

# ARM<sup>®</sup> Compiler toolchain

Version 4.1

## **Assembler Reference**



# ARM Compiler toolchain

## Assembler Reference

Copyright © 2010 ARM. All rights reserved.

### Release Information

The following changes have been made to this book.

#### Change History

Date	Issue	Confidentiality	Change
May 2010	A	Non Confidential	ARM Compiler v4.1 Release

### Proprietary Notice

Words and logos marked with ® or ™ are registered trademarks or trademarks of ARM® in the EU and other countries, except as otherwise stated below in this proprietary notice. Other brands and names mentioned herein may be the trademarks of their respective owners.

Neither the whole nor any part of the information contained in, or the product described in, this document may be adapted or reproduced in any material form except with the prior written permission of the copyright holder.

The product described in this document is subject to continuous developments and improvements. All particulars of the product and its use contained in this document are given by ARM in good faith. However, all warranties implied or expressed, including but not limited to implied warranties of merchantability, or fitness for purpose, are excluded.

This document is intended only to assist the reader in the use of the product. ARM shall not be liable for any loss or damage arising from the use of any information in this document, or any error or omission in such information, or any incorrect use of the product.

Where the term ARM is used it means “ARM or any of its subsidiaries as appropriate”.

### Confidentiality Status

This document is Non-Confidential. The right to use, copy and disclose this document may be subject to license restrictions in accordance with the terms of the agreement entered into by ARM and the party that ARM delivered this document to.

### Product Status

The information in this document is final, that is for a developed product.

### Web Address

<http://www.arm.com>

# Contents

## ARM Compiler toolchain Assembler Reference

<b>Chapter 1</b>	<b>Conventions and feedback</b>	
<b>Chapter 2</b>	<b>Assembler command line options</b>	
2.1	Assembler command line syntax .....	2-2
2.2	Assembler command line options .....	2-3
<b>Chapter 3</b>	<b>ARM and Thumb Instructions</b>	
3.1	Instruction summary .....	3-3
3.2	Instruction width specifiers .....	3-11
3.3	Memory access instructions .....	3-12
3.4	General data processing instructions .....	3-50
3.5	Multiply instructions .....	3-85
3.6	Saturating instructions .....	3-107
3.7	Parallel instructions .....	3-112
3.8	Packing and unpacking instructions .....	3-120
3.9	Branch and control instructions .....	3-129
3.10	Coprocessor instructions .....	3-139
3.11	Miscellaneous instructions .....	3-151
3.12	ThumbEE instructions .....	3-173
3.13	Pseudo-instructions .....	3-177
3.14	Condition codes .....	3-186

<b>Chapter 4</b>	<b>NEON and VFP Programming</b>	
4.1	Instruction summary .....	4-2
4.2	Instructions shared by NEON and VFP .....	4-8
4.3	NEON logical and compare operations .....	4-18
4.4	NEON general data processing instructions .....	4-28
4.5	NEON shift instructions .....	4-42
4.6	NEON general arithmetic instructions .....	4-50
4.7	NEON multiply instructions .....	4-66
4.8	NEON load and store element and structure instructions .....	4-74
4.9	NEON and VFP pseudo-instructions .....	4-82
4.10	VFP instructions .....	4-91
 <b>Chapter 5</b>	 <b>Wireless MMX Technology Instructions</b>	
5.1	Introduction .....	5-2
5.2	ARM support for Wireless MMX technology .....	5-3
5.3	Wireless MMX instructions .....	5-7
5.4	Wireless MMX pseudo-instructions .....	5-9
 <b>Chapter 6</b>	 <b>Directives Reference</b>	
6.1	Alphabetical list of directives .....	6-2
6.2	Symbol definition directives .....	6-4
6.3	Data definition directives .....	6-18
6.4	Assembly control directives .....	6-39
6.5	Frame directives .....	6-50
6.6	Reporting directives .....	6-67
6.7	Instruction set and syntax selection directives .....	6-74
6.8	Miscellaneous directives .....	6-77

# Chapter 1

## Conventions and feedback

The following describes the typographical conventions and how to give feedback:

### Typographical conventions

The following typographical conventions are used:

- `monospace` Denotes text that can be entered at the keyboard, such as commands, file and program names, and source code.
- `monospace` Denotes a permitted abbreviation for a command or option. The underlined text can be entered instead of the full command or option name.
- `monospace`* *italic* Denotes arguments to commands and functions where the argument is to be replaced by a specific value.
- `monospace` **bold** Denotes language keywords when used outside example code.
- italic* Highlights important notes, introduces special terminology, denotes internal cross-references, and citations.
- bold** Highlights interface elements, such as menu names. Also used for emphasis in descriptive lists, where appropriate, and for ARM® processor signal names.

## Feedback on this product

If you have any comments and suggestions about this product, contact your supplier and give:

- your name and company
- the serial number of the product
- details of the release you are using
- details of the platform you are using, such as the hardware platform, operating system type and version
- a small standalone sample of code that reproduces the problem
- a clear explanation of what you expected to happen, and what actually happened
- the commands you used, including any command-line options
- sample output illustrating the problem
- the version string of the tools, including the version number and build numbers.

## Feedback on content

If you have comments on content then send an e-mail to [errata@arm.com](mailto:errata@arm.com). Give:

- the title
- the number, ARM DUI 0489A
- if viewing online, the topic names to which your comments apply
- if viewing a PDF version of a document, the page numbers to which your comments apply
- a concise explanation of your comments.

ARM also welcomes general suggestions for additions and improvements.

ARM periodically provides updates and corrections to its documentation on the ARM Information Center, together with knowledge articles and *Frequently Asked Questions* (FAQs).

## Other information

- ARM Information Center, <http://infocenter.arm.com/help/index.jsp>
- ARM Technical Support Knowledge Articles, <http://infocenter.arm.com/help/topic/com.arm.doc.faq/index.html>
- Keil Distributors, <http://www.keil.com/distis>.

## Chapter 2

# Assembler command line options

The following topics describe the ARM® Compiler toolchain assembler command-line syntax and the command-line options accepted by the assembler, `armasm`:

- *Assembler command line syntax* on page 2-2
- *Assembler command line options* on page 2-3.

## 2.1 Assembler command line syntax

The command for invoking the ARM assembler is:

```
armasm {options} {inputfile}
```

where:

*options* are commands to the assembler. You can invoke the assembler with any combination of options separated by spaces. You can specify values for some options. To specify a value for an option, use either '=' (*option=value*) or a space character (*option value*).

*inputfile* can be one or more assembly source files separated by spaces. Input files must be UAL, or pre-UAL ARM or Thumb assembly language source files.

### See also

*Using the Compiler:*

- *Order of compiler command-line options* on page 3-12.



## 2.2 Assembler command line options

The following command line options are supported by the assembler:

- `--16` on page 2-5
- `--32` on page 2-5
- `--apcs=qualifier...qualifier` on page 2-5
- `--arm` on page 2-7
- `--arm_only` on page 2-7
- `--bi` on page 2-7
- `--bigend` on page 2-7
- `--brief_diagnostics` on page 2-8
- `--checkreglist` on page 2-8
- `--compatible=name` on page 2-8
- `--cpreproc` on page 2-9
- `--cpreproc_opts=options` on page 2-9
- `--cpu=list` on page 2-9
- `--cpu=name` on page 2-10
- `--debug` on page 2-10
- `--depend=dependfile` on page 2-11
- `--depend_format=string` on page 2-11
- `--device=list` on page 2-11
- `--device=name` on page 2-12
- `--diag_error=tag{, tag}` on page 2-12
- `--diag_remark=tag{, tag}` on page 2-13
- `--diag_style=style` on page 2-13
- `--diag_suppress=tag{, tag}` on page 2-13
- `--diag_warning=tag{, tag}` on page 2-14
- `--dllexport_all` on page 2-14
- `--dwarf2` on page 2-15
- `--dwarf3` on page 2-15
- `--errors=errorfile` on page 2-15
- `--exceptions` on page 2-15
- `--exceptions_unwind` on page 2-15
- `--fpmode=model` on page 2-16
- `--fpu=list` on page 2-17
- `--fpu=name` on page 2-17
- `-g` on page 2-19
- `--help` on page 2-19

- *-idir{dir, ...}* on page 2-19
- *--keep* on page 2-19
- *--length=n* on page 2-19
- *--li* on page 2-20
- *--library\_type=lib* on page 2-20
- *--licretry* on page 2-20
- *--list=file* on page 2-21
- *--list=* on page 2-21
- *--littleend* on page 2-21
- *-m* on page 2-22
- *--maxcache=n* on page 2-22
- *--md* on page 2-22
- *--no\_code\_gen* on page 2-22
- *--no\_esc* on page 2-22
- *--no\_exceptions* on page 2-22
- *--no\_exceptions\_unwind* on page 2-23
- *--no\_hide\_all* on page 2-23
- *--no\_project* on page 2-23
- *--no\_reduce\_paths* on page 2-23
- *--no\_regs* on page 2-23
- *--no\_terse* on page 2-24
- *--no\_unaligned\_access* on page 2-24
- *--no\_warn* on page 2-24
- *-o filename* on page 2-24
- *--pd* on page 2-25
- *--predefine "directive"* on page 2-25
- *--project=filename* on page 2-25
- *--reduce\_paths* on page 2-26
- *--regnames=none* on page 2-26
- *--regnames=callstd* on page 2-26
- *--regnames=all* on page 2-27
- *--reinitialize\_workdir* on page 2-27
- *--report-if-not-wysiwyg* on page 2-27
- *--show\_cmdline* on page 2-27
- *--split\_ldm* on page 2-28
- *--thumb* on page 2-28
- *--thumbx* on page 2-28

- `--unaligned_access` on page 2-29
- `--unsafe` on page 2-29
- `--untyped_local_labels` on page 2-29
- `--version_number` on page 2-29
- `--via=file` on page 2-30
- `--vsn` on page 2-30
- `--width=n` on page 2-30
- `--workdir=directory` on page 2-30
- `--xref` on page 2-31.

### 2.2.1 `--16`

This option instructs the assembler to interpret instructions as Thumb® instructions using the pre-UAL Thumb syntax. This is equivalent to a `CODE16` directive at the head of the source file. Use the `--thumb` option to specify Thumb instructions using the UAL syntax.

#### See also

- `--thumb` on page 2-28
- *ARM, THUMB, THUMBX, CODE16 and CODE32* on page 6-75.

### 2.2.2 `--32`

This option is a synonym for `--arm`.

#### See also

- `--arm` on page 2-7.

### 2.2.3 `--apcs=qualifier...qualifier`

This option specifies whether you are using the *Procedure Call Standard for the ARM Architecture* (AAPCS). It can also specify some attributes of code sections.

The AAPCS forms part of the *Base Standard Application Binary Interface for the ARM Architecture* (BSABI) specification. By writing code that adheres to the AAPCS, you can ensure that separately compiled and assembled modules can work together.

---

**Note**

---

AAPCS qualifiers do not affect the code produced by the assembler. They are an assertion by the programmer that the code in *inputfile* complies with a particular variant of AAPCS. They cause attributes to be set in the object file produced by the assembler. The linker uses these attributes to check compatibility of files, and to select appropriate library variants.

---

Values for *qualifier* are:

none	Specifies that <i>inputfile</i> does not use AAPCS. AAPCS registers are not set up. Other qualifiers are not permitted if you use none.
/interwork, /nointerwork	/interwork specifies that the code in the <i>inputfile</i> can interwork between ARM and Thumb safely. The default is /nointerwork.
/inter, /nointer	Are synonyms for /interwork and /nointerwork.
/ropi, /noropi	/ropi specifies that the code in <i>inputfile</i> is Read-Only Position-Independent (ROPI). The default is /noropi.
/pic, /nopic	Are synonyms for /ropi and /noropi.
/rwpi, /norwpi	/rwpi specifies that the code in <i>inputfile</i> is Read-Write Position-Independent (RWPI). The default is /norwpi.
/pid, /nopid	Are synonyms for /rwpi and /norwpi.
/fpic, /nofpic	/fpic specifies that the code in <i>inputfile</i> is read-only independent and references to addresses are suitable for use in a Linux shared object. The default is /nofpic.

---

**Note**

---

You must specify at least one *qualifier*. If you specify more than one *qualifier*, ensure that there are no spaces or commas between the individual qualifiers in the list.

---

**Example**

```
armasm --apcs=/inter/ropi inputfile.s
```

**See also**

*Procedure Call Standard for the ARM Architecture*,  
<http://infocenter.arm.com/help/topic/com.arm.doc.ih0042-/index.html>.

*Developing Software for ARM Processors:*

- Chapter 5 *Interworking ARM and Thumb*.

**2.2.4 --arm**

This option instructs the assembler to interpret instructions as ARM instructions. It does not, however, guarantee ARM-only code in the object file. This is the default. Using this option is equivalent to specifying the ARM or CODE32 directive at the start of the source file.

**See also**

- --32 on page 2-5
- --arm\_only
- ARM, THUMB, THUMBX, CODE16 and CODE32 on page 6-75.

**2.2.5 --arm\_only**

This option instructs the assembler to only generate ARM code. This is similar to --arm but also has the property that the assembler does not permit the generation of any Thumb code.

**See also**

- --arm.

**2.2.6 --bi**

This option is a synonym for --bigend.

**See also**

- --bigend
- --littleend on page 2-21

**2.2.7 --bigend**

This option instructs the assembler to assemble code suitable for a big-endian ARM. The default is --littleend.

See also

- `--littleend` on page 2-21.

2.2.8 `--brief_diagnostics`

This option instructs the assembler to use a shorter form of the diagnostic output. In this form, the original source line is not displayed and the error message text is not wrapped when it is too long to fit on a single line. The default is `--no_brief_diagnostics`.

See also

- `--diag_error=tag{, tag}` on page 2-12
- `--diag_warning=tag{, tag}` on page 2-14.

2.2.9 `--checkreglist`

This option instructs the assembler to check RLIST, LDM, and STM register lists to ensure that all registers are provided in increasing register number order. A warning is given if registers are not listed in order.

This option is deprecated. Use `--diag_warning 1206` instead.

See also

- `--diag_warning=tag{, tag}` on page 2-14.

2.2.10 `--compatible=name`

This option specifies a second processor or architecture, *name*, for which the assembler generates compatible code.

When you specify a processor or architecture name using `--compatible`, valid values of *name* for both the `--cpu` and `--compatible` options are restricted to those shown in Table 2-1 and must not be from the same group.

Table 2-1 Compatible processor or architecture combinations

Group 1	ARM7TDMI, 4T
Group 2	Cortex-M0, Cortex-M1, Cortex-M3, Cortex-M4, 7-M, 6-M, 6S-M

Specify `--compatible=NONE` to turn off all previous instances of the option on the command line.

**Example**

```
armasm --cpu=arm7tdmi --compatible=cortex-m3 inputfile.s
```

**See also**

- `--cpu=name` on page 2-10.

**2.2.11 --cpreproc**

This option instructs the assembler to call `armcc` to preprocess the input file before assembling it.

**See also**

- `--cpreproc_opts=options`.

*Using the Assembler:*

- *Using the C preprocessor* on page 7-18.

**2.2.12 --cpreproc\_opts=options**

This option enables the assembler to pass compiler options to `armcc` when using the C preprocessor.

*options* is a comma-separated list of options and their values.

**Example**

```
armasm --cpreproc --cpreproc_opts='-DDEBUG=1' inputfile.s
```

**See also**

- `--cpreproc`.

*Using the Assembler:*

- *Using the C preprocessor* on page 7-18.

**2.2.13 --cpu=list**

This option lists the supported CPU and architecture names that can be used with the `--cpu name` option.

**Example**

```
armasm --cpu=list
```

### See also

- `--cpu=name`.

## 2.2.14 `--cpu=name`

This option sets the target CPU. Some instructions produce either errors or warnings if assembled for the wrong target CPU.

Valid values for *name* are architecture names such as 4T, 5TE, or 6T2, or part numbers such as ARM7TDMI®. The default is ARM7TDMI.

---

### Note

Using `--cpu=7` generates code that is supported by the ARMv7-A, ARMv7-R, and ARMv7-M architectures. This means that the assembler is restricted to producing only the Thumb instructions that are available on the ARMv-7A, ARMv7-R, and ARMv7-M architectures.

---

When you specify an alternative processor or architecture name using `--compatible`, valid values of *name* for both the `--cpu` and `--compatible` options are restricted to those shown in Table 2-1 on page 2-8.

### Example

```
armasm --cpu=Cortex-M3 inputfile.s
```

### See also

- `--cpu=list` on page 2-9
- `--unsafe` on page 2-29
- `--compatible=name` on page 2-8
- *ARM Architecture Reference Manual*,  
<http://infocenter.arm.com/help/topic/com.arm.doc.subset.arch.reference/index.html>.

## 2.2.15 `--debug`

This option instructs the assembler to generate DWARF debug tables. `--debug` is a synonym for `-g`. The default is DWARF 3.

---

### Note

Local symbols are not preserved with `--debug`. You must specify `--keep` if you want to preserve the local symbols to aid debugging.

---



**See also**

- `--dwarf2` on page 2-15
- `--dwarf3` on page 2-15
- `--keep` on page 2-19.

**2.2.16 --depend=dependfile**

This option instructs the assembler to save source file dependency lists to *dependfile*. These are suitable for use with make utilities.

**See also**

- `--depend_format=string`.

**2.2.17 --depend\_format=string**

This option changes the format of output dependency files to UNIX-style format, for compatibility with some UNIX make programs.

The value of *string* can be one of:

`unix`                      Generates dependency files with UNIX-style path separators.

`unix_escaped`              Is the same as `unix`, but escapes spaces with backslash.

`unix_quoted`                Is the same as `unix`, but surrounds path names with double quotes.

**See also**

- `--depend=dependfile`.

**2.2.18 --device=list**

This option lists the supported device names that can be used with the `--device=name` option.

**See also**

- `--device=name` on page 2-12.

2.2.19 --device=*name*

This option selects a specified device as the target and sets the associated processor settings.

See also

- --device=*list* on page 2-11
- --cpu=*name* on page 2-10
- --device=*name* on page 3-55 in the *Compiler Reference*.

2.2.20 --diag\_error=*tag*{, *tag*}

Diagnostic messages output by the assembler can be identified by a tag in the form of {*prefix*}*number*, where the *prefix* is A. The --diag\_error option sets the diagnostic messages that have the specified tags to the error severity.

You can specify more than one tag with these options by separating each tag using a comma. You can specify the optional assembler prefix A before the tag number. If any prefix other than A is included, the message number is ignored.

Table 2-2 shows the meaning of the term *severity* used in the option descriptions.

Table 2-2 Severity of diagnostic messages

Severity	Description
Error	Errors indicate violations in the syntactic or semantic rules of assembly language. Assembly continues, but object code is not generated.
Warning	Warnings indicate unusual conditions in your code that might indicate a problem. Assembly continues, and object code is generated unless any problems with an Error severity are detected.
Remark	Remarks indicate common, but not recommended, use of assembly language. These diagnostics are not issued by default. Assembly continues, and object code is generated unless any problems with an Error severity are detected.

You can set the *tag* to warning to treat all warnings as errors.

See also

- --brief\_diagnostics on page 2-8
- --diag\_warning=*tag*{, *tag*} on page 2-14
- --diag\_suppress=*tag*{, *tag*} on page 2-13.

### 2.2.21 --diag\_remark=tag{, tag}

Diagnostic messages output by the assembler can be identified by a tag in the form of {*prefix*}*number*, where the *prefix* is A. The --diag\_remark option sets the diagnostic messages that have the specified tags to the remark severity.

You can specify more than one tag with these options by separating each tag using a comma. You can specify the optional assembler prefix A before the tag number. If any prefix other than A is included, the message number is ignored.

#### See also

- --brief\_diagnostics on page 2-8
- --diag\_error=tag{, tag} on page 2-12.

### 2.2.22 --diag\_style=style

This option instructs the assembler to display diagnostic messages using the specified *style*, where *style* is one of:

arm	Display messages using the ARM assembler style. This is the default if --diag_style is not specified.
ide	Include the line number and character count for the line that is in error. These values are displayed in parentheses.
gnu	Display messages using the GNU style.

Choosing the option --diag\_style=ide implicitly selects the option --brief\_diagnostics. Explicitly selecting --no\_brief\_diagnostics on the command line overrides the selection of --brief\_diagnostics implied by --diag\_style=ide.

Selecting either the option --diag\_style=arm or the option --diag\_style=gnu does not imply any selection of --brief\_diagnostics.

#### See also

- --brief\_diagnostics on page 2-8
- --diag\_style=style.

### 2.2.23 --diag\_suppress=tag{, tag}

Diagnostic messages output by the assembler can be identified by a tag in the form of {*prefix*}*number*, where the *prefix* is A. The --diag\_suppress option disables the diagnostic messages that have the specified tags.

You can specify more than one tag with these options by separating each tag using a comma.

For example, to suppress the warning messages that have numbers 1293 and 187, use the following command:

```
armasm --diag_suppress=1293,187
```

You can specify the optional assembler prefix A before the tag number. For example:

```
armasm --diag_suppress=A1293,A187
```

If any prefix other than A is included, the message number is ignored. Diagnostic message tags can be cut and pasted directly into a command line.

You can also set the *tag* to:

- warning, to suppress all warnings
- error, to suppress all errors.

#### See also

- `--diag_error=tag{, tag}` on page 2-12.

### 2.2.24 --diag\_warning=tag{, tag}

Diagnostic messages output by the assembler can be identified by a tag in the form of `{prefix}number`, where the *prefix* is A. The `--diag_warning` option sets the diagnostic messages that have the specified tags to the warning severity.

You can specify more than one tag with these options by separating each tag using a comma. You can specify the optional assembler prefix A before the tag number. If any prefix other than A is included, the message number is ignored.

You can set the *tag* to error to treat all errors as warnings.

#### See also

- `--diag_error=tag{, tag}` on page 2-12.

### 2.2.25 --dllexport\_all

This option gives all exported global symbols STV\_PROTECTED visibility in ELF rather than STV\_HIDDEN, unless overridden by source directives.

#### See also

- *EXPORT* or *GLOBAL* on page 6-91.

**2.2.26 --dwarf2**

This option can be used with `--debug`, to instruct the assembler to generate DWARF 2 debug tables.

**See also**

- `--debug` on page 2-10
- `--dwarf3`.

**2.2.27 --dwarf3**

This option can be used with `--debug`, to instruct the assembler to generate DWARF 3 debug tables. This is the default if `--debug` is specified.

**See also**

- `--debug` on page 2-10
- `--dwarf2`.

**2.2.28 --errors=errorfile**

This option instructs the assembler to output error messages to *errorfile*.

**2.2.29 --exceptions**

This option instructs the assembler to switch on exception table generation for all functions defined by `FUNCTION` (or `PROC`) and `ENDFUNC` (or `ENDP`).

**See also**

- `--no_exceptions` on page 2-22
- `--exceptions_unwind`
- `--no_exceptions_unwind` on page 2-23
- *FRAME UNWIND ON* on page 6-63
- *FUNCTION or PROC* on page 6-65
- *ENDFUNC or ENDP* on page 6-66
- *FRAME UNWIND OFF* on page 6-63.

**2.2.30 --exceptions\_unwind**

This option instructs the assembler to produce *unwind* tables for functions where possible. This is the default.

For finer control, use `FRAME UNWIND ON` and `FRAME UNWIND OFF` directives.

### See also

- `--no_exceptions_unwind` on page 2-23
- `--exceptions` on page 2-15
- `--no_exceptions` on page 2-22
- `FRAME UNWIND ON` on page 6-63
- `FRAME UNWIND OFF` on page 6-63
- `FUNCTION` or `PROC` on page 6-65
- `ENDFUNC` or `ENDP` on page 6-66.

### 2.2.31 `--fpmode=model`

This option specifies the floating-point model, and sets library attributes and floating-point optimizations to select the most suitable library when linking.

#### ————— **Note** —————

This does not cause any changes to the code that you write.

