register.

iflags
Is a sequence of one or more flags:

i
Set or clear the Priority Mask Register (PRIMASK).

f
Set or clear the Fault Mask Register (FAULTMASK).

10.2.2 Operation

CPS changes the PRIMASK and FAULTMASK special register values. See the Stellaris® Data Sheet for more information about these registers.

10.2.3 Restrictions

The restrictions are:

- Use CPS only from privileged software; it has no effect if used in unprivileged software.
- CPS cannot be conditional and so must not be used inside an IT block.

10.2.4 Condition Flags

This instruction does not change the flags.

10.2.5 Examples

CPSID i ; Disable interrupts and configurable fault handlers (set PRIMASK).
CPSID f ; Disable interrupts and all fault handlers (set FAULTMASK).
CPSIE i ; Enable interrupts and configurable fault handlers (clear PRIMASK).
CPSIE f ; Enable interrupts and fault handlers (clear FAULTMASK).
10.3  DMB

Data Memory Barrier.

<table>
<thead>
<tr>
<th>Applies to...</th>
<th>M3</th>
<th>M4</th>
<th>M4F</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

10.3.1  Syntax

DMB (cond)

where:

cond
   Is an optional condition code. See Table 1-2 on page 33.

10.3.2  Operation

DMB acts as a data memory barrier. It ensures that all explicit memory accesses that appear before the DMB instruction (in program order) are completed before any explicit memory accesses that appear after the DMB instruction (in program order). DMB does not affect the ordering or execution of instructions that do not access memory.

10.3.3  Condition Flags

This instruction does not change the flags.

10.3.4  Examples

DMB ; Data Memory Barrier
10.4 **DSB**

Data Synchronization Barrier.

<table>
<thead>
<tr>
<th>Applies to...</th>
<th>M3</th>
<th>M4</th>
<th>M4F</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

### 10.4.1 Syntax

DSB(`cond`)

where:

- `cond` is an optional condition code. See Table 1-2 on page 33.

### 10.4.2 Operation

**DSB** acts as a special data synchronization memory barrier. Instructions that come after **DSB** (in program order) do not execute until the **DSB** instruction completes. The **DSB** instruction completes when all explicit memory accesses before it complete.

### 10.4.3 Condition Flags

This instruction does not change the flags.

### 10.4.4 Examples

DSB ; Data Synchronization Barrier
10.5 **ISB**

Instruction Synchronization Barrier.

<table>
<thead>
<tr>
<th>Applies to...</th>
<th>M3</th>
<th>M4</th>
<th>M4F</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

### 10.5.1 Syntax

```
ISB(cond)
```

where:

- `cond` is an optional condition code. See Table 1-2 on page 33.

### 10.5.2 Operation

`ISB` acts as an instruction synchronization barrier. It flushes the pipeline of the processor, so that all instructions following the `ISB` are fetched from cache or memory again, after the `ISB` instruction has been completed.

### 10.5.3 Condition Flags

This instruction does not change the flags.

### 10.5.4 Examples

```
ISB ; Instruction Synchronization Barrier
```
10.6 **MRS**

Move the contents of a special register to a general-purpose register.

<table>
<thead>
<tr>
<th>Applies to...</th>
<th>M3</th>
<th>M4</th>
<th>M4F</th>
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<tbody>
<tr>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
</tbody>
</table>

### 10.6.1 Syntax

\[
\text{MRS}(\text{cond}) \text{ Rd, spec\_reg}
\]

where:

- **cond**
  - Is an optional condition code. See Table 1-2 on page 33.

- **Rd**
  - Is the destination register.

- **spec\_reg**
  - Can be any of the following special registers: **APSR**, **IPSR**, **EPSR**, **IEPSR**, **IAPSR**, **EAPSR**, **PSR**, **MSP**, **PSP**, **PRIMASK**, **BASEPRI**, **BASEPRI\_MAX**, **FAULTMASK**, or **CONTROL**.

### 10.6.2 Operation

Use **MRS** in combination with **MSR** as part of a read-modify-write sequence for updating a **PSR**, for example to clear the Q flag.

In process swap code, the programmers model state of the process being swapped out must be saved, including relevant **PSR** contents. Similarly, the state of the process being swapped in must also be restored. These operations use **MRS** in the state-saving instruction sequence and **MSR** in the state-restoring instruction sequence.

**Note:** **BASEPRI\_MAX** is an alias of **BASEPRI** when used with the **MRS** instruction.

See also “**MSR**” on page 215.

### 10.6.3 Restrictions

**Rd** must not be **SP** and must not be **PC**.

### 10.6.4 Condition Flags

This instruction does not change the flags.

### 10.6.5 Examples

\[
\text{MRS} \text{ R0, PRIMASK} \; \text{; Read PRIMASK value and write it to R0.}
\]
10.7 **MSR**

Move the contents of a general-purpose register to a special register.

<table>
<thead>
<tr>
<th>Applies to...</th>
<th>M3</th>
<th>M4</th>
<th>M4F</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

10.7.1 **Syntax**

```
MSR{cond} spec_reg, Rn
```

where:

- **cond**
  - Is an optional condition code. See Table 1-2 on page 33.
- **Rn**
  - Is the source register.
- **spec_reg**
  - Can be any of: APSR, IPSR, EPSR, IEPSR, IAPSR, EAPSR, PSR, MSP, PSP, PRIMASK, BASEPRI, BASEPRI_MAX, FAULTMASK, or CONTROL.