`model` can be one of:

<code>ieee_full</code>	All facilities, operations, and representations guaranteed by the IEEE standard are available in single and double-precision. Modes of operation can be selected dynamically at runtime.
<code>ieee_fixed</code>	IEEE standard with round-to-nearest and no inexact exception.
<code>ieee_no_fenv</code>	IEEE standard with round-to-nearest and no exceptions. This mode is compatible with the Java floating-point arithmetic model.
<code>std</code>	IEEE finite values with denormals flushed to zero, round-to-nearest and no exceptions. It is C and C++ compatible. This is the default option.  Finite values are as predicted by the IEEE standard. It is not guaranteed that NaNs and infinities are produced in all circumstances defined by the IEEE model, or that when they are produced, they have the same sign. Also, it is not guaranteed that the sign of zero is that predicted by the IEEE model.
<code>fast</code>	Some value altering optimizations, where accuracy is sacrificed to fast execution. This is not IEEE compatible, and is not standard C.

**Example**

```
armasm --fpmode ieee_full inputfile.s
```

**See also**

- `--fpu=name`.

**2.2.32 --fpu=list**

This option lists the supported FPU names that can be used with the `--fpu=name` option.

**Example**

```
armasm --fpu=list
```

**See also**

- `--fpu=name`
- `--fpmode=model` on page 2-16.

**2.2.33 --fpu=name**

This option selects the target *floating-point unit* (FPU) architecture. If you specify this option it overrides any implicit FPU set by the `--cpu` option. The assembler produces an error if the FPU you specify explicitly is incompatible with the CPU. Floating-point instructions also produce either errors or warnings if assembled for the wrong target FPU.

The assembler sets a build attribute corresponding to *name* in the object file. The linker determines compatibility between object files, and selection of libraries, accordingly.

Valid values for *name* are:

none	Selects no floating-point architecture. This makes your assembled object file compatible with object files built with any FPU.
vfpv3	Selects hardware floating-point unit conforming to architecture VFPv3.
vfpv3_fp16	Selects hardware floating-point unit conforming to architecture VFPv3 with half-precision floating-point extension.
vfpv3_d16	Selects hardware floating-point unit conforming to architecture VFPv3-D16.

vfpv3_d16_fp16	Selects hardware floating-point unit conforming to architecture VFPv3-D16 with half-precision floating-point extension.
vfpv4	Selects hardware floating-point unit conforming to architecture VFPv4.
vfpv4_d16	Selects hardware floating-point unit conforming to architecture VFPv4-D16.
fpv4_sp	Selects hardware floating-point unit conforming to the single precision variant of architecture FPv4.
vfpv2	Selects hardware floating-point unit conforming to architecture VFPv2.
softvfp	Selects software floating-point linkage. This is the default if you do not specify a <code>--fpu</code> option and the <code>--cpu</code> option selected does not imply a particular FPU.
softvfp+vfpv2	Selects a floating-point library with software floating-point linkage that uses VFP instructions. This is otherwise equivalent to using <code>--fpu vfpv2</code> .
softvfp+vfpv3	Selects a floating-point library with software floating-point linkage that uses VFP instructions. This is otherwise equivalent to using <code>--fpu vfpv3</code> .
softvfp+vfpv3_fp16	Selects a floating-point library with software floating-point linkage that uses VFP instructions. This is otherwise equivalent to using <code>--fpu vfpv3_fp16</code> .
softvfp+vfpv3_d16	Selects a floating-point library with software floating-point linkage that uses VFP instructions. This is otherwise equivalent to using <code>--fpu vfpv3_d16</code> .
softvfp+vfpv3_d16_fp16	Selects a floating-point library with software floating-point linkage that uses VFP instructions. This is otherwise equivalent to using <code>--fpu vfpv3_d16_fp16</code> .
softvfp+vfpv4	Selects a floating-point library with software floating-point linkage that uses VFP instructions. This is otherwise equivalent to using <code>--fpu vfpv4</code> .



- |                   |   |
|-------------------|---|
| softvfp+vfpv4_d16 | Selects a floating-point library with software floating-point linkage that uses VFP instructions.<br>This is otherwise equivalent to using <code>--fpu vfpv4_d16</code> . |
| softvfp+fpv4_sp   | Selects a floating-point library with software floating-point linkage that uses VFP instructions.<br>This is otherwise equivalent to using <code>--fpu fpv4_sp</code> .   |

**See also**

- `--fpmode=model` on page 2-16.

**2.2.34 -g**

This option is a synonym for `--debug`.

**See also**

- `--debug` on page 2-10.

**2.2.35 --help**

This option instructs the assembler to show a summary of the available command line options.

**2.2.36 -idir{,dir, ...}**

This option adds directories to the source file include path. Any directories added using this option have to be fully qualified.

**See also**

- *GET or INCLUDE* on page 6-94.

**2.2.37 --keep**

This option instructs the assembler to keep local labels in the symbol table of the object file, for use by the debugger.

**2.2.38 --length=*n***

This option sets the listing page length to *n*. Length zero means an unpaginated listing. The default is 66 lines.

**See also**

- `--list=file` on page 2-21.

**2.2.39 --li**

This option is a synonym for `--littleend`.

**See also**

- `--littleend` on page 2-21
- `--bigend` on page 2-7.

**2.2.40 --library\_type=lib**

This option enables the relevant library selection to be used at link time.

Where *lib* can be one of:

standardlib	Specifies that the full ARM runtime libraries are selected at link time. This is the default.
microlib	Specifies that the C micro-library (microlib) is selected at link time.

———— **Note** ————

This option can be used with the compiler, assembler or linker when use of the libraries require more specialized optimizations.

Use this option with the linker to override all other `--library_type` options.

**See also**

- *Building an application with microlib* on page 3-8 in the *Using ARM C and C++ Libraries and Floating Point Support*
- `--library_type=lib` on page 3-96 in the *Compiler Reference*.

**2.2.41 --licretry**

This option instructs the assembler to retry checking out licenses up to 10 times, approximately 10 seconds apart, upon encountering certain FLEXnet error codes.

**2.2.42 --list=file**

This option instructs the assembler to output a detailed listing of the assembly language produced by the assembler to *file*.

If - is given as *file*, listing is sent to stdout.

Use the following command-line options to control the behavior of --list:

- --no\_terse
- --width
- --length
- --xref.

**See also**

- --no\_terse on page 2-24
- --width=*n* on page 2-30
- --length=*n* on page 2-19
- --xref on page 2-31.

**2.2.43 --list=**

This option instructs the assembler to send the detailed assembly language listing to *inputfile.lst*.

———— **Note** —————

You can use --list without a filename to send the output to *inputfile.lst*. However, this syntax is deprecated and the assembler issues a warning. This syntax will be removed in a later release. Use --list= instead.

**See also**

- --list=*file*.

**2.2.44 --littleend**

This option instructs the assembler to assemble code suitable for a little-endian ARM.

**See also**

- --bigend on page 2-7.

### 2.2.45 -m

This option instructs the assembler to write source file dependency lists to stdout.

#### See also

- *--md*.

### 2.2.46 --maxcache=*n*

This option sets the maximum source cache size to *n* bytes. The default is 8MB. *armasm* gives a warning if size is less than 8MB.

### 2.2.47 --md

This option instructs the assembler to write source file dependency lists to *inputfile.d*.

#### See also

- *-m*.

### 2.2.48 --no\_code\_gen

This option instructs the assembler to exit after pass 1. No object file is generated. This option is useful if you only want to check the syntax of the source code or directives.

### 2.2.49 --no\_esc

This option instructs the assembler to ignore C-style escaped special characters, such as *\n* and *\t*.

### 2.2.50 --no\_exceptions

This option instructs the assembler to switch off exception table generation. No tables are generated. This is the default.

#### See also

- *--exceptions* on page 2-15
- *--exceptions\_unwind* on page 2-15
- *--no\_exceptions\_unwind* on page 2-23
- *FRAME UNWIND ON* on page 6-63
- *FRAME UNWIND OFF* on page 6-63.

**2.2.51 --no\_exceptions\_unwind**

This option instructs the assembler to produce *nounwind* tables for every function.

**See also**

- *--exceptions* on page 2-15
- *--no\_exceptions* on page 2-22
- *--exceptions\_unwind* on page 2-15.

**2.2.52 --no\_hide\_all**

This option gives all exported and imported global symbols STV\_DEFAULT visibility in ELF rather than STV\_HIDDEN, unless overridden by source directives.

**See also**

- *EXPORT* or *GLOBAL* on page 6-91
- *IMPORT* and *EXTERN* on page 6-95.

**2.2.53 --no\_project**

This option disables the use of a project template file.

**See also**

- *--project=filename*, *--no\_project* on page 3-126 in the *Compiler Reference*
- *--reinitialize\_workdir* on page 2-27
- *--workdir=directory* on page 2-30.

**2.2.54 --no\_reduce\_paths**

This option disables the elimination of redundant pathname information in file paths. This is the default setting. This option is valid for Windows systems only.

**See also**

- *--reduce\_paths* on page 2-26
- *--reduce\_paths*, *--no\_reduce\_paths* on page 3-128 in the *Compiler Reference*.

**2.2.55 --no\_regs**

This option instructs the assembler not to predefine register names.

This option is deprecated. Use *--regnames=none* instead.

**See also**

- *--regnames=none* on page 2-26
- *Predeclared core register names* on page 3-15 in *Using the Assembler*
- *Predeclared extension register names* on page 3-16 in *Using the Assembler*
- *Predeclared XScale register names* on page 3-17 in *Using the Assembler*
- *Predeclared coprocessor names* on page 3-19 in *Using the Assembler*.

**2.2.56 --no\_terse**

This option instructs the assembler to show the lines of assembler code that have been skipped due to conditional assembly in the list file. When this option is not specified on the command line, the assembler does not output the skipped assembler code to the list file.

This option turns off the terse flag. By default the terse flag is on.

**See also**

- *--list=file* on page 2-21.

**2.2.57 --no\_unaligned\_access**

This option instructs the assembler to set an attribute in the object file to disable the use of unaligned accesses.

**See also**

- *--unaligned\_access* on page 2-29.

**2.2.58 --no\_warn**

This option turns off warning messages.

**See also**

- *--diag\_warning=tag{, tag}* on page 2-14.

**2.2.59 -o filename**

This option names the output object file. If this option is not specified, the assembler creates an object filename of the form *inputfilename.o*. This option is case-sensitive.

### 2.2.60 --pd

This option is a synonym for `--predefine`.

#### See also

- `--predefine "directive"`.

### 2.2.61 --predefine "*directive*"

This option instructs the assembler to pre-execute one of the SET directives. This is useful for conditional assembly.

The *directive* is one of the SETA, SETL, or SETS directives. You must enclose *directive* in quotes, for example:

```
armasm --predefine "VariableName SETA 20" inputfile.s
```

The assembler also executes a corresponding GBLR, GBLR, or GBLA directive to define the variable before setting its value.

The variable name is case-sensitive. The variables defined using the command line are global to the assembler source files specified on the command line.

#### ————— Note —————

The command line interface of your system might require you to enter special character combinations, such as `\`, to include strings in *directive*. Alternatively, you can use `--via file` to include a `--predefine` argument. The command line interface does not alter arguments from `--via` files.

#### See also

- `--pd`
- *Assembly conditional on a variable being defined* on page 6-47.

### 2.2.62 --project=*filename*

This option enables the use of a project template file.

Project templates are files containing project information such as command-line options for a particular configuration. These files are stored in the project template working directory.

#### See also

- `--project=filename`, `--no_project` on page 3-126 in the *Compiler Reference*

- `--reinitialize_workdir` on page 2-27
- `--workdir=directory` on page 2-30.

### 2.2.63 `--reduce_paths`

This option enables the elimination of redundant pathname information in file paths. This option is valid for Windows systems only.

Windows systems impose a 260 character limit on file paths. Where relative pathnames exist whose absolute names expand to longer than 260 characters, you can use the `--reduce_paths` option to reduce absolute pathname length by matching up directories with corresponding instances of `..` and eliminating the `directory/..` sequences in pairs.

#### ———— **Note** ————

It is recommended that you avoid using long and deeply nested file paths, in preference to minimizing path lengths using the `--reduce_paths` option.

#### **See also**

- `--no_reduce_paths` on page 2-23
- `--reduce_paths`, `--no_reduce_paths` on page 3-128 in the *Compiler Reference*.

### 2.2.64 `--regnames=none`

This option instructs the assembler not to predefine register names.

#### **See also**

- `--regnames=callstd`
- `--regnames=all` on page 2-27
- `--no_regs` on page 2-23
- *Predeclared core register names* on page 3-15 in *Using the Assembler*
- *Predeclared extension register names* on page 3-16 in *Using the Assembler*
- *Predeclared XScale register names* on page 3-17 in *Using the Assembler*
- *Predeclared coprocessor names* on page 3-19 in *Using the Assembler*.

### 2.2.65 `--regnames=callstd`

This option defines additional register names based on the AAPCS variant that you are using as specified by the `--apcs` option.



**See also**

- `--apcs=qualifier...qualifier` on page 2-5
- `--regnames=none` on page 2-26
- `--regnames=all`.

**2.2.66 --regnames=all**

This option defines all AAPCS registers regardless of the value of `--apcs`.

- `--apcs=qualifier...qualifier` on page 2-5
- `--regnames=none` on page 2-26
- `--regnames=callstd` on page 2-26.

**2.2.67 --reinitialize\_workdir**

This option enables you to reinitialize the project template working directory.

**See also**

- `--reinitialize_workdir` in the *Compiler Reference*.
- `--project=filename` on page 2-25
- `--workdir=directory` on page 2-30

**2.2.68 --report-if-not-wysiwyg**

This option instructs the assembler to report when the assembler outputs an encoding that was not directly requested in the source code. This can happen when the assembler:

- uses a pseudo-instruction that is not available in other assemblers, for example `MOV32`
- outputs an encoding that does not directly match the instruction mnemonic, for example if the assembler outputs the `MVN` encoding when assembling the `MOV` instruction
- inserts additional instructions where necessary for instruction syntax semantics, for example the assembler can insert a missing `IT` instruction before a conditional Thumb instruction.

**2.2.69 --show\_cmdline**

This option shows how the assembler processes the command line. The commands are shown normalized, and the contents of any via files are expanded. The output is sent to the standard output stream (stdout).

### 2.2.70 --split\_ldm

This option instructs the assembler to fault LDM and STM instructions with a large number of registers. Use of this option is deprecated.

This option faults LDM instructions if the maximum number of registers transferred exceeds:

- 5, for LDMs that do not load the PC
- 4, for LDMs that load the PC.

This option faults STM instructions if the maximum number of registers transferred exceeds 5.

Avoiding large multiple register transfers can reduce interrupt latency on ARM systems that:

- do not have a cache or a write buffer (for example, a cacheless ARM7TDMI)
- use zero wait-state, 32-bit memory.

Also, avoiding large multiple register transfers:

- always increases code size.
- has no significant benefit for cached systems or processors with a write buffer.
- has no benefit for systems without zero wait-state memory, or for systems with slow peripheral devices. Interrupt latency in such systems is determined by the number of cycles required for the slowest memory or peripheral access. This is typically much greater than the latency introduced by multiple register transfers.

### 2.2.71 --thumb

This option instructs the assembler to interpret instructions as Thumb instructions, using the UAL syntax. This is equivalent to a THUMB directive at the start of the source file.

#### See also

- *--arm* on page 2-7
- *ARM, THUMB, THUMBX, CODE16 and CODE32* on page 6-75.

### 2.2.72 --thumbx

This option instructs the assembler to interpret instructions as Thumb-2EE instructions, using the UAL syntax. This is equivalent to a THUMBX directive at the start of the source file.

**See also**

- *ARM, THUMB, THUMBX, CODE16 and CODE32* on page 6-75.

**2.2.73 --unaligned\_access**

This option instructs the assembler to set an attribute in the object file to enable the use of unaligned accesses.

**See also**

- *--no\_unaligned\_access* on page 2-24.

**2.2.74 --unsafe**

This option enables instructions from differing architectures to be assembled without error. It changes corresponding error messages to warning messages. It also suppresses warnings about operator precedence.

**See also**

- *--diag\_error=tag{, tag}* on page 2-12
- *--diag\_warning=tag{, tag}* on page 2-14
- *Binary operators* on page 8-29 in *Using the Assembler*.

**2.2.75 --untyped\_local\_labels**

This option forces the assembler not to set the Thumb bit when referencing local labels in Thumb code.

**See also**

- *LDR pseudo-instruction* on page 3-182
- *Local labels* on page 8-15 in *Using the Assembler*.

**2.2.76 --version\_number**

This option instructs the assembler to display an integer that increases with each version of *armasm*. The format of the integer is *PVbbbb*, where:

***P*** is the major version  
***V*** is the minor version  
***bbbb*** is the build number.

For example if the assembler prints 400123, the version number of *armasm* is 4.0 and the build number is 123.

**See also**

- `--vs $n$`
- `--help` on page 2-19.

**2.2.77 `--via=file`**

This option instructs the assembler to open *file* and read in command-line arguments to the assembler.

**See also**

- Appendix B *Via File Syntax* in the *Compiler Reference*.

**2.2.78 `--vs $n$`**

This option displays the version information and license details.

**See also**

- `--version_number` on page 2-29
- `--help` on page 2-19.

**2.2.79 `--width= $n$`**

This option sets the listing page width to *n*. The default is 79 characters.

**See also**

- `--list=file` on page 2-21.

**2.2.80 `--workdir=directory`**

This option enables you to provide a working directory for a project template.

**See also**

- `--project=filename` on page 2-25
- `--reinitialize_workdir` on page 2-27
- `--workdir=directory` on page 3-160 in the *Compiler Reference*.

### 2.2.81 --xref

This option instructs the assembler to list cross-referencing information on symbols, including where they were defined and where they were used, both inside and outside macros. The default is off.

#### See also

- *--list=file* on page 2-21.



# Chapter 3

## ARM and Thumb Instructions

The following topics describe the ARM, Thumb (all versions), and ThumbEE instructions supported by the ARM assembler:

- *Instruction summary* on page 3-3
- *Instruction width specifiers* on page 3-11
- *Memory access instructions* on page 3-12
- *General data processing instructions* on page 3-50
- *Multiply instructions* on page 3-85
- *Saturating instructions* on page 3-107
- *Parallel instructions* on page 3-112
- *Packing and unpacking instructions* on page 3-120
- *Branch and control instructions* on page 3-129
- *Coprocessor instructions* on page 3-139
- *Miscellaneous instructions* on page 3-151
- *ThumbEE instructions* on page 3-173
- *Pseudo-instructions* on page 3-177.
- *Condition codes* on page 3-186

Some instruction sections have an Architectures subsection. Instructions that do not have an Architecture subsection are available in all versions of the ARM instruction set, and all versions of the Thumb instruction set.



### 3.1 Instruction summary

Table 3-1 gives an overview of the instructions available in the ARM, Thumb, and ThumbEE instruction sets. Use it to locate individual instructions and pseudo-instructions.

**Note**

Unless stated otherwise, ThumbEE instructions are identical to Thumb instructions.

**Table 3-1 Location of instructions**

Mnemonic	Brief description	See	Arch. <sup>a</sup>
ADC, ADD	Add with Carry, Add	page 3-57	All
ADR	Load program or register-relative address (short range)	page 3-27	All
ADRL pseudo-instruction	Load program or register-relative address (medium range)	page 3-178	x6M
AND	Logical AND	page 3-64	All
ASR	Arithmetic Shift Right	page 3-81	All
B	Branch	page 3-130	All
BFC, BFI	Bit Field Clear and Insert	page 3-121	T2
BIC	Bit Clear	page 3-64	All
BKPT	Breakpoint	page 3-152	5
BL	Branch with Link	page 3-130	All
BLX	Branch with Link, change instruction set	page 3-130	T
BX	Branch, change instruction set	page 3-130	T
BXJ	Branch, change to Jazelle	page 3-130	J, x7M
CBZ, CBNZ	Compare and Branch if {Non}Zero	page 3-137	T2
CDP	Coprocessor Data Processing operation	page 3-140	x6M
CDP2	Coprocessor Data Processing operation	page 3-140	5, x6M
CHKA	Check array	page 3-175	EE
CLREX	Clear Exclusive	page 3-47	K, x6M

**Table 3-1 Location of instructions (continued)**

<b>Mnemonic</b>	<b>Brief description</b>	<b>See</b>	<b>Arch. <sup>a</sup></b>
CLZ	Count leading zeros	page 3-67	5, x6M
CMN, CMP	Compare Negative, Compare	page 3-69	All
CPS	Change Processor State	page 3-160	6
DBG	Debug	page 3-167	7
DMB, DSB	Data Memory Barrier, Data Synchronization Barrier	page 3-168	7, 6M
ENTERX, LEAVEX	Change state to or from ThumbEE	page 3-174	EE
EOR	Exclusive OR	page 3-64	All
HB, HBL, HBLP, HBP	Handler Branch, branches to a specified handler	page 3-176	EE
ISB	Instruction Synchronization Barrier	page 3-168	7, 6M
IT	If-Then	page 3-134	T2
LDC	Load Coprocessor	page 3-149	x6M
LDC2	Load Coprocessor	page 3-149	5, x6M
LDM	Load Multiple registers	page 3-34	All
LDR	Load Register with word	page 3-12	All
LDR pseudo-instruction	Load Register pseudo-instruction	page 3-182	All
LDRB	Load Register with byte	page 3-12	All
LDRBT	Load Register with byte, user mode	page 3-12	x6M
LDRD	Load Registers with two words	page 3-12	5E, x6M
LDREX	Load Register Exclusive	page 3-44	6, x6M
LDREXB, LDREXH	Load Register Exclusive Byte, Halfword	page 3-44	K, x6M
LDREXD	Load Register Exclusive Doubleword	page 3-44	K, x7M
LDRH	Load Register with halfword	page 3-12	All
LDRHT	Load Register with halfword, user mode	page 3-12	T2
LDRSB	Load Register with signed byte	page 3-12	All
LDRSBT	Load Register with signed byte, user mode	page 3-12	T2

**Table 3-1 Location of instructions (continued)**

<b>Mnemonic</b>	<b>Brief description</b>	<b>See</b>	<b>Arch. <sup>a</sup></b>
LDRSH	Load Register with signed halfword	page 3-12	All
LDRSHT	Load Register with signed halfword, user mode	page 3-12	T2
LDRT	Load Register with word, user mode	page 3-12	x6M
LSL, LSR	Logical Shift Left, Logical Shift Right	page 3-81	All
MAR	Move from Registers to 40-bit Accumulator	page 3-171	XScale
MCR	Move from Register to Coprocessor	page 3-141	x6M
MCR2	Move from Register to Coprocessor	page 3-141	5, x6M
MCRR	Move from Registers to Coprocessor	page 3-141	5E, x6M
MCRR2	Move from Registers to Coprocessor	page 3-141	6, x6M
MIA, MIAPH, MIAxy	Multiply with Internal 40-bit Accumulate	page 3-105	XScale
MLA	Multiply Accumulate	page 3-86	x6M
MLS	Multiply and Subtract	page 3-86	T2
MOV	Move	page 3-71	All
MOVT	Move Top	page 3-74	T2
MOV32 pseudo-instruction	Move 32-bit immediate to register	page 3-180	T2
MRA	Move from 40-bit Accumulator to Registers	page 3-171	XScale
MRC	Move from Coprocessor to Register	page 3-143	x6M
MRC2	Move from Coprocessor to Register	page 3-143	5, x6M
MRRC	Move from Coprocessor to Registers	page 3-143	5E, x6M
MRRC2	Move from Coprocessor to Registers	page 3-143	6, x6M
MRS	Move from PSR to register	page 3-155	All
MRS	Move from system Coprocessor to Register	page 3-146	7A, 7R
MSR	Move from register to PSR	page 3-157	All
MSR	Move from Register to system Coprocessor	page 3-145	7A, 7R
MUL	Multiply	page 3-86	All