10.7.2 **Operation**

The register access operation in MSR depends on the privilege level. Unprivileged software can only access the Application Program Status Register (APSR) (see APSR in the Stellaris® Data Sheet). Privileged software can access all special registers.

In unprivileged software writes to unallocated or execution state bits in the PSR are ignored.

**Note:** When you write to BASEPRI_MAX, the instruction writes to BASEPRI only if either:

- Rn is non-zero and the current BASEPRI value is 0.
- Rn is non-zero and less than the current BASEPRI value.

See also “MRS” on page 214.

10.7.3 **Restrictions**

Rn must not be SP and must not be PC.

10.7.4 **Condition Flags**

This instruction updates the flags explicitly based on the value in Rn.

10.7.5 **Examples**

```
MSR CONTROL, R1 ; Read R1 value and write it to the CONTROL register.
```
10.8 **NOP**

No Operation.

<table>
<thead>
<tr>
<th>Applies to...</th>
<th>M3</th>
<th>M4</th>
<th>M4F</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

### 10.8.1 Syntax

\[
\text{NOP}\{\text{cond}\}
\]

where:

\(\text{cond}\)

Is an optional condition code. See Table 1-2 on page 33.

### 10.8.2 Operation

\texttt{NOP} does nothing. \texttt{NOP} is not necessarily a time-consuming \texttt{NOP}. The processor might remove it from the pipeline before it reaches the execution stage.

Use \texttt{NOP} for padding, for example to place the following instruction on a 64-bit boundary.

### 10.8.3 Condition Flags

This instruction does not change the flags.

### 10.8.4 Examples

\[
\text{NOP} \; ; \; \text{No Operation}
\]
10.9 SEV

Send Event.

<table>
<thead>
<tr>
<th>Applies to...</th>
<th>M3</th>
<th>M4</th>
<th>M4F</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

10.9.1 Syntax

SEV\{ cond\}

where:

\textit{cond}

Is an optional condition code. See Table 1-2 on page 33.

10.9.2 Operation

SEV is a hint instruction that causes an event to be signaled to all processors within a multiprocessor system. It also sets the one-bit event register to 1. See "Power Management" in the \textit{Stellaris\textregistered Data Sheet}.

10.9.3 Condition Flags

This instruction does not change the flags.

10.9.4 Examples

SEV ; Send Event
10.10 **SVC**

Supervisor Call.

<table>
<thead>
<tr>
<th>Applies to...</th>
<th>M3</th>
<th>M4</th>
<th>M4F</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

### 10.10.1 Syntax

\[
\text{SVC}(\text{cond}) \ #\text{imm}
\]

where:

- \(\text{cond}\) is an optional condition code. See Table 1-2 on page 33.
- \(\text{imm}\) is an expression evaluating to an integer in the range 0-255 (8-bit value).

### 10.10.2 Operation

The **SVC** instruction causes the **SVC** exception.

\(\text{imm}\) is ignored by the processor. If required, it can be retrieved by the exception handler to determine what service is being requested.

### 10.10.3 Condition Flags

This instruction does not change the flags.

### 10.10.4 Examples

\[
\text{SVC} \ 0x32 \ ; \ \text{Supervisor Call (SVC handler can extract the immediate value by locating it via the stacked PC).}
\]
10.11 **WFE**

Wait For Event.

<table>
<thead>
<tr>
<th>Applies to...</th>
<th>M3</th>
<th>M4</th>
<th>M4F</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

### 10.11.1 Syntax

\[ \text{WFE} \left( \text{cond} \right) \]

where:

\( \text{cond} \)

Is an optional condition code. See Table 1-2 on page 33.

### 10.11.2 Operation

**WFE** is a hint instruction.

If the one-bit event register is 0, **WFE** suspends execution until one of the following events occurs:

- An exception, unless masked by the exception mask registers (PRIMASK, FAULTMASK, and BASEPRI) or the current priority level.
- An exception enters the Pending state, if SEVONPEND in the **System Control Register (SCR)** is set.
- A Debug Entry request, if Debug is enabled.
- An event signaled by a peripheral or another processor in a multiprocessor system using the SEV instruction.

If the event register is 1, **WFE** clears it to 0 and returns immediately.

For more information, see "Power Management" in the **Stellaris® Data Sheet**.

### 10.11.3 Condition Flags

This instruction does not change the flags.

### 10.11.4 Examples

\[ \text{WFE ; Wait for Event} \]
10.12 **WFI**

Wait for Interrupt.

<table>
<thead>
<tr>
<th>Applies to...</th>
<th>M3</th>
<th>M4</th>
<th>M4F</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

10.12.1 **Syntax**

WFI *(cond)*

where:

*cond*  
Is an optional condition code. See Table 1-2 on page 33.

10.12.2 **Operation**

WFI is a hint instruction that suspends execution until one of the following events occurs:

- An exception.
- A Debug Entry request, regardless of whether Debug is enabled.

10.12.3 **Condition Flags**

This instruction does not change the flags.

10.12.4 **Examples**

WFI ; Wait for Interrupt
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Applications

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