**Table 3-1 Location of instructions (continued)**

<b>Mnemonic</b>	<b>Brief description</b>	<b>See</b>	<b>Arch. <sup>a</sup></b>
MVN	Move Not	page 3-71	All
NOP	No Operation	page 3-164	All
ORN	Logical OR NOT	page 3-64	T2
ORR	Logical OR	page 3-64	All
PKHBT, PKHTB	Pack Halfwords	page 3-127	6, x7M
PLD	Preload Data	page 3-31	5E, x6M
PLDW	Preload Data with intent to Write	page 3-31	7MP
PLI	Preload Instruction	page 3-31	7
PUSH, POP	PUSH registers to stack, POP registers from stack	page 3-37	All
QADD, QDADD, QDSUB, QSUB	Saturating Arithmetic	page 3-108	5E, x7M
QADD8, QADD16, QASX, QSUB8, QSUB16, QSAX	Parallel signed Saturating Arithmetic	page 3-113	6, x7M
RBIT	Reverse Bits	page 3-79	T2
REV, REV16, REVSH	Reverse byte order	page 3-79	6
RFE	Return From Exception	page 3-39	T2, x7M
ROR	Rotate Right Register	page 3-81	All
RRX	Rotate Right with Extend	page 3-81	x6M
RSB	Reverse Subtract	page 3-57	All
RSC	Reverse Subtract with Carry	page 3-57	x7M
SADD8, SADD16, SASX	Parallel signed arithmetic	page 3-113	6, x7M
SBC	Subtract with Carry	page 3-57	All
SBFX, UBFX	Signed, Unsigned Bit Field eXtract	page 3-123	T2
SDIV	Signed divide	page 3-84	7M, 7R
SEL	Select bytes according to APSR GE flags	page 3-77	6, x7M
SETEND	Set Endianness for memory accesses	page 3-163	6, x7M

**Table 3-1 Location of instructions (continued)**

<b>Mnemonic</b>	<b>Brief description</b>	<b>See</b>	<b>Arch. <sup>a</sup></b>
SEV	Set Event	page 3-165	K, 6M
SHADD8, SHADD16, SHASX, SHSUB8, SHSUB16, SHSAX	Parallel signed Halving arithmetic	page 3-113	6, x7M
SMC	Secure Monitor Call	page 3-162	Z
SMLAxy	Signed Multiply with Accumulate ( $32 \leq 16 \times 16 + 32$ )	page 3-90	5E, x7M
SMLAD	Dual Signed Multiply Accumulate ( $32 \leq 32 + 16 \times 16 + 16 \times 16$ )	page 3-100	6, x7M
SMLAL	Signed Multiply Accumulate ( $64 \leq 64 + 32 \times 32$ )	page 3-88	x6M
SMLALxy	Signed Multiply Accumulate ( $64 \leq 64 + 16 \times 16$ )	page 3-94	5E, x7M
SMLALD	Dual Signed Multiply Accumulate Long ( $64 \leq 64 + 16 \times 16 + 16 \times 16$ )	page 3-102	6, x7M
SMLAWy	Signed Multiply with Accumulate ( $32 \leq 32 \times 16 + 32$ )	page 3-92	5E, x7M
SMLSD	Dual Signed Multiply Subtract Accumulate ( $32 \leq 32 + 16 \times 16 - 16 \times 16$ )	page 3-100	6, x7M
SMLSLD	Dual Signed Multiply Subtract Accumulate Long ( $64 \leq 64 + 16 \times 16 - 16 \times 16$ )	page 3-102	6, x7M
SMMLA	Signed top word Multiply with Accumulate ( $32 \leq$ TopWord( $32 \times 32 + 32$ ))	page 3-98	6, x7M
SMMLS	Signed top word Multiply with Subtract ( $32 \leq$ TopWord( $32 - 32 \times 32$ ))	page 3-98	6, x7M
SMMUL	Signed top word Multiply ( $32 \leq$ TopWord( $32 \times 32$ ))	page 3-98	6, x7M
SMUAD, SMUSD	Dual Signed Multiply, and Add or Subtract products	page 3-96	6, x7M
SMULxy	Signed Multiply ( $32 \leq 16 \times 16$ )	page 3-90	5E, x7M
SMULL	Signed Multiply ( $64 \leq 32 \times 32$ )	page 3-88	x6M
SMULWy	Signed Multiply ( $32 \leq 32 \times 16$ )	page 3-92	5E, x7M
SRS	Store Return State	page 3-42	T2, x7M

**Table 3-1 Location of instructions (continued)**

<b>Mnemonic</b>	<b>Brief description</b>	<b>See</b>	<b>Arch. <sup>a</sup></b>
SSAT	Signed Saturate	page 3-110	6, x6M
SSAT16	Signed Saturate, parallel halfwords	page 3-118	6, x7M
SSUB8, SSUB16, SSAX	Parallel signed arithmetic	page 3-113	6, x7M
STC	Store Coprocessor	page 3-149	x6M
STC2	Store Coprocessor	page 3-149	5, x6M
STM	Store Multiple registers	page 3-34	All
STR	Store Register with word	page 3-12	All
STRB	Store Register with byte	page 3-12	All
STRBT	Store Register with byte, user mode	page 3-12	x6M
STRD	Store Registers with two words	page 3-12	5E, x6M
STREX	Store Register Exclusive	page 3-44	6, x6M
STREXB, STREXH	Store Register Exclusive Byte, Halfword	page 3-44	K, x6M
STREXD	Store Register Exclusive Doubleword	page 3-44	K, x7M
STRH	Store Register with halfword	page 3-12	All
STRHT	Store Register with halfword, user mode	page 3-12	T2
STRT	Store Register with word, user mode	page 3-12	x6M
SUB	Subtract	page 3-57	All
SUBS pc, 1r	Exception return, no stack	page 3-62	T2, x7M
SVC (formerly SWI)	SuperVisor Call	page 3-153	All
SWP, SWPB	Swap registers and memory (ARM only)	page 3-48	All, x7M
SXTAB, SXTAB16, SXTAH	Signed extend, with Addition	page 3-124	6, x7M
SXTB, SXTH	Signed extend	page 3-124	6
SXTB16	Signed extend	page 3-124	6, x7M
SYS	Execute system coprocessor instruction	page 3-148	7A, 7R
TBB, TBH	Table Branch Byte, Halfword	page 3-138	T2

**Table 3-1 Location of instructions (continued)**

<b>Mnemonic</b>	<b>Brief description</b>	<b>See</b>	<b>Arch. <sup>a</sup></b>
TEQ	Test Equivalence	page 3-75	x6M
TST	Test	page 3-75	All
UADD8, UADD16, UASX	Parallel Unsigned Arithmetic	page 3-113	6, x7M
UDIV	Unsigned divide	page 3-84	7M, 7R
UHADD8, UHADD16, UHASX, UHSUB8, UHSUB16, UHSAX	Parallel Unsigned Halving Arithmetic	page 3-113	6, x7M
UMAAL	Unsigned Multiply Accumulate Accumulate Long (64 <= 32 + 32 + 32 x 32)	page 3-104	6, x7M
UMLAL, UMULL	Unsigned Multiply Accumulate, Unsigned Multiply (64 <= 32 x 32 + 64), (64 <= 32 x 32)	page 3-88	x6M
UQADD8, UQADD16, UQASX, UQSUB8, UQSUB16, UQSAX	Parallel Unsigned Saturating Arithmetic	page 3-113	6, x7M
USAD8	Unsigned Sum of Absolute Differences	page 3-116	6, x7M
USADA8	Accumulate Unsigned Sum of Absolute Differences	page 3-116	6, x7M
USAT	Unsigned Saturate	page 3-110	6, x6M
USAT16	Unsigned Saturate, parallel halfwords	page 3-118	6, x7M
USUB8, USUB16, USAX	Parallel unsigned arithmetic	page 3-113	6, x7M
UXTAB, UXTAB16, UXTAH	Unsigned extend with Addition	page 3-124	6, x7M
UXTB, UXTH	Unsigned extend	page 3-124	6
UXTB16	Unsigned extend	page 3-124	6, x7M
V*	See Chapter 4 <i>NEON and VFP Programming</i>		
WFE, WFI, YIELD	Wait For Event, Wait For Interrupt, Yield	page 3-165	T2, 6M

a. Entries in the Architecture column have the following meanings:

<b>All</b>	These instructions are available in all versions of the ARM architecture.
<b>5</b>	These instructions are available in the ARMv5T*, ARMv6*, and ARMv7 architectures.
<b>5E</b>	These instructions are available in the ARMv5TE, ARMv6*, and ARMv7 architectures.
<b>6</b>	These instructions are available in the ARMv6* and ARMv7 architectures.
<b>6M</b>	These instructions are available in the ARMv6-M and ARMv7 architectures.
<b>x6M</b>	These instructions are not available in the ARMv6-M profile.
<b>7</b>	These instructions are available in the ARMv7 architectures.
<b>7M</b>	These instructions are available in the ARMv7-M profile.
<b>x7M</b>	These instructions are not available in the ARMv6-M or ARMv7-M profile.
<b>7R</b>	These instructions are available in the ARMv7-R profile.
<b>7MP</b>	These instructions are available in the ARMv7 architectures that implement the Multiprocessing Extensions.
<b>EE</b>	These instructions are available in ThumbEE variants of the ARM architecture.
<b>J</b>	This instruction is available in the ARMv5TEJ, ARMv6*, and ARMv7 architectures.
<b>K</b>	These instructions are available in the ARMv6K, and ARMv7 architectures.
<b>T</b>	These instructions are available in ARMv4T, ARMv5T*, ARMv6*, and ARMv7 architectures.
<b>T2</b>	These instructions are available in the ARMv6T2 and above architectures.
<b>XScale</b>	These instructions are available in XScale versions of the ARM architecture.
<b>Z</b>	This instruction is available if Security Extensions are implemented.



## 3.2 Instruction width specifiers

The instruction width specifiers `.W` and `.N` control the instruction size of Thumb code assembled for ARMv6T2 or later.

In Thumb code (ARMv6T2 or later) the `.W` width specifier forces the assembler to generate a 32-bit encoding, even if a 16-bit encoding is available. The `.W` specifier has no effect when assembling to ARM code.

In Thumb code the `.N` width specifier forces the assembler to generate a 16-bit encoding. In this case, if the instruction cannot be encoded in 16 bits or if `.N` is used in ARM code, the assembler generates an error.

If you use an instruction width specifier, you must place it immediately after the instruction mnemonic and any condition code, for example:

```
BCS.W  label    ; forces 32-bit instruction even for a short branch
B.N    label    : faults if label out of range for 16-bit instruction
```

### 3.3 Memory access instructions

This section contains the following subsections:

- *LDR and STR (immediate offset)* on page 3-14  
Load and Store with immediate offset, pre-indexed immediate offset, or post-indexed immediate offset.
- *LDR and STR (register offset)* on page 3-17  
Load and Store with register offset, pre-indexed register offset, or post-indexed register offset.
- *LDR and STR, unprivileged* on page 3-19  
Load and Store, with User mode privilege.
- *LDR (PC-relative)* on page 3-21  
Load register. The address is an offset from the PC.
- *LDR (register-relative)* on page 3-24  
Load register. The address is an offset from a base register.
- *ADR (PC-relative)* on page 3-27  
Load a PC-relative address.
- *ADR (register-relative)* on page 3-29  
Load a register-relative address.
- *PLD, PLDW, and PLI* on page 3-31  
Preload an address for the future.
- *LDM and STM* on page 3-34  
Load and Store Multiple Registers.
- *PUSH and POP* on page 3-37  
Push low registers, and optionally the LR, onto the stack.  
Pop low registers, and optionally the PC, off the stack.
- *RFE* on page 3-39  
Return From Exception.
- *SRS* on page 3-42  
Store Return State.

- *LDREX and STREX* on page 3-44  
Load and Store Register Exclusive.
- *CLREX* on page 3-47  
Clear Exclusive.
- *SWP and SWPB* on page 3-48  
Swap data between registers and memory.

---

**Note**

---

There is also an LDR pseudo-instruction. This pseudo-instruction either assembles to an LDR instruction, or to a MOV or MVN instruction.

---

**See also****Reference:**

- *LDR pseudo-instruction* on page 3-182.

### 3.3.1 LDR and STR (immediate offset)

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

#### Syntax

```

op{type}{cond} Rt, [Rn {, #offset}]      ; immediate offset
op{type}{cond} Rt, [Rn, #offset]!        ; pre-indexed
op{type}{cond} Rt, [Rn], #offset         ; post-indexed
opD{cond} Rt, Rt2, [Rn {, #offset}]      ; immediate offset, doubleword
opD{cond} Rt, Rt2, [Rn, #offset]!        ; pre-indexed, doubleword
opD{cond} Rt, Rt2, [Rn], #offset         ; post-indexed, doubleword

```

where:

<i>op</i>	can be either: LDR      Load Register STR      Store Register.
<i>type</i>	can be any one of: B          unsigned Byte (Zero extend to 32 bits on loads.) SB        signed Byte (LDR only. Sign extend to 32 bits.) H          unsigned Halfword (Zero extend to 32 bits on loads.) SH        signed Halfword (LDR only. Sign extend to 32 bits.) -          omitted, for Word.
<i>cond</i>	is an optional condition code.
<i>Rt</i>	is the register to load or store.
<i>Rn</i>	is the register on which the memory address is based.
<i>offset</i>	is an offset. If <i>offset</i> is omitted, the address is the contents of <i>Rn</i> .
<i>Rt2</i>	is the additional register to load or store for doubleword operations.

Not all options are available in every instruction set and architecture.

## Offset ranges and architectures

Table 3-2 shows the ranges of offsets and availability of these instructions.

**Table 3-2 Offsets and architectures, LDR/STR, word, halfword, and byte**

Instruction	Immediate offset	Pre-indexed	Post-indexed	Arch.
ARM, word or byte <sup>a</sup>	–4095 to 4095	–4095 to 4095	–4095 to 4095	All
ARM, signed byte, halfword, or signed halfword	–255 to 255	–255 to 255	–255 to 255	All
ARM, doubleword	–255 to 255	–255 to 255	–255 to 255	v5TE +
32-bit Thumb, word, halfword, signed halfword, byte, or signed byte <sup>a</sup>	–255 to 4095	–255 to 255	–255 to 255	v6T2, v7
32-bit Thumb, doubleword	–1020 to 1020 <sup>c</sup>	–1020 to 1020 <sup>c</sup>	–1020 to 1020 <sup>c</sup>	v6T2, v7
16-bit Thumb, word <sup>b</sup>	0 to 124 <sup>c</sup>	Not available	Not available	All T
16-bit Thumb, unsigned halfword <sup>b</sup>	0 to 62 <sup>d</sup>	Not available	Not available	All T
16-bit Thumb, unsigned byte <sup>b</sup>	0 to 31	Not available	Not available	All T
16-bit Thumb, word, Rn is SP <sup>e</sup>	0 to 1020 <sup>c</sup>	Not available	Not available	All T
16-bit ThumbEE, word <sup>b</sup>	–28 to 124 <sup>c</sup>	Not available	Not available	T-2EE
16-bit ThumbEE, word, Rn is R9 <sup>e</sup>	0 to 252 <sup>c</sup>	Not available	Not available	T-2EE
16-bit ThumbEE, word, Rn is R10 <sup>e</sup>	0 to 124 <sup>c</sup>	Not available	Not available	T-2EE

- a. For word loads, Rt can be the PC. A load to the PC causes a branch to the address loaded. In ARMv4, bits[1:0] of the address loaded must be 0b00. In ARMv5T and above, bits[1:0] must not be 0b10, and if bit[0] is 1, execution continues in Thumb state, otherwise execution continues in ARM state.
- b. Rt and Rn must be in the range R0-R7.
- c. Must be divisible by 4.
- d. Must be divisible by 2.
- e. Rt must be in the range R0-R7.

**Doubleword register restrictions**

For Thumb-2 instructions, you must not specify SP or PC for either  $Rt$  or  $Rt2$ .

For ARM instructions:

- $Rt$  must be an even-numbered register
- $Rt$  must not be LR
- it is strongly recommended that you do not use R12 for  $Rt$
- $Rt2$  must be  $R(t + 1)$ .

**Examples**

```
LDR    r8,[r10]           ; loads R8 from the address in R10.
LDRNE  r2,[r5,#960]!      ; (conditionally) loads R2 from a word
                           ; 960 bytes above the address in R5, and
                           ; increments R5 by 960.
STR     r2,[r9,#consta-struct] ; consta-struct is an expression evaluating
                           ; to a constant in the range 0-4095.
```

**See also****Reference:**

- *Condition codes* on page 3-186.

### 3.3.2 LDR and STR (register offset)

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

#### Syntax

*op*{*type*}{*cond*} *Rt*, [*Rn*, +/-*Rm* {, *shift*}] ; register offset

*op*{*type*}{*cond*} *Rt*, [*Rn*, +/-*Rm* {, *shift*}]! ; pre-indexed

*op*{*type*}{*cond*} *Rt*, [*Rn*], +/-*Rm* {, *shift*} ; post-indexed

*opD*{*cond*} *Rt*, *Rt2*, [*Rn*, +/-*Rm*] ; register offset, doubleword

*opD*{*cond*} *Rt*, *Rt2*, [*Rn*, +/-*Rm*]! ; pre-indexed, doubleword

*opD*{*cond*} *Rt*, *Rt2*, [*Rn*], +/-*Rm* ; post-indexed, doubleword

where:

*op* can be either:

LDR Load Register

STR Store Register.

*type* can be any one of:

B unsigned Byte (Zero extend to 32 bits on loads.)

SB signed Byte (LDR only. Sign extend to 32 bits.)

H unsigned Halfword (Zero extend to 32 bits on loads.)

SH signed Halfword (LDR only. Sign extend to 32 bits.)

- omitted, for Word.

*cond* is an optional condition code.

*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. *Rm* must not be PC.  
-*Rm* is not allowed in Thumb code.

*shift* is an optional shift.

*Rt2* is the additional register to load or store for doubleword operations.

Not all options are available in every instruction set and architecture.

Offset register and shift options

Table 3-3 shows the ranges of offsets and availability of these instructions.

Table 3-3 Options and architectures, LDR/STR (register offsets)

Instruction	+/-Rm <sup>a</sup>	shift			Arch.
ARM, word or byte <sup>b</sup>	+/-Rm	LSL #0-31	LSR #1-32		All
		ASR #1-32	ROR #1-31	RRX	
ARM, signed byte, halfword, or signed halfword	+/-Rm	Not available			All
ARM, doubleword	+/-Rm	Not available			v5TE +
32-bit Thumb, word, halfword, signed halfword, byte, or signed byte <sup>b</sup>	+Rm	LSL #0-3			v6T2, v7
16-bit Thumb, all except doubleword <sup>c</sup>	+Rm	Not available			All T
16-bit ThumbEE, word <sup>b</sup>	+Rm	LSL #2 (required)			T-2EE
16-bit ThumbEE, halfword, signed halfword <sup>b</sup>	+Rm	LSL #1 (required)			T-2EE
16-bit ThumbEE, byte, signed byte <sup>b</sup>	+Rm	Not available			T-2EE

- a. Where +/-Rm is shown, you can use -Rm, +Rm, or Rm. Where +Rm is shown, you cannot use -Rm.
- b. For word loads, Rt can be the PC. A load to the PC causes a branch to the address loaded. In ARMv4, bits[1:0] of the address loaded must be 0b00. In ARMv5T and above, bits[1:0] must not be 0b10, and if bit[0] is 1, execution continues in Thumb state, otherwise execution continues in ARM state.
- c. Rt, Rn, and Rm must all be in the range R0-R7.

Doubleword register restrictions

For ARM instructions:

- Rt must be an even-numbered register
- Rt must not be LR
- it is strongly recommended that you do not use R12 for Rt
- Rt2 must be R(t + 1).

See also

Reference:

- Condition codes on page 3-186.



### 3.3.3 LDR and STR, unprivileged

Unprivileged load and Store, byte, halfword, or word.

When these instructions are executed by privileged software, they access memory with the same restrictions as they would have if they were executed by unprivileged software.

When executed by unprivileged software these instructions behave in exactly the same way as the corresponding load or store instruction, for example LDRSBT behaves in the same way as LDRSB.

#### Syntax

```

op{type}T{cond} Rt, [Rn {, #offset}]      ; immediate offset (Thumb-2 only)
op{type}T{cond} Rt, [Rn] {, #offset}      ; post-indexed (ARM only)
op{type}T{cond} Rt, [Rn], +/-Rm {, shift} ; post-indexed (register) (ARM only)

```

where:

<i>op</i>	can be either:
LDR	Load Register
STR	Store Register.
<i>type</i>	can be any one of:
B	unsigned Byte (Zero extend to 32 bits on loads.)
SB	signed Byte (LDR only. Sign extend to 32 bits.)
H	unsigned Halfword (Zero extend to 32 bits on loads.)
SH	signed Halfword (LDR only. Sign extend to 32 bits.)
-	omitted, for Word.
<i>cond</i>	is an optional condition code.
<i>Rt</i>	is the register to load or store.
<i>Rn</i>	is the register on which the memory address is based.
<i>offset</i>	is an offset. If offset is omitted, the address is the value in <i>Rn</i> .
<i>Rm</i>	is a register containing a value to be used as the offset. <i>Rm</i> must not be PC.
<i>shift</i>	is an optional shift.

Offset ranges and architectures

Table 3-2 on page 3-15 shows the ranges of offsets and availability of these instructions.

Table 3-4 Offsets and architectures, LDR/STR (User mode)

Instruction	Immediate offset	Post-indexed	+/-Rm <sup>a</sup>	shift	Arch.
ARM, word or byte	Not available	-4095 to 4095	+/-Rm	LSL #0-31	All
				LSR #1-32	
				ASR #1-32	
				ROR #1-31	
				RRX	
ARM, signed byte, halfword, or signed halfword	Not available	-255 to 255	+/-Rm	Not available	v6T2, v7
32-bit Thumb, word, halfword, signed halfword, byte, or signed byte	0 to 255	Not available	Not available		v6T2, v7

a. You can use -Rm, +Rm, or Rm.

### 3.3.4 LDR (PC-relative)

Load register. The address is an offset from the PC.

#### Syntax

`LDR{type}{cond}{.W} Rt, label`

`LDRD{cond} Rt, Rt2, label` ; Doubleword

where:

*type* can be any one of:

B	unsigned Byte (Zero extend to 32 bits on loads.)
SB	signed Byte (LDR only. Sign extend to 32 bits.)
H	unsigned Halfword (Zero extend to 32 bits on loads.)
SH	signed Halfword (LDR only. Sign extend to 32 bits.)
-	omitted, for Word.

*cond* is an optional condition code.

*.W* is an optional instruction width specifier.

*Rt* is the register to load or store.

*Rt2* is the second register to load or store.

*label* is a PC-relative expression.

*label* must be within a limited distance of the current instruction.

Offset range and architectures

The assembler calculates the offset from the PC for you. The assembler generates an error if *label* is out of range.

Table 3-5 shows the possible offsets between label and the current instruction.

Table 3-5 PC-relative offsets

Instruction	Offset range	Architectures
ARM LDR, LDRB, LDRSB, LDRH, LDRSH <sup>a</sup>	+/- 4095	All
ARM LDRD	+/- 255	v5TE +
32-bit Thumb LDR, LDRB, LDRSB, LDRH, LDRSH <sup>a</sup>	+/- 4095	v6T2, v7
32-bit Thumb LDRD	+/- 1020 <sup>b</sup>	v6T2, v7
16-bit Thumb LDR <sup>c</sup>	0-1020 <sup>b</sup>	All T

- a. For word loads, Rt can be the PC. A load to the PC causes a branch to the address loaded. In ARMv4, bits[1:0] of the address loaded must be 0b00. In ARMv5T and above, bits[1:0] must not be 0b10, and if bit[0] is 1, execution continues in Thumb state, otherwise execution continues in ARM state.
- b. Must be a multiple of 4.
- c. Rt must be in the range R0-R7. There are no byte, halfword, or doubleword 16-bit instructions.

LDR (PC-relative) in Thumb-2

You can use the .W width specifier to force LDR to generate a 32-bit instruction in Thumb-2 code. LDR.W always generates a 32-bit instruction, even if the target could be reached using a 16-bit LDR.

For forward references, LDR without .W always generates a 16-bit instruction in Thumb code, even if that results in failure for a target that could be reached using a 32-bit Thumb-2 LDR instruction.

Doubleword register restrictions

For Thumb-2 instructions, you must not specify SP or PC for either *Rt* or *Rt2*.

For ARM instructions:

- *Rt* must be an even-numbered register
- *Rt* must not be LR
- it is strongly recommended that you do not use R12 for *Rt*
- *Rt2* must be  $R(\tau + 1)$ .

**See also****Concepts:**

*Using the Assembler:*

- *Register-relative and PC-relative expressions* on page 8-9.

**Reference:**

- *Pseudo-instructions* on page 3-177
- *LDR (PC-relative) in Thumb-2* on page 3-22
- *Condition codes* on page 3-186.

### 3.3.5 LDR (register-relative)

Load register. The address is an offset from a base register.

#### Syntax

`LDR{type}{cond}{.W} Rt, label`

`LDRD{cond} Rt, Rt2, label ; Doubleword`

where:

*type* can be any one of:

- B unsigned Byte (Zero extend to 32 bits on loads.)
- SB signed Byte (LDR only. Sign extend to 32 bits.)
- H unsigned Halfword (Zero extend to 32 bits on loads.)
- SH signed Halfword (LDR only. Sign extend to 32 bits.)
- omitted, for Word.

*cond* is an optional condition code.

*.W* is an optional instruction width specifier.

*Rt* is the register to load or store.

*Rt2* is the second register to load or store.

*label* is a symbol defined by the FIELD directive. *label* specifies an offset from the base register which is defined using the MAP directive.

*label* must be within a limited distance of the value in the base register.

## Offset range and architectures

The assembler calculates the offset from the base register for you. The assembler generates an error if *label* is out of range.

Table 3-5 on page 3-22 shows the possible offsets between label and the current instruction.

**Table 3-6 register-relative offsets**

Instruction	Offset range	Architectures
ARM LDR, LDRB <sup>a</sup>	+/- 4095	All
ARM LDRSB, LDRH, LDRSH	+/- 255	All
ARM LDRD	+/- 255	v5TE +
32-bit Thumb LDR, LDRB, LDRSB, LDRH, LDRSH <sup>a</sup>	-255 to 4095	v6T2, v7
32-bit Thumb LDRD	+/- 1020 <sup>b</sup>	v6T2, v7
16-bit Thumb LDR <sup>c</sup>	0 to 124 <sup>b</sup>	All T
16-bit Thumb LDRH <sup>c</sup>	0 to 62 <sup>d</sup>	All T
16-bit Thumb LDRB <sup>c</sup>	0 to 31	All T
16-bit Thumb LDR, base register is SP <sup>e</sup>	0 to 1020 <sup>b</sup>	All T
16-bit ThumbEE LDR <sup>c</sup>	-28 to 124 <sup>b</sup>	T-2EE
16-bit Thumb LDR, base register is R9 <sup>e</sup>	0 to 252 <sup>b</sup>	T-2EE
16-bit ThumbEE LDR, base register is R10 <sup>e</sup>	0 to 124 <sup>b</sup>	T-2EE

- a. For word loads, Rt can be the PC. A load to the PC causes a branch to the address loaded. In ARMv4, bits[1:0] of the address loaded must be 0b00. In ARMv5T and above, bits[1:0] must not be 0b10, and if bit[0] is 1, execution continues in Thumb state, otherwise execution continues in ARM state.
- b. Must be a multiple of 4.
- c. Rt and base register must be in the range R0-R7.
- d. Must be a multiple of 2.
- e. Rt must be in the range R0-R7.

## LDR (register-relative) in Thumb-2

You can use the *.W* width specifier to force LDR to generate a 32-bit instruction in Thumb-2 code. LDR.*W* always generates a 32-bit instruction, even if the target could be reached using a 16-bit LDR.

For forward references, LDR without .W always generates a 16-bit instruction in Thumb code, even if that results in failure for a target that could be reached using a 32-bit Thumb-2 LDR instruction.

### Doubleword register restrictions

For Thumb-2 instructions, you must not specify SP or PC for either *Rt* or *Rt2*.

For ARM instructions:

- *Rt* must be an even-numbered register
- *Rt* must not be LR
- it is strongly recommended that you do not use R12 for *Rt*
- *Rt2* must be  $R(t + 1)$ .

### See also

#### Concepts

*Using the Assembler:*

- *Register-relative and PC-relative expressions* on page 8-9.

#### Reference:

- *Pseudo-instructions* on page 3-177
- *LDR (register-relative) in Thumb-2* on page 3-25
- *FIELD* on page 6-22
- *MAP* on page 6-21
- *Condition codes* on page 3-186.



### 3.3.6 ADR (PC-relative)

ADR generates a PC-relative address in the destination register, for a label in the current area.

#### Syntax

`ADR{cond}{.W} Rd, label`

where:

*cond* is an optional condition code.

.W is an optional instruction width specifier.

*Rd* is the destination register to load.

*label* is a PC-relative expression.

*label* must be within a limited distance of the current instruction.

#### Usage

ADR produces position-independent code, because the assembler generates an instruction that adds or subtracts a value to the PC.

Use the ADRL pseudo-instruction to assemble a wider range of effective addresses.

*label* must evaluate to an address in the same assembler area as the ADR instruction.

If you use ADR to generate a target for a BX or BLX instruction, it is your responsibility to set the Thumb bit (bit 0) of the address if the target contains Thumb instructions.

## Offset range and architectures

The assembler calculates the offset from the PC for you. The assembler generates an error if *label* is out of range.

Table 3-5 on page 3-22 shows the possible offsets between label and the current instruction.

**Table 3-7 PC-relative offsets**

Instruction	Offset range	Architectures
ARM ADR	See <i>Operand 2 as a constant</i> on page 3-51	All
32-bit Thumb ADR	+/- 4095	v6T2, v7
16-bit Thumb ADR <sup>a</sup>	0-1020 <sup>b</sup>	All T

a. Rd must be in the range R0-R7.

b. Must be a multiple of 4.

## ADR in Thumb-2

You can use the `.w` width specifier to force ADR to generate a 32-bit instruction in Thumb-2 code. ADR with `.w` always generates a 32-bit instruction, even if the address can be generated in a 16-bit instruction.

For forward references, ADR without `.w` always generates a 16-bit instruction in Thumb code, even if that results in failure for an address that could be generated in a 32-bit Thumb-2 ADD instruction.

## See also

### Concepts

*Using the Assembler:*

- *Register-relative and PC-relative expressions* on page 8-9.

### Reference:

- *ADRL pseudo-instruction* on page 3-178
- *AREA* on page 6-81
- *Condition codes* on page 3-186.

### 3.3.7 ADR (register-relative)

ADR generates a register-relative address in the destination register, for a label defined in a storage map.

#### Syntax

`ADR{cond}{.W} Rd, label`

where:

<i>cond</i>	is an optional condition code.
.W	is an optional instruction width specifier.
<i>Rd</i>	is the destination register to load.
<i>label</i>	is a symbol defined by the FIELD directive. <i>label</i> specifies an offset from the base register which is defined using the MAP directive. <i>label</i> must be within a limited distance from the base register.

#### Usage

ADR generates code to easily access named fields inside a storage map.

Use the ADRL pseudo-instruction to assemble a wider range of effective addresses.

#### Restrictions

In Thumb code:

- *Rd* cannot be PC
- *Rd* can be SP only if the base register is SP.

Offset range and architectures

The assembler calculates the offset from the base register for you. The assembler generates an error if *label* is out of range.

Table 3-5 on page 3-22 shows the possible offsets between label and the current instruction.

Table 3-8 register-relative offsets

Instruction	Offset range	Architectures
ARM ADR	See <i>Operand 2 as a constant</i> on page 3-51	All
32-bit Thumb ADR	+/- 4095	v6T2, v7
16-bit Thumb ADR, base register is SP <sup>a</sup>	0-1020 <sup>b</sup>	All T

- a. *Rd* must be in the range R0-R7 or SP. If *Rd* is SP, the offset range is -508 to 508 and must be a multiple of 4
- b. Must be a multiple of 4.

ADR in Thumb-2

You can use the *.W* width specifier to force ADR to generate a 32-bit instruction in Thumb-2 code. ADR with *.W* always generates a 32-bit instruction, even if the address can be generated in a 16-bit instruction.

For forward references, ADR without *.W*, with base register SP, always generates a 16-bit instruction in Thumb code, even if that results in failure for an address that could be generated in a 32-bit Thumb-2 ADD instruction.

See also

Concepts

*Using the Assembler:*

- *Register-relative and PC-relative expressions* on page 8-9.

Reference:

- *MAP* on page 6-21
- *FIELD* on page 6-22
- *ADRL pseudo-instruction* on page 3-178
- *Condition codes* on page 3-186.

### 3.3.8 PLD, PLDW, and PLI

Preload Data and Preload Instruction. The processor can signal the memory system that a data or instruction load from an address is likely in the near future.

#### Syntax

$PLtype\{cond\} [Rn \{, \#offset\}]$

$PLtype\{cond\} [Rn, +/-Rm \{, shift\}]$

$PLtype\{cond\} label$

where:

*type* can be one of:

D	Data address
DW	Data address with intention to write
I	Instruction address.

*type* cannot be DW if the syntax specifies *label*.

*cond* is an optional condition code.

#### ———— Note ————

*cond* is allowed only in Thumb-2 code, using a preceding IT instruction. This is an unconditional instruction in ARM and you must not use *cond*.

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

*offset* is an immediate offset. If offset is omitted, the address is the value in *Rn*.

*Rm* is a register containing a value to be used as the offset. *Rm* must not be PC. For Thumb instructions *Rm* must also not be SP.

*shift* is an optional shift.

*label* is a PC-relative expression.

#### Range of offset

The offset is applied to the value in *Rn* before the preload takes place. The result is used as the memory address for the preload. The range of offsets allowed is:

- –4095 to +4095 for ARM instructions
- –255 to +4095 for Thumb-2 instructions, when *Rn* is not PC.
- –4095 to +4095 for Thumb-2 instructions, when *Rn* is PC.

The assembler calculates the offset from the PC for you. The assembler generates an error if *label* is out of range.

### Register or shifted register offset

In ARM, the value in *Rm* is added to or subtracted from the value in *Rn*. In Thumb-2, the value in *Rm* can only be added to the value in *Rn*. The result used as the memory address for the preload.

The range of shifts allowed is:

- LSL #0 to #3 for Thumb-2 instructions
- Any one of the following for ARM instructions:
  - LSL #0 to #31
  - LSR #1 to #32
  - ASR #1 to #32
  - ROR #1 to #31
  - RRX

### Address alignment for preloads

No alignment checking is performed for preload instructions.

### Architectures

ARM PLD is available in ARMv5TE and above.

32-bit Thumb PLD is available in ARMv6T2 and above.

PLDW is available only in ARMv7 and above that implement the Multiprocessing Extensions.

PLI is available only in ARMv7 and above.

There are no 16-bit Thumb PLD, PLDW, or PLI instructions.

These are hint instructions, and their implementation is optional. If they are not implemented, they execute as NOPs.

**See also****Concepts**

*Using the Assembler:*

- *Register-relative and PC-relative expressions* on page 8-9.

**Reference:**

- *Condition codes* on page 3-186.

### 3.3.9 LDM and STM

Load and Store Multiple registers. Any combination of registers R0 to R15 (PC) can be transferred in ARM state, but there are some restrictions in Thumb state.

#### Syntax

*op*{*addr\_mode*}{*cond*} *Rn*{!}, *reglist*{*^*}

where:

*op* can be either:

LDM	Load Multiple registers
STM	Store Multiple registers.

*addr\_mode* is any one of the following:

IA	Increment address After each transfer. This is the default, and can be omitted.
IB	Increment address Before each transfer (ARM only).
DA	Decrement address After each transfer (ARM only).
DB	Decrement address Before each transfer.

You can also use the stack oriented addressing mode suffixes, for example, when implementing stacks.

*cond* is an optional condition code.

*Rn* is the *base register*, the ARM register holding the initial address for the transfer. *Rn* must not be PC.

! is an optional suffix. If ! is present, the final address 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.

*^* is an optional suffix, available in ARM state only. You must not use it in User mode or System mode. It has the following purposes:

- If the instruction is LDM (with any addressing mode) and *reglist* contains the PC (R15), in addition to the normal multiple register transfer, the SPSR is copied into the CPSR. This is for returning from exception handlers. Use this only from exception modes.
- Otherwise, data is transferred into or out of the User mode registers instead of the current mode registers.



## Restrictions on reglist in 32-bit Thumb instructions

In 32-bit Thumb instructions:

- the SP cannot be in the list
- the PC cannot be in the list in an STM instruction
- the PC and LR cannot both be in the list in an LDM instruction
- there must be two or more registers in the list.

If you write an STM or LDM instruction with only one register in *reglist*, the assembler automatically substitutes the equivalent STR or LDR instruction. Be aware of this when comparing disassembly listings with source code.

You can use the `--diag_warning 1645` assembler command-line option to check when an instruction substitution occurs.

## 16-bit instructions

16-bit versions of a subset of these instructions are available in Thumb code.

The following restrictions apply to the 16-bit instructions:

- all registers in *reglist* must be Lo registers
- *Rn* must be a Lo register
- *addr\_mode* must be omitted (or IA), meaning increment address after each transfer
- writeback must be specified for STM instructions
- writeback must be specified for LDM instructions where *Rn* is not in the *reglist*.

### ———— Note ————

16-bit Thumb STM instructions with writeback that specify *Rn* as the lowest register in the *reglist* are deprecated.

In addition, the PUSH and POP instructions are subsets of the STM and LDM instructions and can therefore be expressed using the STM and LDM instructions. Some forms of PUSH and POP are also 16-bit instructions.

### ———— Note ————

These 16-bit instructions are not available in Thumb-2EE.

## Loading to the PC

A load to the PC causes a branch to the instruction at the address loaded.

In ARMv4, bits[1:0] of the address loaded must be 0b00.

In ARMv5T and above:

- bits[1:0] must not be 0b10
- if bit[0] is 1, execution continues in Thumb state
- if bit[0] is 0, execution continues in ARM state.

### Loading or storing the base register, with writeback

In ARM or 16-bit Thumb instructions, if *Rn* is in *reglist*, and writeback is specified with the ! suffix:

- if the instruction is STM or STMIA and *Rn* is the lowest-numbered register in *reglist*, the initial value of *Rn* is stored
- otherwise, the loaded or stored value of *Rn* cannot be relied upon.

32-bit Thumb instructions are unpredictable if *Rn* is in *reglist*, and writeback is specified with the ! suffix.

### Examples

```
LDM    r8,{r0,r2,r9}      ; LDMIA is a synonym for LDM
STMDB  r1!,{r3-r6,r11,r12}
```

### Incorrect examples

```
STM    r5!,{r5,r4,r9} ; value stored for R5 unpredictable
LDMDA  r2, {}          ; must be at least one register in list
```

### See also

#### Concepts

*Using the Assembler:*

- *Stack implementation using LDM and STM* on page 5-28.

#### Reference:

- *PUSH and POP* on page 3-37
- *Condition codes* on page 3-186.

### 3.3.10 PUSH and POP

Push registers onto, and pop registers off a full descending stack.

#### Syntax

`PUSH{cond} reglist`

`POP{cond} reglist`

where:

*cond* is an optional condition code.

*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.

#### Usage

PUSH is a synonym for `STMDB sp!, reglist` and POP is a synonym for `LDMIA sp! reglist`. PUSH and POP are the preferred mnemonics in these cases.

#### Note

LDM and LDMFD are synonyms of LDMIA. STMFD is a synonym of STMDB.

Registers are stored on the stack in numerical order, with the lowest numbered register at the lowest address.

#### POP, with *reglist* including the PC

This instruction causes a branch to the address popped off the stack into the PC. This is usually a return from a subroutine, where the LR was pushed onto the stack at the start of the subroutine.

In ARMv5T and above:

- bits[1:0] must not be 0b10
- if bit[0] is 1, execution continues in Thumb state
- if bit[0] is 0, execution continues in ARM state.

In ARMv4, bits[1:0] of the address loaded must be 0b00.

## Thumb instructions

A subset of these instructions are available in the Thumb instruction set.

The following restrictions apply to the 16-bit instructions:

- For PUSH, *reglist* can only include the Lo registers and the LR
- For POP, *reglist* can only include the Lo registers and the PC.

The following restrictions apply to the 32-bit instructions:

- *reglist* must not include the SP
- For PUSH, *reglist* must not include the PC
- For POP, *reglist* can include either the LR or the PC, but not both.

## Examples

```
PUSH    {r0,r4-r7}
PUSH    {r2,lr}
POP     {r0,r10,pc} ; no 16-bit version available
```

## See also

### Reference:

- *LDM and STM* on page 3-34
- *Condition codes* on page 3-186.

### 3.3.11 RFE

Return From Exception.

#### Syntax

`RFE{addr_mode}{cond} Rn{!}`

where:

*addr\_mode* is any one of the following:

- IA Increment address After each transfer (Full Descending stack)
- IB Increment address Before each transfer (ARM only)
- DA Decrement address After each transfer (ARM only)
- DB Decrement address Before each transfer.

If *addr\_mode* is omitted, it defaults to Increment After.

*cond* is an optional condition code.

#### ———— Note ————

*cond* is allowed only in Thumb code, using a preceding IT instruction.  
This is an unconditional instruction in ARM.

*Rn* specifies the base register. Do not use PC for *Rn*.

! is an optional suffix. If ! is present, the final address is written back into *Rn*.

#### Usage

You can use RFE to return from an exception if you previously saved the return state using the SRS instruction. *Rn* is usually the SP where the return state information was saved.

#### Operation

Loads the PC and the CPSR from the address contained in *Rn*, and the following address. Optionally updates *Rn*.

## Notes

RFE writes an address to the PC. The alignment of this address must be correct for the instruction set in use after the exception return:

- For a return to ARM, the address written to the PC must be word-aligned.
- For a return to Thumb, the address written to the PC must be halfword-aligned.
- For a return to Jazelle®, there are no alignment restrictions on the address written to the PC.

The results of breaking these rules are unpredictable. However, no special precautions are required in software, if the instructions are used to return after a valid exception entry mechanism.

Where addresses are not word-aligned, RFE ignores the least significant two bits of *Rn*.

The time order of the accesses to individual words of memory generated by RFE is not architecturally defined. Do not use this instruction on memory-mapped I/O locations where access order matters.

Do not use RFE in unprivileged software execution.

Do not use RFE in Thumb2-EE.

## Architectures

This ARM instruction is available in ARMv6 and above.

This 32-bit Thumb instruction is available in ARMv6T2 and above, except the ARMv7-M profile.

There is no 16-bit version of this instruction.

## Example

```
RFE sp!
```

## See also

### Concepts

*Using the Assembler:*

- *Processor modes, and privileged and unprivileged software execution on page 3-6.*

**Reference:**

- *SRS* on page 3-42
- *Condition codes* on page 3-186.

### 3.3.12 SRS

Store Return State onto a stack.

#### Syntax

`SRS{addr_mode}{cond} sp{!}, #modenum`

`SRS{addr_mode}{cond} #modenum{!}` ; This is a pre-UAL syntax

where:

*addr\_mode* is any one of the following:

- IA Increment address After each transfer
- IB Increment address Before each transfer (ARM only)
- DA Decrement address After each transfer (ARM only)
- DB Decrement address Before each transfer (Full Descending stack).

If *addr\_mode* is omitted, it defaults to Increment After. You can also use stack oriented addressing mode suffixes, for example, when implementing stacks.

*cond* is an optional condition code.

#### ———— Note ————

*cond* is allowed only in Thumb code, using a preceding IT instruction. This is an unconditional instruction in ARM.

! is an optional suffix. If ! is present, the final address is written back into the SP of the mode specified by *modenum*.

*modenum* specifies the number of the mode whose banked SP is used as the base register.

#### Operation

SRS stores the LR and the SPSR of the current mode, at the address contained in SP of the mode specified by *modenum*, and the following word respectively. Optionally updates SP of the mode specified by *modenum*. This is compatible with the normal use of the STM instruction for stack accesses.

#### ———— Note ————

For full descending stack, you must use SRSFD or SRSDB.



## Usage

You can use SRS to store return state for an exception handler on a different stack from the one automatically selected.

## Notes

Where addresses are not word-aligned, SRS ignores the least significant two bits of the specified address.

The time order of the accesses to individual words of memory generated by SRS is not architecturally defined. Do not use this instruction on memory-mapped I/O locations where access order matters.

Do not use SRS in User and System modes because these modes do not have a SPSR.

Do not use SRS in Thumb-2EE.

SRS is unpredictable in a non-secure state if *modenum* specifies monitor mode.

## Architectures

This ARM instruction is available in ARMv6 and above.

This 32-bit Thumb instruction is available in ARMv6T2 and above, except the ARMv7-M profile.

There is no 16-bit version of this instruction.

## Example

```
R13_usr EQU 16
        SRSFD sp, #R13_usr
```

## See also

### Concepts

*Using the Assembler:*

- *Stack implementation using LDM and STM* on page 5-28
- *Processor modes, and privileged and unprivileged software execution* on page 3-6.

### Reference:

- *LDM and STM* on page 3-34
- *Condition codes* on page 3-186.

### 3.3.13 LDREX and STREX

Load and Store Register Exclusive.

#### Syntax

LDREX{*cond*} *Rt*, [*Rn* {, #*offset*}]

STREX{*cond*} *Rd*, *Rt*, [*Rn* {, #*offset*}]

LDREXB{*cond*} *Rt*, [*Rn*]

STREXB{*cond*} *Rd*, *Rt*, [*Rn*]

LDREXH{*cond*} *Rt*, [*Rn*]

STREXH{*cond*} *Rd*, *Rt*, [*Rn*]

LDREXD{*cond*} *Rt*, *Rt2*, [*Rn*]

STREXD{*cond*} *Rd*, *Rt*, *Rt2*, [*Rn*]

where:

*cond* is an optional condition code.

*Rd* is the destination register for the returned status.

*Rt* is the register to load or store.

*Rt2* is the second register for doubleword loads or stores.

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

*offset* is an optional offset applied to the value in *Rn*. *offset* is allowed only in Thumb-2 instructions. If *offset* is omitted, an offset of 0 is assumed.

#### LDREX

LDREX loads data from memory.

- If the physical address has the Shared TLB attribute, LDREX tags the physical address as exclusive access for the current processor, and clears any exclusive access tag for this processor for any other physical address.
- Otherwise, it tags the fact that the executing processor has an outstanding tagged physical address.

## STREX

STREX performs a conditional store to memory. The conditions are as follows:

- If the physical address does not have the Shared TLB attribute, and the executing processor has an outstanding tagged physical address, the store takes place, the tag is cleared, and the value 0 is returned in *Rd*.
- If the physical address does not have the Shared TLB attribute, and the executing processor does not have an outstanding tagged physical address, the store does not take place, and the value 1 is returned in *Rd*.
- If the physical address has the Shared TLB attribute, and the physical address is tagged as exclusive access for the executing processor, the store takes place, the tag is cleared, and the value 0 is returned in *Rd*.
- If the physical address has the Shared TLB attribute, and the physical address is not tagged as exclusive access for the executing processor, the store does not take place, and the value 1 is returned in *Rd*.

## Restrictions

PC must not be used for any of *Rd*, *Rt*, *Rt2*, or *Rn*.

For STREX, *Rd* must not be the same register as *Rt*, *Rt2*, or *Rn*.

For ARM instructions:

- *Rt* must be an even numbered register, and not LR
- *Rt2* must be  $R(t+1)$
- *offset* is not allowed.

For Thumb instructions:

- SP must not be used for any of *Rd*, *Rt*, or *Rt2*
- for LDREXD, *Rt* and *Rt2* must not be the same register
- the value of *offset* can be any multiple of four in the range 0-1020.

## Usage

Use LDREX and STREX to implement interprocess communication in multiple-processor and shared-memory systems.

For reasons of performance, keep the number of instructions between corresponding LDREX and STREX instruction to a minimum.

---

### Note

---

The address used in a STREX instruction must be the same as the address in the most recently executed LDREX instruction. The result of executing a STREX instruction to a different address is unpredictable.

---

## Architectures

ARM LDREX and STREX are available in ARMv6 and above.

ARM LDREXB, LDREXH, LDREXD, STREXB, STREXD, and STREXH are available in ARMv6K and above.

All these 32-bit Thumb instructions are available in ARMv6T2 and above, except that LDREXD and STREXD are not available in the ARMv7-M profile.

There are no 16-bit versions of these instructions.

## Examples

```

        MOV r1, #0x1           ; load the 'lock taken' value
try
    LDREX r0, [LockAddr]       ; load the lock value
    CMP r0, #0                 ; is the lock free?
    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

```

## See also

### Reference:

- *Condition codes* on page 3-186.

### 3.3.14 CLREX

Clear Exclusive. Clears the local record of the executing processor that an address has had a request for an exclusive access.

#### Syntax

CLREX{*cond*}

where:

*cond* is an optional condition code.

#### ———— Note ————

*cond* is allowed only in Thumb code, using a preceding IT instruction. This is an unconditional instruction in ARM.

#### Usage

Use the CLREX instruction to return a closely-coupled exclusive access monitor to its open-access state. This removes the requirement for a dummy store to memory.

It is implementation defined whether CLREX also clears the global record of the executing processor that an address has had a request for an exclusive access.

#### Architectures

This ARM instruction is available in ARMv6K and above.

This 32-bit Thumb instruction is available in ARMv7 and above.

There is no 16-bit Thumb CLREX instruction.

#### See also

#### Reference:

- *Condition codes* on page 3-186.
- *ARM Architecture Reference Manual*,  
<http://infocenter.arm.com/help/topic/com.arm.doc.subset.arch.reference/index.html>.

### 3.3.15 SWP and SWPB

Swap data between registers and memory.

#### Syntax

`SWP{B}{cond} Rt, Rt2, [Rn]`

where:

<i>cond</i>	is an optional condition code.
B	is an optional suffix. If B is present, a byte is swapped. Otherwise, a 32-bit word is swapped.
<i>Rt</i>	is the destination register.
<i>Rt2</i>	is the source register. <i>Rt2</i> can be the same register as <i>Rt</i> .
<i>Rn</i>	contains the address in memory. <i>Rn</i> must be a different register from both <i>Rt</i> and <i>Rt2</i> .

#### Usage

You can use SWP and SWPB to implement semaphores:

- Data from memory is loaded into *Rt*.
- The contents of *Rt2* is saved to memory.
- If *Rt2* is the same register as *Rt*, the contents of the register is swapped with the contents of the memory location.

#### Note

The use of SWP and SWPB is deprecated in ARMv6 and above. You can use LDREX and STREX instructions to implement more sophisticated semaphores in ARMv6 and above.

#### Architectures

These ARM instructions are available in all versions of the ARM architecture.

There are no Thumb SWP or SWPB instructions.

**See also**

**Reference:**

- *LDREX and STREX* on page 3-44
- *Condition codes* on page 3-186.

### 3.4 General data processing instructions

This section contains the following subsections:

- *Flexible second operand (Operand2)* on page 3-51
- *Operand 2 as a constant* on page 3-51
- *Operand2 as a register with optional shift* on page 3-52
- *Shift Operations* on page 3-53
- *ADD, SUB, RSB, ADC, SBC, and RSC* on page 3-57  
Add, Subtract, and Reverse Subtract, each with or without Carry.
- *SUBS pc, lr* on page 3-62  
Return from exception without popping the stack.
- *AND, ORR, EOR, BIC, and ORN* on page 3-64  
Logical AND, OR, Exclusive OR, OR NOT, and Bit Clear.
- *CLZ* on page 3-67  
Count Leading Zeros.
- *CMP and CMN* on page 3-69  
Compare and Compare Negative.
- *MOV and MVN* on page 3-71  
Move and Move Not.
- *MOVT* on page 3-74  
Move Top, Wide.
- *TST and TEQ* on page 3-75  
Test and Test Equivalence.
- *SEL* on page 3-77  
Select bytes from each operand according to the state of the APSR GE flags.
- *REV, REV16, REVSH, and RBIT* on page 3-79  
Reverse bytes or Bits.
- *ASR, LSL, LSR, ROR, and RRX* on page 3-81  
Arithmetic Shift Right.



- *SDIV and UDIV* on page 3-84  
Signed Divide and Unsigned Divide.

### 3.4.1 Flexible second operand (Operand2)

Many ARM and Thumb 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
- register with optional shift.

### 3.4.2 Operand 2 as a constant

You specify an Operand2 constant in the form:

*#constant*

where *constant* is an expression evaluating to a numeric value.

In ARM instructions, *constant* can have any value that can be produced by rotating an 8-bit value right by any even number of bits within a 32-bit word.

In Thumb instructions, *constant* can be:

- 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 shown 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 detailed 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.

### Instruction substitution

If a value of *constant* is not available, but its logical inverse or negation is available, then the assembler produces an equivalent instruction and inverts or negates *constant*.

For example, an assembler might assemble the instruction `CMP Rd, #0xFFFFFFFF` as the equivalent instruction `CMN Rd, #0x2`.

Be aware of this when comparing disassembly listings with source code.

You can use the `--diag_warning 1645` assembler command-line option to check when an instruction substitution occurs.

### 3.4.3 Operand2 as a 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,  $1 \leq n \leq 32$ .

LSL *#n* logical shift left *n* bits,  $1 \leq n \leq 31$ .

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

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

RRX rotate right one bit, with extend.

*type Rs* available in ARM code only, where:

*type* is one of ASR, LSL, LSR, ROR.

*Rs* is a register supplying the shift amount, and only the least significant byte is used.

- 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* remains unchanged. Specifying a register with shift also updates the carry flag when used with certain instructions.

### 3.4.4 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. 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 the flexible second operand description. 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.

#### ASR

Arithmetic shift right 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 3-1.

You can use the 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 ASRS or when ASR *#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[*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*.

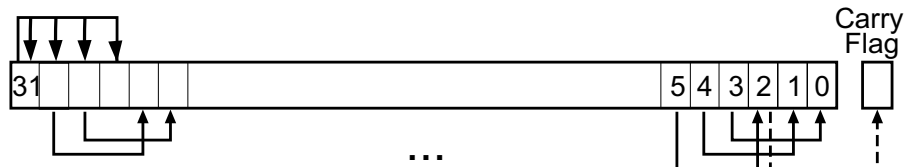


Figure 3-1 ASR #3

## LSR

Logical shift right 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 3-2.

You can use the 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 LSRS or when LSR  $\#n$  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[ $n-1$ ], 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.

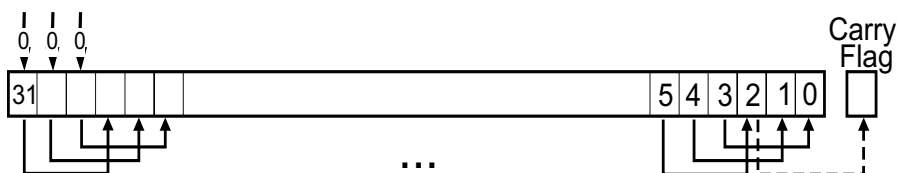


Figure 3-2 LSR #3

## LSL

Logical shift left 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 3-3 on page 3-55.

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.

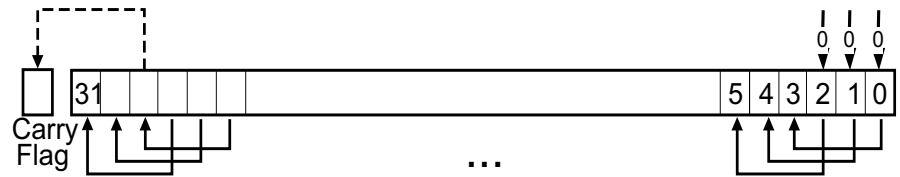


Figure 3-3 LSL #3

## ROR

Rotate right 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 3-4.

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 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  $n-32$ .

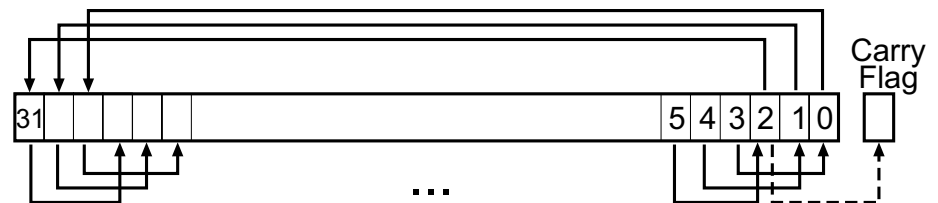
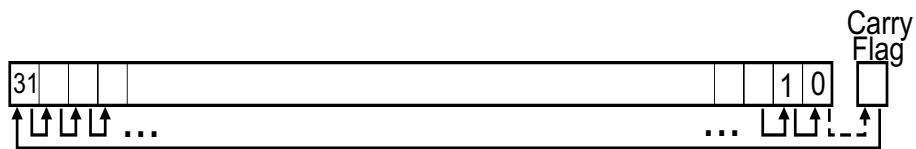


Figure 3-4 ROR #3

## RRX

Rotate right with extend moves the bits of the register  $Rm$  to the right by one bit. And it copies the carry flag into bit[31] of the result. See Figure 3-5 on page 3-56.

When the instruction is RRXS or when RRX is used in *Operand2* with the instructions MOV<sub>S</sub>, MVN<sub>S</sub>, AND<sub>S</sub>, ORR<sub>S</sub>, ORN<sub>S</sub>, EOR<sub>S</sub>, BIC<sub>S</sub>, TEQ or TST, the carry flag is updated to bit[0] of the register *Rm*.



**Figure 3-5 RRX**

## See also

### Concepts

- *Flexible second operand (Operand2)* on page 3-51.

### 3.4.5 ADD, SUB, RSB, ADC, SBC, and RSC

Add, Subtract, and Reverse Subtract, each with or without Carry.

#### Syntax

*op*{*S*}{*cond*} {*Rd*}, *Rn*, *Operand2*

*op*{*cond*} {*Rd*}, *Rn*, #*imm12* ; Thumb-2 ADD and SUB only

where:

*op* is one of:

ADD	Add.
ADC	Add with Carry.
SUB	Subtract.
RSB	Reverse Subtract.
SBC	Subtract with Carry.
RSC	Reverse Subtract with Carry (ARM only).

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

*cond* is an optional condition code.

*Rd* is the destination register.

*Rn* is the register holding the first operand.

*Operand2* is a flexible second operand.

*imm12* is any value in the range 0-4095.

#### Usage

The ADD instruction adds the values in *Rn* and *Operand2* or *imm12*.

The SUB instruction subtracts the value of *Operand2* or *imm12* from the value in *Rn*.

The RSB (Reverse Subtract) instruction subtracts the value in *Rn* from the value of *Operand2*. This is useful because of the wide range of options for *Operand2*.

You can use ADC, SBC, and RSC to synthesize multiword arithmetic.

The ADC (Add with Carry) instruction adds the values in *Rn* and *Operand2*, together with the carry flag.

The SBC (Subtract with Carry) instruction subtracts the value of *Operand2* from the value in *Rn*. If the carry flag is clear, the result is reduced by one.

The RSC (Reverse Subtract with Carry) instruction subtracts the value in *Rn* from the value of *Operand2*. If the carry flag is clear, the result is reduced by one.

In certain circumstances, the assembler can substitute one instruction for another. Be aware of this when reading disassembly listings.

### Use of PC in 32-bit Thumb instructions

In most of these instructions, you cannot use PC (R15) for *Rd*, or any operand.

The exception is that you can use PC for *Rn* in ADD and SUB instructions, with a constant *Operand2* value in the range 0-4095, and no S suffix. These instructions are useful for generating PC-relative addresses. Bit[1] of the PC value reads as 0 in this case, so that the base address for the calculation is always word-aligned.

### Use of PC and SP in 16-bit Thumb

The following 16-bit Thumb instructions are deprecated:

- ADD{*cond*} PC, SP, PC
- ADD{*cond*} SP, SP, PC
- ADD{*cond*} SP, SP, SP.

### Use of PC in ARM instructions

If you use PC (R15) as *Rn*, the value used is the address of the instruction plus 8.

If you use PC as *Rd*:

- Execution branches to the address corresponding to the result.
- If you use the S suffix, the SPSR of the current mode is copied to the CPSR. You can use this to return from exceptions.

#### ———— Caution ————

Do not use the S suffix when using PC as *Rd* in User mode or System mode. The effect of such an instruction is unpredictable, but the assembler cannot warn you at assembly time.

You cannot use PC for *Rd* or any operand in any data processing instruction that has a register-controlled shift.



## Condition flags

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

## 16-bit instructions

The following forms of these instructions are available in Thumb code, and are 16-bit instructions:

ADDS <i>Rd</i> , <i>Rn</i> , # <i>imm</i>	<i>imm</i> range 0-7. <i>Rd</i> and <i>Rn</i> must both be Lo registers.
ADDS <i>Rd</i> , <i>Rn</i> , <i>Rm</i>	<i>Rd</i> , <i>Rn</i> and <i>Rm</i> must all be Lo registers.
ADD <i>Rd</i> , <i>Rd</i> , <i>Rm</i>	ARMv6 and earlier: either <i>Rd</i> or <i>Rm</i> , or both, must be a Hi register. ARMv6T2 and above: this restriction does not apply.
ADDS <i>Rd</i> , <i>Rd</i> , # <i>imm</i>	<i>imm</i> range 0-255. <i>Rd</i> must be a Lo register.
ADCS <i>Rd</i> , <i>Rd</i> , <i>Rm</i>	<i>Rd</i> , <i>Rn</i> and <i>Rm</i> must all be Lo registers.
ADD SP, SP, # <i>imm</i>	<i>imm</i> range 0-508, word aligned.
ADD <i>Rd</i> , SP, # <i>imm</i>	<i>imm</i> range 0-1020, word aligned. <i>Rd</i> must be a Lo register.
ADD <i>Rd</i> , pc, # <i>imm</i>	<i>imm</i> range 0-1020, word aligned. <i>Rd</i> must be a Lo register. Bits[1:0] of the PC are read as 0 in this instruction.
SUBS <i>Rd</i> , <i>Rn</i> , <i>Rm</i>	<i>Rd</i> , <i>Rn</i> and <i>Rm</i> must all be Lo registers.
SUBS <i>Rd</i> , <i>Rn</i> , # <i>imm</i>	<i>imm</i> range 0-7. <i>Rd</i> and <i>Rn</i> both Lo registers.
SUBS <i>Rd</i> , <i>Rd</i> , # <i>imm</i>	<i>imm</i> range 0-255. <i>Rd</i> must be a Lo register.
SBCS <i>Rd</i> , <i>Rd</i> , <i>Rm</i>	<i>Rd</i> , <i>Rn</i> and <i>Rm</i> must all be Lo registers.
SUB SP, SP, # <i>imm</i>	<i>imm</i> range 0-508, word aligned.
RSBS <i>Rd</i> , <i>Rn</i> , #0	<i>Rd</i> and <i>Rn</i> both Lo registers.

**Examples**

```

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
RSCSLE r0, r5, r0, LSL r4 ; conditional, flags set

```

**Incorrect example**

```

RSCSLE r0, pc, r0, LSL r4 ; PC not permitted with register
                        ; controlled shift

```

**Multiword arithmetic examples**

These two instructions add a 64-bit integer contained in R2 and R3 to another 64-bit integer contained in R0 and R1, and place the result in R4 and R5.

```

ADDS   r4, r0, r2      ; adding the least significant words
ADC    r5, r1, r3      ; adding the most significant words

```

These instructions subtract one 96-bit integer from another:

```

SUBS   r3, r6, r9
SBCS   r4, r7, r10
SBC    r5, r8, r11

```

For clarity, the above examples use consecutive registers for multiword values. There is no requirement to do this. The following, for example, is perfectly valid:

```

SUBS   r6, r6, r9
SBCS   r9, r2, r1
SBC    r2, r8, r11

```

**See also****Concepts:**

- *Flexible second operand (Operand2)* on page 3-51
- *Instruction substitution* on page 3-52.

*Developing Software for ARM Processors:*

- Chapter 6 *Handling Processor Exceptions*.

**Reference:**

- *Parallel add and subtract* on page 3-113
- *SUBS pc, lr* on page 3-62

- *ADR (PC-relative)* on page 3-27
- *ADR (register-relative)* on page 3-29
- *ADRL pseudo-instruction* on page 3-178
- *Condition codes* on page 3-186.

### 3.4.6 SUBS pc, lr

Exception return, without stack popping.

#### Syntax

SUBS{*cond*} pc, lr, #*imm*

where:

*imm* is an immediate value. In Thumb code, it is limited to the range 0-255. In ARM code, it is a flexible second operand.

*cond* is an optional condition code.

#### Usage

You can use SUBS pc, lr, #*imm* to return from an exception if there is no return state on the stack. The value of #*imm* depends on the exception to return from.

SUBS pc, lr, #*imm* subtracts a value from the link register and loads the PC with the result, then copies the SPSR to the CPSR.

#### Notes

SUBS pc, lr, #*imm* writes an address to the PC. The alignment of this address must be correct for the instruction set in use after the exception return:

- For a return to ARM, the address written to the PC must be word-aligned.
- For a return to Thumb, the address written to the PC must be halfword-aligned.
- For a return to Jazelle, there are no alignment restrictions on the address written to the PC.

The results of breaking these rules are unpredictable. However, no special precautions are required in software, if the instructions are used to return after a valid exception entry mechanism.

MOVS pc, lr is a synonym of SUBS pc, lr, #0 in Thumb.

#### Architectures

This ARM instruction is available in all versions of the ARM architecture.

This 32-bit Thumb instruction is available in ARMv6T2 and above, except the ARMv7-M profile.

There is no 16-bit Thumb version of this instruction.

**See also****Concepts:**

- *Flexible second operand (Operand2)* on page 3-51.

**Reference:**

- *ADD, SUB, RSB, ADC, SBC, and RSC* on page 3-57
- *Condition codes* on page 3-186.

### 3.4.7 AND, ORR, EOR, BIC, and ORN

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

#### Syntax

*op*{*S*}{*cond*} *Rd*, *Rn*, *Operand2*

where:

*op* is one of:

AND	logical AND.
ORR	logical OR.
EOR	logical Exclusive OR.
BIC	logical AND NOT.
ORN	logical OR NOT (Thumb only).

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

*cond* is an optional condition code.

*Rd* is the destination register.

*Rn* is the register holding the first operand.

*Operand2* is a flexible second operand.

#### Usage

The AND, EOR, and ORR instructions perform bitwise AND, Exclusive OR, and OR operations on the values in *Rn* and *Operand2*.

The BIC (Bit Clear) instruction performs an AND operation on the bits in *Rn* with the complements of the corresponding bits in the value of *Operand2*.

The ORN Thumb instruction performs an OR operation on the bits in *Rn* with the complements of the corresponding bits in the value of *Operand2*.

In certain circumstances, the assembler can substitute BIC for AND, AND for BIC, ORN for ORR, or ORR for ORN. Be aware of this when reading disassembly listings.

#### Use of PC in Thumb-2 instructions

You cannot use PC (R15) for *Rd* or any operand in any of these instructions.

## Use of PC in ARM instructions

---

### Note

---

All these uses of PC in these ARM instructions are deprecated.

---

If you use PC as *Rn*, the value used is the address of the instruction plus 8.

If you use PC as *Rd*:

- Execution branches to the address corresponding to the result.
- If you use the S suffix, the SPSR of the current mode is copied to the CPSR. You can use this to return from exceptions.

---

### Caution

---

Do not use the S suffix when using PC as *Rd* in User mode or System mode. The effect of such an instruction is unpredictable, but the assembler cannot warn you at assembly time.

---

You cannot use PC for any operand in any data processing instruction that has a register-controlled shift.

## 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*
- do not affect the V flag.

## 16-bit instructions

The following forms of these instructions are available in Thumb code, and are 16-bit instructions:

ANDS *Rd, Rd, Rm*     *Rd* and *Rm* must both be Lo registers.

EORS *Rd, Rd, Rm*     *Rd* and *Rm* must both be Lo registers.

ORRS *Rd, Rd, Rm*     *Rd* and *Rm* must both be Lo registers.

BICS *Rd, Rd, Rm*     *Rd* and *Rm* must both be Lo registers.

In the first three cases, it does not matter if you specify *OPS Rd, Rm, Rd*. The instruction is the same.

**Examples**

```

AND    r9,r2,#0xFF00
ORREQ  r2,r0,r5
EORS   r0,r0,r3,ROR r6
ANDS   r9, r8, #0x19
EORS   r7, r11, #0x18181818
BIC    r0, r1, #0xab
ORN    r7, r11, l r, ROR #4
ORNS   r7, r11, l r, ASR #32

```

**Incorrect example**

```

EORS    r0,pc,r3,ROR r6    ; PC not permitted with register
                        ; controlled shift

```

**See also****Concepts:**

- *Flexible second operand (Operand2)* on page 3-51
- *Instruction substitution* on page 3-52.

*Developing Software for ARM Processors:*

- Chapter 6 *Handling Processor Exceptions*.

**Reference:**

- *Condition codes* on page 3-186.



### 3.4.8 CLZ

Count Leading Zeros.

#### Syntax

CLZ{*cond*} *Rd*, *Rm*

where:

*cond* is an optional condition code.  
*Rd* is the destination register. *Rd* must not be PC.  
*Rm* is the operand register. *Rm* must not be PC.

#### Usage

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.

#### Condition flags

This instruction does not change the flags.

#### Architectures

This ARM instruction is available in ARMv5T and above.

This 32-bit Thumb instruction is available in ARMv6T2 and above.

There is no 16-bit Thumb version of this instruction.

#### Examples

```
CLZ    r4, r9
CLZNE  r2, r3
```

Use the CLZ Thumb instruction followed by a left shift of *Rm* by the resulting *Rd* value to normalize the value of register *Rm*. Use MOV<sub>S</sub>, rather than MOV, to flag the case where *Rm* is zero:

```
CLZ    r5, r9
MOVS  r9, r9, LSL r5
```

**See also**

**Reference:**

- *Condition codes* on page 3-186.

### 3.4.9 CMP and CMN

Compare and Compare Negative.

#### Syntax

`CMP{cond} Rn, Operand2`

`CMN{cond} Rn, Operand2`

where:

*cond* is an optional condition code.

*Rn* is the ARM register holding the first operand.

*Operand2* is a flexible second operand.

#### Usage

These instructions compare the value in a register with *Operand2*. They update the condition flags on the result, but do not place the result in any register.

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

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

In certain circumstances, the assembler can substitute CMN for CMP, or CMP for CMN. Be aware of this when reading disassembly listings.

#### Use of PC in ARM instructions

##### ———— Note ————

Use of PC (R15) in these ARM instructions is deprecated.

If you use PC as *Rn*, the value used is the address of the instruction plus 8.

You cannot use PC for any operand in any data processing instruction that has a register-controlled shift.

#### Use of PC in Thumb-2 instructions

You cannot use PC (R15) for any operand in these instructions.

**Use of SP in 16-bit Thumb instructions**

Use of SP as *Rm* in a 16-bit Thumb CMP *Rn*, *Rm* instruction is deprecated.

**Condition flags**

These instructions update the N, Z, C and V flags according to the result.

**16-bit instructions**

The following forms of these instructions are available in Thumb code, and are 16-bit instructions:

CMP <i>Rn</i> , <i>Rm</i>	Lo register restriction does not apply.
CMN <i>Rn</i> , <i>Rm</i>	<i>Rn</i> and <i>Rm</i> must both be Lo registers.
CMP <i>Rn</i> , # <i>imm</i>	<i>Rn</i> must be a Lo register. <i>imm</i> range 0-255.

**Examples**

```

CMP    r2, r9
CMN    r0, #6400
CMPGT  sp, r7, LSL #2

```

**Incorrect example**

```

CMP    r2, pc, ASR r0 ; PC not permitted with register controlled shift

```

**See also****Concepts:**

- *Flexible second operand (Operand2)* on page 3-51
- *Instruction substitution* on page 3-52.

**Reference:**

- *Condition codes* on page 3-186.

### 3.4.10 MOV and MVN

Move and Move Not.

#### Syntax

`MOV{S}{cond} Rd, Operand2`

`MOV{cond} Rd, #imm16`

`MVN{S}{cond} Rd, Operand2`

where:

<i>S</i>	is an optional suffix. If <i>S</i> is specified, the condition code flags are updated on the result of the operation.
<i>cond</i>	is an optional condition code.
<i>Rd</i>	is the destination register.
<i>Operand2</i>	is a flexible second operand.
<i>imm16</i>	is any value in the range 0-65535.

#### Usage

The MOV instruction copies the value of *Operand2* into *Rd*.

The MVN instruction takes the value of *Operand2*, performs a bitwise logical NOT operation on the value, and places the result into *Rd*.

In certain circumstances, the assembler can substitute MVN for MOV, or MOV for MVN. Be aware of this when reading disassembly listings.

#### Use of PC and SP in 32-bit Thumb MOV and MVN

You cannot use PC (R15) for *Rd*, or in *Operand2*, in 32-bit Thumb MOV or MVN instructions. With the following exceptions, you cannot use SP (R13) for *Rd*, or in *Operand2*:

- `MOV{cond}.W Rd, SP`, where *Rd* is not SP
- `MOV{cond}.W SP, Rm`, where *Rm* is not SP.

#### Use of PC and SP in 16-bit Thumb MOV

Use of the 16-bit Thumb MOV (register) instruction in which both *Rd* and *Rm* are both SP or PC is deprecated.

## Use of PC in ARM MOV and MVN

---

### Note

---

MOV *Rd*, *Rm* syntax is allowed with *Rd* or *Rm* set to PC, but not both. All other uses of PC are deprecated.

---

If you use PC as *Rm*, the value used is the address of the instruction plus 8.

If you use PC as *Rd*:

- Execution branches to the address corresponding to the result.
- If you use the S suffix, the SPSR of the current mode is copied to the CPSR. You can use this to return from exceptions.

---

### Caution

---

Do not use the S suffix when using PC as *Rd* in User mode or System mode. The effect of such an instruction is unpredictable, but the assembler cannot warn you at assembly time.

---

You cannot use PC for *Rd* or any operand in any data processing instruction that has a register-controlled shift.

## 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*
- do not affect the V flag.

## 16-bit instructions

The following forms of these instructions are available in Thumb code, and are 16-bit instructions:

MOVS *Rd*, #*imm*      *Rd* must be a Lo register. *imm* range 0-255.

MOVS *Rd*, *Rm*      *Rd* and *Rm* must both be Lo registers.

MOV *Rd*, *Rm*      In architectures before ARMv6, either *Rd* or *Rm*, or both, must be a Hi register. In ARMv6 and above, this restriction does not apply.

## Architectures

The *#imm16* form of the ARM instruction is available in ARMv6T2 and above. The other forms of the ARM instruction are available in all versions of the ARM architecture.

These 32-bit Thumb instructions are available in ARMv6T2 and above.

These 16-bit Thumb instructions are available in all T variants of the ARM architecture.

## Example

```
MVNNE    r11, #0xF000000B ; ARM only. This immediate value is not
                        ; available in T2.
```

## Incorrect example

```
MVN      pc,r3,ASR r0      ; PC not permitted with register controlled shift
```

## See also

### Concepts:

- *Flexible second operand (Operand2)* on page 3-51
- *Instruction substitution* on page 3-52.

*Developing Software for ARM Processors:*

- Chapter 6 *Handling Processor Exceptions*.

### Reference:

- *Condition codes* on page 3-186.

### 3.4.11 MOV<sup>T</sup>

Move Top. Writes a 16-bit immediate value to the top halfword of a register, without affecting the bottom halfword.

#### Syntax

MOV<sup>T</sup>{*cond*} *Rd*, #*imm16*

where:

*cond* is an optional condition code.  
*Rd* is the destination register. *Rd* cannot be the PC.  
*imm16* is a 16-bit immediate value.

#### Usage

MOV<sup>T</sup> writes *imm16* to *Rd*[31:16]. The write does not affect *Rd*[15:0].

You can generate any 32-bit immediate with a MOV, MOV<sup>T</sup> instruction pair. The assembler implements the MOV32 pseudo-instruction for convenient generation of this instruction pair.

#### Condition flags

This instruction does not change the flags.

#### Architectures

This ARM instruction is available in ARMv6T2 and above.

This 32-bit Thumb instruction is available in ARMv6T2 and above.

There is no 16-bit Thumb version of this instruction.

#### See also

##### Reference:

- *MOV32 pseudo-instruction* on page 3-180
- *Condition codes* on page 3-186.



### 3.4.12 TST and TEQ

Test bits and Test Equivalence.

#### Syntax

TST{*cond*} *Rn*, *Operand2*

TEQ{*cond*} *Rn*, *Operand2*

where:

*cond* is an optional condition code.

*Rn* is the ARM register holding the first operand.

*Operand2* is a flexible second operand.

#### Usage

These instructions test the value in a register against *Operand2*. They update the condition flags on the result, but do not place the result in any register.

The TST instruction performs a bitwise AND operation on the value in *Rn* and the value of *Operand2*. This is the same as an ANDS instruction, except that the result is discarded.

The TEQ instruction performs a bitwise Exclusive OR operation on the value in *Rn* and the value of *Operand2*. This is the same as a EORS instruction, except that the result is discarded.

Use the TEQ instruction to test if two values are equal, without affecting the V or C flags (as CMP does).

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.

#### Use of PC

##### ————— Note —————

Use of PC (R15) in these ARM instructions is deprecated.

For ARM instructions:

- if you use PC (R15) as *Rn*, the value used is the address of the instruction plus 8
- you cannot use PC for any operand in any data processing instruction that has a register-controlled shift.

For Thumb instructions, you cannot use PC for *Rn* or in *Operand2*.

### Condition flags

These instructions:

- update the N and Z flags according to the result
- can update the C flag during the calculation of *Operand2*
- do not affect the V flag.

### 16-bit instructions

The following form of the TST instruction is available in Thumb code, and is a 16-bit instruction:

TST *Rn*, *Rm*                      *Rn* and *Rm* must both be Lo registers.

### Architectures

These ARM instructions are available in all architectures with ARM.

The TST Thumb instruction is available in all architectures with Thumb.

The TEQ Thumb instruction is available in ARMv6T2 and above.

### Examples

```
TST    r0, #0x3F8
TEQEQ  r10, r9
TSTNE  r1, r5, ASR r1
```

### Incorrect example

```
TEQ    pc, r1, ROR r0      ; PC not permitted with register
                        ; controlled shift
```

### See also

#### Concepts:

- *Flexible second operand (Operand2)* on page 3-51.

#### Reference:

- *Condition codes* on page 3-186.

### 3.4.13 SEL

Select bytes from each operand according to the state of the APSR GE flags.

#### Syntax

`SEL{cond} {Rd}, Rn, Rm`

where:

<i>cond</i>	is an optional condition code.
<i>Rd</i>	is the destination register.
<i>Rn</i>	is the register holding the first operand.
<i>Rm</i>	is the register holding the second operand.

#### Operation

The SEL instruction selects bytes from *Rn* or *Rm* according to the APSR GE flags:

- if GE[0] is set, Rd[7:0] come from Rn[7:0], otherwise from Rm[7:0]
- if GE[1] is set, Rd[15:8] come from Rn[15:8], otherwise from Rm[15:8]
- if GE[2] is set, Rd[23:16] come from Rn[23:16], otherwise from Rm[23:16]
- if GE[3] is set, Rd[31:24] come from Rn[31:24], otherwise from Rm[31:24].

#### Usage

Do not use PC for *Rd*, *Rn*, or *Rm*.

Use the SEL instruction after one of the signed parallel instructions. You can use this to select maximum or minimum values in multiple byte or halfword data.

#### Condition flags

This instruction does not change the flags.

#### Architectures

This ARM instruction is available in ARMv6 and above.

These 32-bit Thumb instructions are available in ARMv6T2 and above, except the ARMv7-M profile.

There is no 16-bit Thumb version of this instruction.

## Examples

```
SEL    r0, r4, r5
SELLT  r4, r0, r4
```

The following instruction sequence sets each byte in R4 equal to the unsigned minimum of the corresponding bytes of R1 and R2:

```
USUB8  r4, r1, r2
SEL     r4, r2, r1
```

## See also

### Reference:

- *Parallel add and subtract* on page 3-113
- *Condition codes* on page 3-186.

### 3.4.14 REV, REV16, REVSH, and RBIT

Reverse bytes or bits within words or halfwords.

#### Syntax

*op{cond} Rd, Rn*

where:

<i>op</i>	is any one of the following:
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.
<i>cond</i>	is an optional condition code.
<i>Rd</i>	is the destination register. <i>Rd</i> must not be PC.
<i>Rn</i>	is the register holding the operand. <i>Rn</i> must not be PC.

#### Usage

You can use these instructions to change endianness:

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: <ul style="list-style-type: none"> <li>16-bit signed big-endian data into 32-bit signed little-endian data</li> <li>16-bit signed little-endian data into 32-bit signed big-endian data.</li> </ul>

#### Condition flags

These instructions do not change the flags.

## 16-bit instructions

The following forms of these instructions are available in Thumb code, and are 16-bit instructions:

REV *Rd*, *Rm*                      *Rd* and *Rm* must both be Lo registers.

REV16 *Rd*, *Rm*                      *Rd* and *Rm* must both be Lo registers.

REVSH *Rd*, *Rm*                      *Rd* and *Rm* must both be Lo registers.

## Architectures

Other than RBIT, these ARM instructions are available in ARMv6 and above.

The RBIT ARM instruction is available in ARMv6T2 and above.

These 32-bit Thumb instructions are available in ARMv6T2 and above.

These 16-bit Thumb instructions are available in ARMv6 and above.

## Examples

REV	r3, r7	
REV16	r0, r0	
REVSH	r0, r5	; Reverse Signed Halfword
REVHS	r3, r7	; Reverse with Higher or Same condition
RBIT	r7, r8	

## See also

### Reference:

- *Condition codes* on page 3-186.

### 3.4.15 ASR, LSL, LSR, ROR, and RRX

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

These instructions are the preferred synonyms for MOV instructions with shifted register operands.

#### Syntax

*op*{*S*}{*cond*} *Rd*, *Rm*, *Rs*

*op*{*S*}{*cond*} *Rd*, *Rm*, #*sh*

RRX{*S*}{*cond*} *Rd*, *Rm*

where:

*op* is one of ASR, LSL, LSR, or ROR.

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

*Rd* is the destination register.

*Rm* is the register holding the first operand. This operand is shifted right.

*Rs* is a register holding a shift value to apply to the value in *Rm*. Only the least significant byte is used.

*sh* is a constant shift. The range of values permitted depends on the instruction:

ASR	allowed shifts 1-32
LSL	allowed shifts 0-31
LSR	allowed shifts 1-32
ROR	allowed shifts 1-31.

#### Usage

ASR provides the signed value of the contents of a register divided by a power of two. It copies the sign bit into vacated bit positions on the left.

LSL provides the value of a register multiplied by a power of two. LSR provides the unsigned value of a register divided by a variable power of two. Both instructions insert zeros into the vacated bit positions.

ROR provides the value of the contents of a register rotated by a value. The bits that are rotated off the right end are inserted into the vacated bit positions on the left.

RRX provides the value of the contents of a register shifted right one bit. The old carry flag is shifted into bit[31]. If the S suffix is present, the old bit[0] is placed in the carry flag.

### Restrictions in Thumb code

Thumb instructions must not use PC or SP.

### Use of PC in ARM ASR, LSL, LSR, ROR, and RRX instructions

op Rd,Rm,#sh and RRX Rd,Rm syntaxes are allowed with Rd or Rm set to PC, but not both. All other cases are deprecated.

If you use PC as *Rm*, the value used is the address of the instruction plus 8.

If you use PC as *Rd*:

- Execution branches to the address corresponding to the result.
- If you use the S suffix, the SPSR of the current mode is copied to the CPSR. You can use this to return from exceptions.

#### ———— Note ————

The ARM instructions *opS{cond} pc,Rm,#sh* and *RRXS{cond} pc,Rm* always disassemble to the preferred form *MOVS{cond} pc,Rm{,shift}*.

#### ———— Caution ————

Do not use the S suffix when using PC as *Rd* in User mode or System mode. The effect of such an instruction is unpredictable, but the assembler cannot warn you at assembly time.

You cannot use PC for *Rd* or any operand in any of these instructions if they have a register-controlled shift.

### Condition flags

If S is specified, these instructions update the N and Z flags according to the result.

The C flag is unaffected if the shift value is 0. Otherwise, the C flag is updated to the last bit shifted out.



## 16-bit instructions

The following forms of these instructions are available in Thumb code, and are 16-bit instructions:

ASRS <i>Rd</i> , <i>Rm</i> , # <i>sh</i>	<i>Rd</i> and <i>Rm</i> must both be Lo registers.
ASRS <i>Rd</i> , <i>Rd</i> , <i>Rs</i>	<i>Rd</i> and <i>Rs</i> must both be Lo registers.
LSLS <i>Rd</i> , <i>Rm</i> , # <i>sh</i>	<i>Rd</i> and <i>Rm</i> must both be Lo registers.
LSLS <i>Rd</i> , <i>Rd</i> , <i>Rs</i>	<i>Rd</i> and <i>Rs</i> must both be Lo registers.
LSRS <i>Rd</i> , <i>Rm</i> , # <i>sh</i>	<i>Rd</i> and <i>Rm</i> must both be Lo registers.
LSRS <i>Rd</i> , <i>Rd</i> , <i>Rs</i>	<i>Rd</i> and <i>Rs</i> must both be Lo registers.
RORS <i>Rd</i> , <i>Rd</i> , <i>Rs</i>	<i>Rd</i> and <i>Rs</i> must both be Lo registers.

## Architectures

These ARM instructions are available in all architectures.

These 32-bit Thumb instructions are available in ARMv6T2 and above.

These 16-bit Thumb instructions are available in ARMv4T and above.

There is no 16-bit Thumb RRX instruction.

## Examples

```

ASR    r7, r8, r9
LSLS   r1, r2, r3
LSR    r4, r5, r6
ROR    r4, r5, r6

```

## See also

### Reference:

- *MOV and MVN* on page 3-71
- *Condition codes* on page 3-186.

### 3.4.16 SDIV and UDIV

Signed and Unsigned Divide.

#### Syntax

$\text{SDIV}\{\text{cond}\} \{Rd\}, Rn, Rm$

$\text{UDIV}\{\text{cond}\} \{Rd\}, Rn, Rm$

where:

*cond* is an optional condition code.

*Rd* is the destination register.

*Rn* is the register holding the value to be divided.

*Rm* is a register holding the divisor.

#### Register restrictions

PC or SP cannot be used for *Rd*, *Rn* or *Rm*.

#### Architectures

These 32-bit Thumb instructions are available in ARMv7-R and ARMv7-M only.

There are no ARM or 16-bit Thumb SDIV and UDIV instructions.

#### See also

#### Reference:

- *Condition codes* on page 3-186.

## 3.5 Multiply instructions

This section contains the following subsections:

- *MUL, MLA, and MLS* on page 3-86  
Multiply, Multiply Accumulate, and Multiply Subtract (32-bit by 32-bit, bottom 32-bit result).
- *UMULL, UMLAL, SMULL, and SMLAL* on page 3-88  
Unsigned and signed Long Multiply and Multiply Accumulate (32-bit by 32-bit, 64-bit result or 64-bit accumulator).
- *SMULxy and SMLAxy* on page 3-90  
Signed Multiply and Signed Multiply Accumulate (16-bit by 16-bit, 32-bit result).
- *SMULWy and SMLAWy* on page 3-92  
Signed Multiply and Signed Multiply Accumulate (32-bit by 16-bit, top 32-bit result).
- *SMLALxy* on page 3-94  
Signed Multiply Accumulate (16-bit by 16-bit, 64-bit accumulate).
- *SMUAD{X} and SMUSD{X}* on page 3-96  
Dual 16-bit Signed Multiply with Addition or Subtraction of products.
- *SMMUL, SMMLA, and SMMLS* on page 3-98  
Multiply, Multiply Accumulate, and Multiply Subtract (32-bit by 32-bit, top 32-bit result).
- *SMLAD and SMLSD* on page 3-100  
Dual 16-bit Signed Multiply, 32-bit Accumulation of Sum or Difference of 32-bit products.
- *SMLALD and SMLSLD* on page 3-102  
Dual 16-bit Signed Multiply, 64-bit Accumulation of Sum or Difference of 32-bit products.
- *UMAAL* on page 3-104  
Unsigned Multiply Accumulate Accumulate Long.
- *MIA, MIAPH, and MIAxy* on page 3-105  
Multiplies with Internal Accumulate (XScale coprocessor 0 instructions).

### 3.5.1 MUL, MLA, and MLS

Multiply, Multiply-Accumulate, and Multiply-Subtract, with signed or unsigned 32-bit operands, giving the least significant 32 bits of the result.

#### Syntax

$MUL\{S\}\{cond\} \{Rd\}, Rn, Rm$

$MLA\{S\}\{cond\} Rd, Rn, Rm, Ra$

$MLS\{cond\} Rd, Rn, Rm, Ra$

where:

*cond* is an optional condition code.

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

*Rd* is the destination register.

*Rn, Rm* are registers holding the values to be multiplied.

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

#### Usage

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 result from the value from *Ra*, and places the least significant 32 bits of the final result in *Rd*.

Do not use PC for *Rd*, *Rn*, *Rm*, or *Ra*.

## Condition flags

If S is specified, the MUL and MLA instructions:

- update the N and Z flags according to the result
- corrupt the C and V flag in ARMv4
- do not affect the C or V flag in ARMv5T and above.

## Thumb instructions

The following form of the MUL instruction is available in Thumb code, and is a 16-bit instruction:

`MULS Rd, Rn, Rd`     *Rd* and *Rn* must both be Lo registers.

There are no other Thumb multiply instructions that can update the condition code flags.

## Architectures

The MUL and MLA ARM instructions are available in all versions of the ARM architecture.

The MLS ARM instruction is available in ARMv6T2 and above.

These 32-bit Thumb instructions are available in ARMv6T2 and above.

The MULS 16-bit Thumb instruction is available in all T variants of the ARM architecture.

## Examples

```
MUL    r10, r2, r5
MLA    r10, r2, r1, r5
MULS   r0, r2, r2
MULLT  r2, r3, r2
MLS    r4, r5, r6, r7
```

## See also

### Reference:

- *Condition codes* on page 3-186.

### 3.5.2 UMULL, UMLAL, SMULL, and SMLAL

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

#### Syntax

*Op*{S}{*cond*} *RdLo*, *RdHi*, *Rn*, *Rm*

where:

*Op* is one of UMULL, UMLAL, SMULL, or SMLAL.

S is an optional suffix available in ARM state only. If S is specified, the condition code flags are updated on the result of the operation.

*cond* is an optional condition code.

*RdLo*, *RdHi* are the destination registers. For UMLAL and SMLAL they also hold the accumulating value. *RdLo* and *RdHi* must be different registers

*Rn*, *Rm* are ARM registers holding the operands.

Do not use PC for *RdLo*, *RdHi*, *Rn*, or *Rm*.

#### Usage

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 UMLAL instruction interprets the values from *Rn* and *Rm* as unsigned integers. It multiplies these integers, and adds the 64-bit result to the 64-bit unsigned integer contained in *RdHi* and *RdLo*.

The SMULL instruction interprets the values from *Rn* and *Rm* as two's complement signed 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 SMLAL instruction interprets the values from *Rn* and *Rm* as two's complement signed integers. It multiplies these integers, and adds the 64-bit result to the 64-bit signed integer contained in *RdHi* and *RdLo*.

#### Condition flags

If S is specified, these instructions:

- update the N and Z flags according to the result

- do not affect the C or V flags.

### Architectures

These ARM instructions are available in all versions of the ARM architecture.

These 32-bit Thumb instructions are available in ARMv6T2 and above.

There are no 16-bit Thumb versions of these instructions.

### Examples

UMULL	r0, r4, r5, r6
UMLALS	r4, r5, r3, r8

### See also

#### Reference:

- *Condition codes* on page 3-186.

### 3.5.3 SMULxy and SMLAxy

Signed Multiply and Multiply Accumulate, with 16-bit operands and a 32-bit result and accumulator.

#### Syntax

SMUL<x><y>{cond} {Rd}, Rn, Rm

SMLA<x><y>{cond} Rd, Rn, Rm, Ra

where:

<x> is either B or T. B means use the bottom half (bits [15:0]) of *Rn*, T means use the top half (bits [31:16]) of *Rn*.

<y> is either B or T. B means use the bottom half (bits [15:0]) of *Rm*, T means use the top half (bits [31:16]) of *Rm*.

cond is an optional condition code.

Rd is the destination register.

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

Ra is the register holding the value to be added.

#### Usage

Do not use PC for *Rd*, *Rn*, *Rm*, or *Ra*.

SMULxy multiplies the 16-bit signed integers from the selected halves of *Rn* and *Rm*, and places the 32-bit result in *Rd*.

SMLAxy multiplies the 16-bit signed integers from the selected halves of *Rn* and *Rm*, adds the 32-bit result to the 32-bit value in *Ra*, and places the result in *Rd*.

#### Condition flags

These instructions do not affect the N, Z, C, or V flags.

If overflow occurs in the accumulation, SMLAxy sets the Q flag. To read the state of the Q flag, use an MRS instruction.

#### ———— Note ————

SMLAxy never clears the Q flag. To clear the Q flag, use an MSR instruction.



## Architectures

These ARM instructions are available in ARMv6 and above, and E variants of ARMv5T.

These 32-bit Thumb instructions are available in ARMv6T2 and above, except the ARMv7-M profile.

There are no 16-bit Thumb versions of these instructions.

## Examples

SMULTBEQ	r8, r7, r9
SMLABBNE	r0, r2, r1, r10
SMLABT	r0, r0, r3, r5

## See also

### Reference:

- *MRS* on page 3-155
- *MSR* on page 3-157
- *Condition codes* on page 3-186.

### 3.5.4 SMULWy and SMLAWy

Signed Multiply Wide and Signed Multiply-Accumulate Wide, with one 32-bit and one 16-bit operand, providing the top 32-bits of the result.

#### Syntax

SMULW<y>{cond} {Rd}, Rn, Rm

SMLAW<y>{cond} Rd, Rn, Rm, Ra

where:

<y> is either B or T. B means use the bottom half (bits [15:0]) of *Rm*, T means use the top half (bits [31:16]) of *Rm*.

cond is an optional condition code.

Rd is the destination register.

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

Ra is the register holding the value to be added.

#### Usage

Do not use PC for *Rd*, *Rn*, *Rm*, or *Ra*.

SMULWy multiplies the signed integer from the selected half of *Rm* by the signed integer from *Rn*, and places the upper 32-bits of the 48-bit result in *Rd*.

SMLAWy multiplies the signed integer from the selected half of *Rm* by the signed integer from *Rn*, adds the 32-bit result to the 32-bit value in *Ra*, and places the result in *Rd*.

#### Condition flags

These instructions do not affect the N, Z, C, or V flags.

If overflow occurs in the accumulation, SMLAWy sets the Q flag.

#### Architectures

These ARM instructions are available in ARMv6 and above, and E variants of ARMv5T.

These 32-bit Thumb instructions are available in ARMv6T2 and above, except the ARMv7-M profile.

There are no 16-bit Thumb versions of these instructions.

**See also****Reference:**

- *MRS* on page 3-155
- *Condition codes* on page 3-186.

### 3.5.5 SMLALxy

Signed Multiply-Accumulate with 16-bit operands and a 64-bit accumulator.

#### Syntax

`SMLAL<x><y>{cond} RdLo, RdHi, Rn, Rm`

where:

`<x>` is either B or T. B means use the bottom half (bits [15:0]) of *Rn*, T means use the top half (bits [31:16]) of *Rn*.

`<y>` is either B or T. B means use the bottom half (bits [15:0]) of *Rm*, T means use the top half (bits [31:16]) of *Rm*.

`cond` is an optional condition code.

*RdLo*, *RdHi* are the destination registers. They also hold the accumulate value. *RdHi* and *RdLo* must be different registers.

*Rn*, *Rm* are the registers holding the values to be multiplied.

Do not use PC for *RdLo*, *RdHi*, *Rn*, or *Rm*.

#### Usage

SMLALxy multiplies the signed integer from the selected half of *Rm* by the signed integer from the selected half of *Rn*, and adds the 32-bit result to the 64-bit value in *RdHi* and *RdLo*.

#### Condition flags

This instruction does not change the flags.

#### ———— Note —————

SMLALxy cannot raise an exception. If overflow occurs on this instruction, the result wraps round without any warning.

## Architectures

This ARM instruction is available in ARMv6 and above, and E variants of ARMv5T.

These 32-bit Thumb instructions are available in ARMv6T2 and above, except the ARMv7-M profile.

There is no 16-bit Thumb version of this instruction.

## Examples

```
SMLALTB    r2, r3, r7, r1
SMLALBTVS  r0, r1, r9, r2
```

## See also

### Reference:

- *Condition codes* on page 3-186.

### 3.5.6 SMUAD{X} and SMUSD{X}

Dual 16-bit Signed Multiply with Addition or Subtraction of products, and optional exchange of operand halves.

#### Syntax

*op*{*X*}{*cond*} {*Rd*}, *Rn*, *Rm*

where:

*op* is one of:

SMUAD Dual multiply, add products.

SMUSD Dual multiply, subtract products.

*X* is an optional parameter. If *X* is present, the most and least significant halfwords of the second operand are exchanged before the multiplications occur.

*cond* is an optional condition code.

*Rd* is the destination register.

*Rn*, *Rm* are the registers holding the operands.

Do not use PC for any of *Rd*, *Rn*, or *Rm*.

#### Usage

SMUAD multiplies the bottom halfword of *Rn* with the bottom halfword of *Rm*, and the top halfword of *Rn* with the top halfword of *Rm*. It then adds the products and stores the sum to *Rd*.

SMUSD multiplies the bottom halfword of *Rn* with the bottom halfword of *Rm*, and the top halfword of *Rn* with the top halfword of *Rm*. It then subtracts the second product from the first, and stores the difference to *Rd*.

#### Condition flags

The SMUAD instruction sets the Q flag if the addition overflows.

## Architectures

These ARM instructions are available in ARMv6 and above.

These 32-bit Thumb instructions are available in ARMv6T2 and above, except the ARMv7-M profile.

There are no 16-bit Thumb versions of these instructions.

## Examples

```
SMUAD      r2, r3, r2
SMUSDXNE   r0, r1, r2
```

## See also

### Reference:

- *Condition codes* on page 3-186.

### 3.5.7 SMMUL, SMMLA, and SMMLS

Signed Most significant word Multiply, Signed Most significant word Multiply with Accumulation, and Signed Most significant word Multiply with Subtraction. These instructions have 32-bit operands and produce only the most significant 32-bits of the result.

#### Syntax

$\text{SMMUL}\{R\}\{cond\} \{Rd\}, Rn, Rm$

$\text{SMMLA}\{R\}\{cond\} Rd, Rn, Rm, Ra$

$\text{SMMLS}\{R\}\{cond\} Rd, Rn, Rm, Ra$

where:

*R* is an optional parameter. If *R* is present, the result is rounded, otherwise it is truncated.

*cond* is an optional condition code.

*Rd* is the destination register.

*Rn, Rm* are the registers holding the operands.

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

Do not use PC for any of *Rd, Rn, Rm*, or *Ra*.

#### Operation

SMMUL multiplies the values from *Rn* and *Rm*, and stores the most significant 32 bits of the 64-bit result to *Rd*.

SMMLA multiplies the values from *Rn* and *Rm*, adds the value in *Ra* to the most significant 32 bits of the product, and stores the result in *Rd*.

SMMLS multiplies the values from *Rn* and *Rm*, subtracts the product from the value in *Ra* shifted left by 32 bits, and stores the most significant 32 bits of the result in *Rd*.

If the optional *R* parameter is specified, 0x80000000 is added before extracting the most significant 32 bits. This has the effect of rounding the result.

#### Condition flags

These instructions do not change the flags.



## Architectures

These ARM instructions are available in ARMv6 and above.

These 32-bit Thumb instructions are available in ARMv6T2 and above, except the ARMv7-M profile.

There are no 16-bit Thumb versions of these instructions.

## Examples

SMMULGE	r6, r4, r3
SMMULR	r2, r2, r2

## See also

### Reference:

- *Condition codes* on page 3-186.

### 3.5.8 SMLAD and SMLSD

Dual 16-bit Signed Multiply with Addition or Subtraction of products and 32-bit accumulation.

#### Syntax

*op*{*X*}{*cond*} *Rd*, *Rn*, *Rm*, *Ra*

where:

<i>op</i>	is one of:
SMLAD	Dual multiply, accumulate sum of products.
SMLSD	Dual multiply, accumulate difference of products.
<i>cond</i>	is an optional condition code.
<i>X</i>	is an optional parameter. If <i>X</i> is present, the most and least significant halfwords of the second operand are exchanged before the multiplications occur.
<i>Rd</i>	is the destination register.
<i>Rn</i> , <i>Rm</i>	are the registers holding the operands.
<i>Ra</i>	is the register holding the accumulate operand.

Do not use PC for any of *Rd*, *Rn*, *Rm*, or *Ra*.

#### Operation

SMLAD multiplies the bottom halfword of *Rn* with the bottom halfword of *Rm*, and the top halfword of *Rn* with the top halfword of *Rm*. It then adds both products to the value in *Ra* and stores the sum to *Rd*.

SMLSD multiplies the bottom halfword of *Rn* with the bottom halfword of *Rm*, and the top halfword of *Rn* with the top halfword of *Rm*. It then subtracts the second product from the first, adds the difference to the value in *Ra*, and stores the result to *Rd*.

#### Condition flags

These instructions do not change the flags.

## Architectures

These ARM instructions are available in ARMv6 and above.

These 32-bit Thumb instructions are available in ARMv6T2 and above, except the ARMv7-M profile.

There are no 16-bit Thumb versions of these instructions.

## Examples

SMLSD	r1, r2, r0, r7
SMLSX	r11, r10, r2, r3
SMLADLT	r1, r2, r4, r1

## See also

### Reference:

- *Condition codes* on page 3-186.

### 3.5.9 SMLALD and SMLSLD

Dual 16-bit Signed Multiply with Addition or Subtraction of products and 64-bit Accumulation.

#### Syntax

*op*{*X*}{*cond*} *RdLo*, *RdHi*, *Rn*, *Rm*

where:

*op* is one of:

SMLALD Dual multiply, accumulate sum of products.

SMLSLD Dual multiply, accumulate difference of products.

*X* is an optional parameter. If *X* is present, the most and least significant halfwords of the second operand are exchanged before the multiplications occur.

*cond* is an optional condition code.

*RdLo*, *RdHi* are the destination registers for the 64-bit result. They also hold the 64-bit accumulate operand. *RdHi* and *RdLo* must be different registers.

*Rn*, *Rm* are the registers holding the operands.

Do not use PC for any of *RdLo*, *RdHi*, *Rn*, or *Rm*.

#### Operation

SMLALD multiplies the bottom halfword of *Rn* with the bottom halfword of *Rm*, and the top halfword of *Rn* with the top halfword of *Rm*. It then adds both products to the value in *RdLo*, *RdHi* and stores the sum to *RdLo*, *RdHi*.

SMLSLD multiplies the bottom halfword of *Rn* with the bottom halfword of *Rm*, and the top halfword of *Rn* with the top halfword of *Rm*. It then subtracts the second product from the first, adds the difference to the value in *RdLo*, *RdHi*, and stores the result to *RdLo*, *RdHi*.

#### Condition flags

These instructions do not change the flags.

## Architectures

These ARM instructions are available in ARMv6 and above.

These 32-bit Thumb instructions are available in ARMv6T2 and above, except the ARMv7-M profile.

There are no 16-bit Thumb versions of these instructions.

## Examples

SMLALD	r10, r11, r5, r1
SMLSLD	r3, r0, r5, r1

## See also

### Reference:

- *Condition codes* on page 3-186.

### 3.5.10 UMAAL

Unsigned Multiply Accumulate Accumulate Long.

#### Syntax

UMAAL{*cond*} *RdLo*, *RdHi*, *Rn*, *Rm*

where:

*cond* is an optional condition code.

*RdLo*, *RdHi* are the destination registers for the 64-bit result. They also hold the two 32-bit accumulate operands. *RdLo* and *RdHi* must be distinct registers.

*Rn*, *Rm* are the registers holding the multiply operands.

Do not use PC for any of *RdLo*, *RdHi*, *Rn*, or *Rm*.

#### Operation

The UMAAL instruction multiplies the 32-bit values in *Rn* and *Rm*, adds the two 32-bit values in *RdHi* and *RdLo*, and stores the 64-bit result to *RdLo*, *RdHi*.

#### Condition flags

This instruction does not change the flags.

#### Architectures

This ARM instruction is available in ARMv6 and above.

These 32-bit Thumb instructions are available in ARMv6T2 and above, except the ARMv7-M profile.

There is no 16-bit Thumb version of this instruction.

#### Examples

UMAAL	r8, r9, r2, r3
UMAALGE	r2, r0, r5, r3

#### See also

#### Reference:

- *Condition codes* on page 3-186.

### 3.5.11 MIA, MIAPH, and MIAxy

Multiply with internal accumulate (32-bit by 32-bit, 40-bit accumulate).

Multiply with internal accumulate, packed halfwords (16-bit by 16-bit twice, 40-bit accumulate).

Multiply with internal accumulate (16-bit by 16-bit, 40-bit accumulate).

#### Syntax

`MIA{cond} Acc, Rn, Rm`

`MIAPH{cond} Acc, Rn, Rm`

`MIA<x><y>{cond} Acc, Rn, Rm`

where:

*cond* is an optional condition code.

*Acc* is the internal accumulator. The standard name is *accx*, where *x* is an integer in the range 0 to *n*. The value of *n* depends on the processor. It is 0 in current processors.

*Rn, Rm* are the ARM registers holding the values to be multiplied.  
Do not use PC for either *Rn* or *Rm*.

*<x><y>* is one of: BB, BT, TB, TT.

#### Usage

The MIA instruction multiplies the signed integers from *Rn* and *Rm*, and adds the result to the 40-bit value in *Acc*.

The MIAPH instruction multiplies the signed integers from the bottom halves of *Rn* and *Rm*, multiplies the signed integers from the upper halves of *Rn* and *Rm*, and adds the two 32-bit results to the 40-bit value in *Acc*.

The MIAxy instruction multiplies the signed integer from the selected half of *Rs* by the signed integer from the selected half of *Rm*, and adds the 32-bit result to the 40-bit value in *Acc*. *<x>* == B means use the bottom half (bits [15:0]) of *Rn*, *<x>* == T means use the top half (bits [31:16]) of *Rn*. *<y>* == B means use the bottom half (bits [15:0]) of *Rm*, *<y>* == T means use the top half (bits [31:16]) of *Rm*.

## Condition flags

These instructions do not change the flags.

---

### Note

---

These instructions cannot raise an exception. If overflow occurs on these instructions, the result wraps round without any warning.

---

## Architectures

These ARM coprocessor 0 instructions are only available in XScale processors.

There are no Thumb versions of these instructions.

## Examples

MIA	acc0, r5, r0
MIALE	acc0, r1, r9
MIAPH	acc0, r0, r7
MIAPHNE	acc0, r11, r10
MIABB	acc0, r8, r9
MIABT	acc0, r8, r8
MIATB	acc0, r5, r3
MIATT	acc0, r0, r6
MIABTGT	acc0, r2, r5

## See also

### Reference:

- *Condition codes* on page 3-186.



## 3.6 Saturating instructions

This section contains:

- *Saturating arithmetic*
- *QADD, QSUB, QDADD, and QDSUB* on page 3-108
- *SSAT and USAT* on page 3-110.

Some of the parallel instructions are also saturating.

### 3.6.1 Saturating arithmetic

These operations are *saturating* (SAT). This means that, for some value of  $2^n$  that depends on the instruction:

- for a signed saturating operation, if the full result would be less than  $-2^n$ , the result returned is  $-2^n$
- for an unsigned saturating operation, if the full result would be negative, the result returned is zero
- if the full result would be greater than  $2^n - 1$ , the result returned is  $2^n - 1$ .

When any of these things occurs, it is called *saturation*. Some instructions set the Q flag when saturation occurs.

---

#### Note

---

Saturating instructions do not clear the Q flag when saturation does not occur. To clear the Q flag, use an MSR instruction.

---

The Q flag can also be set by two other instructions, but these instructions do not saturate.

#### See also

#### Reference:

- *MSR* on page 3-157
- *SMULxy and SMLAxy* on page 3-90
- *SMULWy and SMLAWy* on page 3-92
- *Parallel instructions* on page 3-112.

### 3.6.2 QADD, QSUB, QDADD, and QDSUB

Signed Add, Subtract, Double and Add, Double and Subtract, saturating the result to the signed range  $-2^{31} \leq x \leq 2^{31}-1$ .

#### Syntax

*op*{*cond*} {*Rd*}, *Rm*, *Rn*

where:

*op* is one of QADD, QSUB, QDADD, or QDSUB.

*cond* is an optional condition code.

*Rd* is the destination register.

*Rm*, *Rn* are the registers holding the operands.

Do not use PC for *Rd*, *Rm*, or *Rn*.

#### Usage

The QADD instruction adds the values in *Rm* and *Rn*.

The QSUB instruction subtracts the value in *Rn* from the value in *Rm*.

The QDADD instruction calculates  $\text{SAT}(Rm + \text{SAT}(Rn * 2))$ . Saturation can occur on the doubling operation, on the addition, or on both. If saturation occurs on the doubling but not on the addition, the Q flag is set but the final result is unsaturated.

The QDSUB instruction calculates  $\text{SAT}(Rm - \text{SAT}(Rn * 2))$ . Saturation can occur on the doubling operation, on the subtraction, or on both. If saturation occurs on the doubling but not on the subtraction, the Q flag is set but the final result is unsaturated.

#### ———— Note ————

All values are treated as two's complement signed integers by these instructions.

#### Condition flags

If saturation occurs, these instructions set the Q flag. To read the state of the Q flag, use an MRS instruction.

## Architectures

These ARM instructions are available in ARMv6 and above, and E variants of ARMv5T.

These 32-bit Thumb instructions are available in ARMv6T2 and above, except the ARMv7-M profile.

There are no 16-bit Thumb versions of these instructions.

## Examples

```
QADD    r0, r1, r9
QDSUBLT r9, r0, r1
```

## See also

### Reference:

- *Parallel add and subtract* on page 3-113
- *MRS* on page 3-155
- *Condition codes* on page 3-186.

### 3.6.3 SSAT and USAT

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

SSAT saturates a signed value to a signed range.

USAT saturates a signed value to an unsigned range.

#### Syntax

*op*{*cond*} *Rd*, #*sat*, *Rm*{, *shift*}

where:

*op* is either SSAT or USAT.

*cond* is an optional condition code.

*Rd* is the destination register. *Rd* must not be PC.

*sat* specifies the bit position to saturate to, in the range 1 to 32 for SSAT, and 0 to 31 for USAT.

*Rm* is the register containing the operand. *Rm* must not be PC.

*shift* is an optional shift. It must be one of the following:

ASR #*n* where *n* is in the range 1-32 (ARM) or 1-31 (Thumb)

LSL #*n* where *n* is in the range 0-31.

#### Operation

The SSAT instruction applies the specified shift, then saturates to the signed range  $-2^{\text{sat}-1} \leq x \leq 2^{\text{sat}-1} - 1$ .

The USAT instruction applies the specified shift, then saturates to the unsigned range  $0 \leq x \leq 2^{\text{sat}} - 1$ .

#### Condition flags

If saturation occurs, these instructions set the Q flag. To read the state of the Q flag, use an MRS instruction.

#### Architectures

These ARM instructions are available in ARMv6 and above.

These 32-bit Thumb instructions are available in ARMv6T2 and above.

There are no 16-bit Thumb versions of these instructions.

### Examples

```
SSAT    r7, #16, r7, LSL #4
USATNE  r0, #7, r5
```

### See also

#### Reference:

- *SSAT16 and USAT16* on page 3-118
- *MRS* on page 3-155
- *Condition codes* on page 3-186.

## 3.7 Parallel instructions

This section contains:

- *Parallel add and subtract* on page 3-113  
Various byte-wise and halfword-wise additions and subtractions.
- *USAD8 and USADA8* on page 3-116  
Unsigned sum of absolute differences, and accumulate unsigned sum of absolute differences.
- *SSAT16 and USAT16* on page 3-118  
Parallel halfword saturating instructions.

There are also parallel unpacking instructions such as SXT, SXTA, UXT, and UXTA.

**See also**

**Reference:**

- *SXT, SXTA, UXT, and UXTA* on page 3-124
- *Packing and unpacking instructions* on page 3-120.

### 3.7.1 Parallel add and subtract

Various byte-wise and halfword-wise additions and subtractions.

#### Syntax

*<prefix>op{cond} {Rd}, Rn, Rm*

where:

<i>&lt;prefix&gt;</i>	is one of:
S	Signed arithmetic modulo $2^8$ or $2^{16}$ . Sets APSR GE flags.
Q	Signed saturating arithmetic.
SH	Signed arithmetic, halving the results.
U	Unsigned arithmetic modulo $2^8$ or $2^{16}$ . Sets APSR GE flags.
UQ	Unsigned saturating arithmetic.
UH	Unsigned arithmetic, halving the results.
<i>op</i>	is one of:
ADD8	Byte-wise Addition
ADD16	Halfword-wise Addition.
SUB8	Byte-wise Subtraction.
SUB16	Halfword-wise Subtraction.
ASX	Exchange halfwords of <i>Rm</i> , then Add top halfwords and Subtract bottom halfwords.
SAX	Exchange halfwords of <i>Rm</i> , then Subtract top halfwords and Add bottom halfwords.
<i>cond</i>	is an optional condition code .
<i>Rd</i>	is the destination register. Do not use PC for <i>Rd</i> .
<i>Rm, Rn</i>	are the ARM registers holding the operands. Do not use PC for <i>Rm</i> or <i>Rn</i> .

#### Operation

These instructions perform arithmetic operations separately on the bytes or halfwords of the operands. They perform two or four additions or subtractions, or one addition and one subtraction.

You can choose various kinds of arithmetic:

- Signed or unsigned arithmetic modulo  $2^8$  or  $2^{16}$ . This sets the APSR GE flags.

- Signed saturating arithmetic to one of the signed ranges  $-2^{15} \leq x \leq 2^{15} - 1$  or  $-2^7 \leq x \leq 2^7 - 1$ . The Q flag is not affected even if these operations saturate.
- Unsigned saturating arithmetic to one of the unsigned ranges  $0 \leq x \leq 2^{16} - 1$  or  $0 \leq x \leq 2^8 - 1$ . The Q flag is not affected even if these operations saturate.
- Signed or unsigned arithmetic, halving the results. This cannot cause overflow.

### Condition flags

These instructions do not affect the N, Z, C, V, or Q flags.

The Q, SH, UQ and UH prefix variants of these instructions do not change the flags.

The S and U prefix variants of these instructions set the GE flags in the APSR as follows:

- For byte-wise operations, the GE flags are used in the same way as the C (Carry) flag for 32-bit SUB and ADD instructions:
  - GE[0] for bits[7:0] of the result
  - GE[1] for bits[15:8] of the result
  - GE[2] for bits[23:16] of the result
  - GE[3] for bits[31:24] of the result.
- For halfword-wise operations, the GE flags are used in the same way as the C (Carry) flag for normal word-wise SUB and ADD instructions:
  - GE[1:0] for bits[15:0] of the result
  - GE[3:2] for bits[31:16] of the result.

You can use these flags to control a following SEL instruction.

#### ————— **Note** —————

For halfword-wise operations, GE[1:0] are set or cleared together, and GE[3:2] are set or cleared together.

---



## Architectures

These ARM instructions are available in ARMv6 and above.

These 32-bit Thumb instructions are available in ARMv6T2 and above, except the ARMv7-M profile.

There are no 16-bit Thumb versions of these instructions.

## Examples

```
SHADD8    r4, r3, r9
USAXNE    r0, r0, r2
```

## Incorrect examples

```
QHADD     r2, r9, r3    ; No such instruction, should be QHADD8 or QHADD16
SAX        r10, r8, r5   ; Must have a prefix.
```

## See also

### Reference:

- *SEL* on page 3-77
- *Condition codes* on page 3-186.

### 3.7.2 USAD8 and USADA8

Unsigned Sum of Absolute Differences, and Accumulate unsigned sum of absolute differences.

#### Syntax

USAD8{*cond*} {*Rd*}, *Rn*, *Rm*

USADA8{*cond*} *Rd*, *Rn*, *Rm*, *Ra*

where:

*cond* is an optional condition code.

*Rd* is the destination register.

*Rn* is the register holding the first operand.

*Rm* is the register holding the second operand.

*Ra* is the register holding the accumulate operand.

Do not use PC for *Rd*, *Rn*, *Rn*, or *Ra*.

#### Operation

The USAD8 instruction finds the four differences between the unsigned values in corresponding bytes of *Rn* and *Rm*. It adds the absolute values of the four differences, and saves the result to *Rd*.

The USADA8 instruction adds the absolute values of the four differences to the value in *Ra*, and saves the result to *Rd*.

#### Condition flags

These instructions do not alter any flags.

#### Architectures

These ARM instructions are available in ARMv6 and above.

These 32-bit Thumb instructions are available in ARMv6T2 and above, except the ARMv7-M profile.

There are no 16-bit Thumb versions of these instructions.

**Examples**

```
USAD8      r2, r4, r6
USADA8      r0, r3, r5, r2
USADA8VS    r0, r4, r0, r1
```

**Incorrect examples**

```
USADA8      r2, r4, r6      ; USADA8 requires four registers
USADA16     r0, r4, r0, r1  ; no such instruction
```

**See also****Reference:**

- *Condition codes* on page 3-186.

### 3.7.3 SSAT16 and USAT16

Parallel halfword Saturating instructions.

SSAT16 saturates a signed value to a signed range.

USAT16 saturates a signed value to an unsigned range.

#### Syntax

*op{cond} Rd, #sat, Rn*

where:

*op* is one of:

SSAT16 Signed saturation.

USAT16 Unsigned saturation.

*cond* is an optional condition code.

*Rd* is the destination register.

*sat* specifies the bit position to saturate to, and is in the range 1 to 16 for SSAT16, or 0 to 15 for USAT16.

*Rn* is the register holding the operand.

Do not use PC for *Rd* or *Rn*.

#### Operation

Halfword-wise signed and unsigned saturation to any bit position.

The SSAT16 instruction saturates each signed halfword to the signed range  $-2^{\text{sat}-1} \leq x \leq 2^{\text{sat}-1} - 1$ .

The USAT16 instruction saturates each signed halfword to the unsigned range  $0 \leq x \leq 2^{\text{sat}} - 1$ .

#### Condition flags

If saturation occurs on either halfword, these instructions set the Q flag. To read the state of the Q flag, use an MRS instruction.

## Architectures

These ARM instructions are available in ARMv6 and above.

These 32-bit Thumb instructions are available in ARMv6T2 and above, except the ARMv7-M profile.

There are no 16-bit Thumb versions of these instructions.

## Examples

```
SSAT16  r7, #12, r7
USAT16  r0, #7, r5
```

## Incorrect examples

```
SSAT16  r1, #16, r2, LSL #4 ; shifts not permitted with halfword saturations
```

## See also

### Reference:

- *MRS* on page 3-155
- *Condition codes* on page 3-186.

## 3.8 Packing and unpacking instructions

This section contains the following subsections:

- *BFC and BFI* on page 3-121  
Bit Field Clear and Bit Field Insert.
- *SBFX and UBFX* on page 3-123  
Signed or Unsigned Bit Field extract.
- *SXT, SXTA, UXT, and UXTA* on page 3-124  
Sign Extend or Zero Extend instructions, with optional Add.
- *PKHBT and PKHTB* on page 3-127  
Halfword Packing instructions.

### 3.8.1 BFC and BFI

Bit Field Clear and Bit Field Insert. Clear adjacent bits in a register, or Insert adjacent bits from one register into another.

#### Syntax

$\text{BFC}\{\text{cond}\} \text{ Rd}, \#1\text{sb}, \#width$

$\text{BFI}\{\text{cond}\} \text{ Rd}, \text{Rn}, \#1\text{sb}, \#width$

where:

*cond* is an optional condition code.

*Rd* is the destination register. *Rd* must not be PC.

*Rn* is the source register. *Rn* must not be PC.

*1sb* is the least significant bit that is to be cleared or copied.

*width* is the number of bits to be cleared or copied. *width* must not be 0, and (*width*+*1sb*) must be less than 32.

#### BFC

*width* bits in *Rd* are cleared, starting at *1sb*. Other bits in *Rd* are unchanged.

#### BFI

*width* bits in *Rd*, starting at *1sb*, are replaced by *width* bits from *Rn*, starting at bit[0]. Other bits in *Rd* are unchanged.

#### Condition flags

These instructions do not change the flags.

#### Architectures

These ARM instructions are available in ARMv6T2 and above.

These 32-bit Thumb instructions are available in ARMv6T2 and above.

There are no 16-bit Thumb versions of these instructions.

**See also**

**Reference:**

- *Condition codes* on page 3-186.



### 3.8.2 SBFX and UBFX

Signed and Unsigned Bit Field Extract. Copies adjacent bits from one register into the least significant bits of a second register, and sign extends or zero extends to 32 bits.

#### Syntax

*op{cond} Rd, Rn, #lsb, #width*

where:

*op* is either SBFX or UBFX.

*cond* is an optional condition code.

*Rd* is the destination register.

*Rn* is the source register.

*lsb* is the bit number of least significant bit in the bitfield, in the range 0 to 31.

*width* is the width of the bitfield, in the range 1 to (32−*lsb*).

Do not use PC for *Rd* or *Rn*.

#### Condition flags

These instructions do not alter any flags.

#### Architectures

These ARM instructions are available in ARMv6T2 and above.

These 32-bit Thumb instructions are available in ARMv6T2 and above.

There are no 16-bit Thumb versions of these instructions.

#### See also

#### Reference:

- *Condition codes* on page 3-186.

### 3.8.3 SXT, SXTA, UXT, and UXTA

Sign extend, Sign extend with Add, Zero extend, and Zero extend with Add.

#### Syntax

$SXT<extend>\{cond\} \{Rd\}, Rm \{,rotation\}$

$SXTA<extend>\{cond\} \{Rd\}, Rn, Rm \{,rotation\}$

$UXT<extend>\{cond\} \{Rd\}, Rm \{,rotation\}$

$UXTA<extend>\{cond\} \{Rd\}, Rn, Rm \{,rotation\}$

where:

*<extend>* is one of:

- |     |  |
|-----|--|
| B16 | Extends two 8-bit values to two 16-bit values. |
| B   | Extends an 8-bit value to a 32-bit value.      |
| H   | Extends a 16-bit value to a 32-bit value.      |

*cond* is an optional condition code.

*Rd* is the destination register.

*Rn* is the register holding the number to add (SXTA and UXTA only).

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

*rotation* is one of:

- |  |  |
|--|--|
| ROR #8   | Value from <i>Rm</i> is rotated right 8 bits.  |
| ROR #16  | Value from <i>Rm</i> is rotated right 16 bits. |
| ROR #24  | Value from <i>Rm</i> is rotated right 24 bits. |
| If <i>rotation</i> is omitted, no rotation is performed. |  |

You must not use PC for *Rd*, *Rn*, or *Rm*.

## Operation

These instructions do the following:

1. Rotate the value from *Rm* right by 0, 8, 16 or 24 bits.
2. Do one of the following to the value obtained:
  - Extract bits[7:0], sign or zero extend to 32 bits. If the instruction is extend and add, add the value from *Rn*.
  - Extract bits[15:0], sign or zero extend to 32 bits. If the instruction is extend and add, add the value from *Rn*.
  - Extract bits[23:16] and bits[7:0] and sign or zero extend them to 16 bits. If the instruction is extend and add, add them to bits[31:16] and bits[15:0] respectively of *Rn* to form bits[31:16] and bits[15:0] of the result.

## Condition flags

These instructions do not change the flags.

## 16-bit instructions

The following forms of these instructions are available in Thumb code, and are 16-bit instructions:

SXTB <i>Rd</i> , <i>Rm</i>	<i>Rd</i> and <i>Rm</i> must both be Lo registers.
SXTH <i>Rd</i> , <i>Rm</i>	<i>Rd</i> and <i>Rm</i> must both be Lo registers.
UXTB <i>Rd</i> , <i>Rm</i>	<i>Rd</i> and <i>Rm</i> must both be Lo registers.
UXTH <i>Rd</i> , <i>Rm</i>	<i>Rd</i> and <i>Rm</i> must both be Lo registers.

## Architectures

These ARM instructions are available in ARMv6 and above.

These 32-bit Thumb instructions are available in ARMv6T2 and above, except the ARMv7-M profile.

These 16-bit Thumb instructions are available in ARMv6 and above.

## Examples

```
SXTH      r3, r9, r4
UXTAB16EQ r0, r0, r4, ROR #16
```

## Incorrect examples

```
SXTH      r9, r3, r2, ROR #12 ; rotation must be by 0, 8, 16, or 24.
```

## See also

### Reference:

- *Condition codes* on page 3-186.

### 3.8.4 PKHBT and PKHTB

Halfword Packing instructions.

Combine a halfword from one register with a halfword from another register. One of the operands can be shifted before extraction of the halfword.

#### Syntax

PKHBT{*cond*} {*Rd*}, *Rn*, *Rm*{, LSL #*leftshift*}

PKHTB{*cond*} {*Rd*}, *Rn*, *Rm*{, ASR #*rightshift*}

where:

PKHBT Combines bits[15:0] of *Rn* with bits[31:16] of the shifted value from *Rm*.

PKHTB Combines bits[31:16] of *Rn* with bits[15:0] of the shifted value from *Rm*.

*cond* is an optional condition code.

*Rd* is the destination register.

*Rn* is the register holding the first operand.

*Rm* is the register holding the first operand.

*leftshift* is in the range 0 to 31.

*rightshift* is in the range 1 to 32.

Do not use PC for *Rd*, *Rn*, or *Rm*.

#### Condition flags

These instructions do not change the flags.

## Architectures

These ARM instructions are available in ARMv6 and above.

These 32-bit Thumb instructions are available in ARMv6T2 and above, except the ARMv7-M profile.

There are no 16-bit Thumb versions of these instructions.

## Examples

```
PKHBT  r0, r3, r5          ; combine the bottom halfword of R3 with
                           ; the top halfword of R5
PKHBT  r0, r3, r5, LSL #16 ; combine the bottom halfword of R3 with
                           ; the bottom halfword of R5
PKHTB  r0, r3, r5, ASR #16 ; combine the top halfword of R3 with
                           ; the top halfword of R5
```

You can also scale the second operand by using different values of shift.

## Incorrect examples

```
PKHBTEQ r4, r5, r1, ASR #8 ; ASR not permitted with PKHBT
```

## See also

### Reference:

- *Condition codes* on page 3-186.

## 3.9 Branch and control instructions

This section contains the following subsections:

- *B, BL, BX, BLX, and BXJ* on page 3-130  
Branch, Branch with Link, Branch and exchange instruction set, Branch with Link and exchange instruction set, Branch and change instruction set to Jazelle.
- *IT* on page 3-134  
If-Then. IT makes up to four following instructions conditional, with either the same condition, or some with one condition and others with the inverse condition. IT is available only in Thumb-2.
- *CBZ and CBNZ* on page 3-137  
Compare against zero and branch. These instructions are available only in Thumb-2.
- *TBB and TBH* on page 3-138  
Table Branch Byte or Halfword. These instructions are available only in Thumb-2.

### 3.9.1 B, BL, BX, BLX, and BXJ

Branch, Branch with Link, Branch and exchange instruction set, Branch with Link and exchange instruction set, Branch and change to Jazelle state.

#### Syntax

*op1*{*cond*}{*.W*} *label*

*op2*{*cond*} *Rm*

where:

*op1* is one of:

B	Branch.
BL	Branch with link.
BLX	Branch with link, and exchange instruction set.

*op2* is one of:

BX	Branch and exchange instruction set.
BLX	Branch with link, and exchange instruction set.
BXJ	Branch, and change to Jazelle execution.

*cond* is an optional condition code. *cond* is not available on all forms of this instruction.

*.W* is an optional instruction width specifier to force the use of a 32-bit B instruction in Thumb-2.

*label* is a PC-relative expression.

*Rm* is a register containing an address to branch to.

#### Operation

All these instructions cause a branch to *label*, or to the address contained in *Rm*. In addition:

- The BL and BLX instructions copy the address of the next instruction into LR (R14, the link register).
- The BX and BLX instructions can change the processor state from ARM to Thumb, or from Thumb to ARM.  
BLX *label* always changes the state.



BX *Rm* and BLX *Rm* derive the target state from bit[0] of *Rm*:

- if bit[0] of *Rm* is 0, the processor changes to, or remains in, ARM state
- if bit[0] of *Rm* is 1, the processor changes to, or remains in, Thumb state.

- The BXJ instruction changes the processor state to Jazelle.

### Instruction availability and branch ranges

Table 3-9 shows the instructions that are available in ARM and Thumb state.

Instructions that are not shown in this table are not available. Notes in brackets show the first architecture version where the instruction is available.

**Table 3-9 Branch instruction availability and range**

Instruction	ARM		16-bit Thumb		32-bit Thumb	
B <i>label</i>	±32MB	(All)	±2KB	(All T)	±16MB <sup>a</sup>	(All T2)
B{ <i>cond</i> } <i>label</i>	±32MB	(All)	–252 to +258	(All T)	±1MB <sup>a</sup>	(All T2)
BL <i>label</i>	±32MB	(All)	±4MB <sup>b</sup>	(All T)	±16MB	(All T2)
BL{ <i>cond</i> } <i>label</i>	±32MB	(All)	-		-	-
BX <i>Rm</i> <sup>c</sup>	Available	(4T, 5)	Available	(All T)	Use 16-bit	(All T2)
BX{ <i>cond</i> } <i>Rm</i> <sup>c</sup>	Available	(4T, 5)	-		-	-
BLX <i>label</i>	±32MB	(5)	±4MB <sup>b</sup>	(5T)	±16MB	(All T2 except ARMv7-M)
BLX <i>Rm</i>	Available	(5)	Available	(5T)	Use 16-bit	(All T2)
BLX{ <i>cond</i> } <i>Rm</i>	Available	(5)	-		-	-
BXJ <i>Rm</i>	Available	(5J, 6)	-		Available	(All T2 except ARMv7-M)
BXJ{ <i>cond</i> } <i>Rm</i>	Available	(5J, 6)	-		-	-

a. Use .w to instruct the assembler to use this 32-bit instruction.

b. This is an instruction pair.

c. The assembler accepts BX{*cond*} *Rm* for code assembled for ARMv4 and converts it to MOV{*cond*} PC, *Rm* at link time, unless objects targeted for ARMv4T are present.

## Extending branch ranges

Machine-level B and BL instructions have restricted ranges from the address of the current instruction. However, you can use these instructions even if *label* is out of range. Often you do not know where the linker places *label*. When necessary, the linker adds code to enable longer branches. The added code is called a *veneer*.

## B in Thumb

You can use the `.W` width specifier to force B to generate a 32-bit instruction in Thumb code.

B.W always generates a 32-bit instruction, even if the target could be reached using a 16-bit instruction.

For forward references, B without `.W` always generates a 16-bit instruction in Thumb code, even if that results in failure for a target that could be reached using a 32-bit Thumb instruction.

## BX, BLX, and BXJ in Thumb-2EE

These instructions can be used as branches in Thumb-2EE code, but cannot be used to change state. You cannot use the `op{cond} label` form of these instructions in Thumb-2EE. In the register form, bit[0] of *Rm* must be 1, and execution continues at the target address in ThumbEE state.

### ———— Note ————

BXJ behaves like BX in Thumb-2EE.

## Condition flags

These instructions do not change the flags.

## Architectures

See Table 3-9 on page 3-131 for details of availability of these instructions in each architecture.

**Examples**

```

B      loopA
BLE    ng+8
BL     subC
BLLT   rtX
BEQ     {PC}+4 ; #0x8004

```

**See also****Concepts:**

*Using the Assembler:*

- *Register-relative and PC-relative expressions* on page 8-9.

*Using the Linker:*

- *Chapter 4 Image structure and generation.*

**Reference:**

- *Condition codes* on page 3-186.

### 3.9.2 IT

The IT (If-Then) instruction makes up to four following instructions (the *IT block*) conditional. The conditions can be all the same, or some of them can be the logical inverse of the others.

#### Syntax

IT{x{y{z}}} {cond}

where:

<i>x</i>	specifies the condition switch for the second instruction in the IT block.
<i>y</i>	specifies the condition switch for the third instruction in the IT block.
<i>z</i>	specifies the condition switch for the fourth instruction in the IT block.
<i>cond</i>	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 <i>cond</i> to the instruction.
E	Else. Applies the inverse condition of <i>cond</i> to the instruction.

#### Usage

The instructions (including branches) in the IT block, except the BKPT instruction, must specify the condition in the {*cond*} part of their syntax.

You do not need to write IT instructions in your code, because the assembler generates them for you automatically according to the conditions specified on the following instructions. However, if you do write IT instructions, the assembler validates the conditions specified in the IT instructions against the conditions specified in the following instructions.

Writing the IT instructions ensures that you consider the placing of conditional instructions, and the choice of conditions, in the design of your code.

When assembling to ARM code, the assembler performs the same checks, but does not generate any IT instructions.

With the exception of CMP, CMN, and TST, the 16-bit instructions that normally affect the condition code flags, do not affect them when used inside an IT block.

A BKPT instruction in an IT block is always executed, so it does not need a condition in the {*cond*} part of its syntax. The IT block continues from the next instruction.

---

**Note**

---

You can use an IT block for unconditional instructions by using the AL condition.

---

Conditional branches inside an IT block have a longer branch range than those outside the IT block.

**Restrictions**

The following instructions are not permitted in an IT block:

- IT
- CBZ and CBNZ
- TBB and TBH
- CPS, CPSID and CPSIE
- SETEND.

Other restrictions when using an IT block are:

- A branch or any instruction that modifies the PC is only allowed in an IT block if it is the last instruction in the block.
- You cannot branch to any instruction in an IT block, unless when returning from an exception handler.
- You cannot use any assembler directives in an IT block.

---

**Note**

---

The assembler shows a diagnostic message when any of these instructions are used in an IT block.

---

**Condition flags**

This instruction does not change the flags.

**Exceptions**

Exceptions can occur between an IT instruction and the corresponding IT block, or within an IT block. This exception results in entry to the appropriate exception handler, with suitable return information in LR and SPSR.

Instructions designed for use as 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 can branch to an instruction in an IT block.

## Architectures

This 16-bit Thumb instruction is available in ARMv6T2 and above.

In ARM code, IT is a pseudo-instruction that does not generate any code.

There is no 32-bit version of this instruction.

## Example

```

ITTE  NE      ; IT can be omitted
ANDNE r0,r0,r1 ; 16-bit AND, not ANDS
ADDSNE r2,r2,#1 ; 32-bit ADDS (16-bit ADDS does not set flags in IT block)
MOVEQ r2,r3    ; 16-bit MOV

ITT   AL      ; emit 2 non-flag setting 16-bit instructions
ADDAL r0,r0,r1 ; 16-bit ADD, not ADDS
SUBAL r2,r2,#1 ; 16-bit SUB, not SUB
ADD   r0,r0,r1 ; expands into 32-bit ADD, and is not in IT block

ITT   EQ
MOVEQ r0,r1
BEQ   dloop    ; branch at end of IT block is allowed

ITT   EQ
MOVEQ r0,r1
BKPT  #1       ; BKPT always executes
ADDEQ r0,r0,#1

```

## Incorrect example

```

IT     NE
ADD    r0,r0,r1 ; syntax error: no condition code used in IT block

```

### 3.9.3 CBZ and CBNZ

Compare and Branch on Zero, Compare and Branch on Non-Zero.

#### Syntax

CBZ *Rn*, *label*

CBNZ *Rn*, *label*

where:

*Rn* is the register holding the operand.

*label* is the branch destination.

#### Usage

You can use the CBZ or CBNZ instructions to avoid changing the condition code flags and to reduce the number of instructions.

Except that it does not change the condition code flags, CBZ *Rn*, *label* is equivalent to:

```
CMP    Rn, #0
BEQ    label
```

Except that it does not change the condition code flags, CBNZ *Rn*, *label* is equivalent to:

```
CMP    Rn, #0
BNE    label
```

#### Restrictions

The branch destination must be within 4 to 130 bytes after the instruction and in the same execution state.

These instructions must not be used inside an IT block.

#### Condition flags

These instructions do not change the flags.

#### Architectures

These 16-bit Thumb instructions are available in ARMv6T2 and above.

There are no ARM or 32-bit Thumb versions of these instructions.

### 3.9.4 TBB and TBH

Table Branch Byte and Table Branch Halfword.

#### Syntax

TBB [*Rn*, *Rm*]

TBH [*Rn*, *Rm*, LSL #1]

where:

*Rn* is the base register. This contains the address of the table of branch lengths. *Rn* must not be SP.  
If PC is specified for *Rn*, the value used is the address of the instruction plus 4.

*Rm* is the index register. This contains an index into the table.  
*Rm* must not be PC or SP.

#### Operation

These instructions cause a PC-relative forward branch using a table of single byte offsets (TBB) or halfword offsets (TBH). *Rn* provides a pointer to the table, and *Rm* supplies an index into the table. The branch length is twice the value of the byte (TBB) or the halfword (TBH) returned from the table. The target of the branch table must be in the same execution state.

#### Notes

In Thumb-2EE, if the value in the base register is zero, execution branches to the NullCheck handler at HandlerBase - 4.

#### Architectures

These 32-bit Thumb instructions are available in ARMv6T2 and above.

There are no ARM, or 16-bit Thumb, versions of these instructions.



## 3.10 Coprocessor instructions

This section contains the following subsections:

- *CDP and CDP2* on page 3-140  
Coprocessor Data oPerations.
- *MCR, MCR2, MCRR, and MCRR2* on page 3-141  
Move to Coprocessor from ARM Register or Registers, possibly with coprocessor operations.
- *MRC, MRC2, MRRC and MRRC2* on page 3-143  
Move to ARM Register or Registers from Coprocessor, possibly with coprocessor operations.
- *MSR* on page 3-145  
Move to system coprocessor from ARM register.
- *MRS* on page 3-146  
Move to ARM register from system coprocessor.
- *SYS* on page 3-148  
Execute system coprocessor instruction.
- *LDC, LDC2, STC, and STC2* on page 3-149  
Transfer data between memory and Coprocessor.

---

### Note

---

A coprocessor instruction causes an Undefined Instruction exception if the specified coprocessor is not present, or if it is not enabled.

---

This section does not describe VFP or Wireless MMX Technology instructions. XScale-specific instructions are described later in this document.

### See also

### Reference

- Chapter 4 *NEON and VFP Programming*
- Chapter 5 *Wireless MMX Technology Instructions*
- *Miscellaneous instructions* on page 3-151.

### 3.10.1 CDP and CDP2

Coprocessor data operations.

#### Syntax

*op*{*cond*} *coproc*, #*opcode1*, *CRd*, *CRn*, *CRm*{, #*opcode2*}

where:

<i>op</i>	is either CDP or CDP2.
<i>cond</i>	is an optional condition code. In ARM code, <i>cond</i> is not allowed for CDP2.
<i>coproc</i>	is the name of the coprocessor the instruction is for. The standard name is <i>pn</i> , where <i>n</i> is an integer in the range 0 to 15.
<i>opcode1</i>	is a 4-bit coprocessor-specific opcode.
<i>opcode2</i>	is an optional 3-bit coprocessor-specific opcode.
<i>CRd</i> , <i>CRn</i> , <i>CRm</i>	are coprocessor registers.

#### Usage

The use of these instructions depends on the coprocessor. See the coprocessor documentation for details.

#### Architectures

The CDP ARM instruction is available in all versions of the ARM architecture.

The CDP2 ARM instruction is available in ARMv5T and above.

These 32-bit Thumb instructions are available in ARMv6T2 and above.

There are no 16-bit Thumb versions of these instructions.

#### See also

#### Reference:

- *Condition codes* on page 3-186.

### 3.10.2 MCR, MCR2, MCRR, and MCRR2

Move to Coprocessor from ARM Register or Registers. Depending on the coprocessor, you might be able to specify various operations in addition.

#### Syntax

*op1*{*cond*} *coproc*, #*opcode1*, *Rt*, *CRn*, *CRm*{, #*opcode2*}

*op2*{*cond*} *coproc*, #*opcode3*, *Rt*, *Rt2*, *CRm*

where:

*op1* is either MCR or MCR2.

*op2* is either MCRR or MCRR2.

*cond* is an optional condition code. In ARM code, *cond* is not allowed for MCR2 or MCRR2.

*coproc* is the name of the coprocessor the instruction is for. The standard name is *pn*, where *n* is an integer in the range 0 to 15.

*opcode1* is a 3-bit coprocessor-specific opcode.

*opcode2* is an optional 3-bit coprocessor-specific opcode.

*opcode3* is a 4-bit coprocessor-specific opcode.

*Rt*, *Rt2* are ARM source registers. MCRR or MCRR2 must not use PC.

*CRn*, *CRm* are coprocessor registers.

#### Usage

The use of these instructions depends on the coprocessor. See the coprocessor documentation for details.

## Architectures

The MCR ARM instruction is available in all versions of the ARM architecture.

The MCR2 ARM instruction is available in ARMv5T and above.

The MCRR ARM instruction is available in ARMv6 and above, and E variants of ARMv5T.

The MCRR2 ARM instruction is available in ARMv6 and above.

These 32-bit Thumb instructions are available in ARMv6T2 and above.

There are no 16-bit Thumb versions of these instructions.

## See also

### Reference:

- *Condition codes* on page 3-186.

### 3.10.3 MRC, MRC2, MRRC and MRRC2

Move to ARM Register or Registers from Coprocessor.

Depending on the coprocessor, you might be able to specify various operations in addition.

#### Syntax

*op1*{*cond*} *coproc*, #*opcode1*, *Rt*, *CRn*, *CRm*{, #*opcode2*}

*op2*{*cond*} *coproc*, #*opcode3*, *Rt*, *Rt2*, *CRm*

where:

*op1* is either MRC or MRC2.

*op2* is either MRRC or MRRC2.

*cond* is an optional condition code. In ARM code, *cond* is not allowed for MRC2 or MRRC2.

*coproc* is the name of the coprocessor the instruction is for. The standard name is *pn*, where *n* is an integer in the range 0 to 15.

*opcode1* is a 3-bit coprocessor-specific opcode.

*opcode2* is an optional 3-bit coprocessor-specific opcode.

*opcode3* is a 4-bit coprocessor-specific opcode.

*Rt*, *Rt2* are ARM destination registers. Do not use PC.

In MRC and MRC2, *Rt* can be APSR\_nzcv. This means that the coprocessor executes an instruction that changes the value of the condition code flags in the APSR.

*CRn*, *CRm* are coprocessor registers.

#### Usage

The use of these instructions depends on the coprocessor. See the coprocessor documentation for details.

## Architectures

The MRC ARM instruction is available in all versions of the ARM architecture.

The MRC2 ARM instruction is available in ARMv5T and above.

The MRRC ARM instruction is available in ARMv6 and above, and E variants of ARMv5T.

The MRRC2 ARM instruction is available in ARMv6 and above.

These 32-bit Thumb instructions are available in ARMv6T2 and above.

There are no 16-bit Thumb versions of these instructions.

## See also

### Reference:

- *Condition codes* on page 3-186.

### 3.10.4 MSR

Move to system coprocessor register from ARM register.

#### Syntax

`MSR{cond} coproc_register, Rn`

where:

*cond* is an optional condition code.

*coproc\_register*

is the name of the coprocessor register.

*Rn* is the ARM source register. Do not use PC.

#### Usage

You can use this instruction to write to any CP14 or CP15 coprocessor writable register. A complete list of the applicable coprocessor register names is in the *ARMv7-AR Architecture Reference Manual*. For example:

```
MSR SCTLr, R1 ; writes the contents of R1 into the CP15 coprocessor register
               ; SCTLr
```

#### Architectures

This MSR ARM instruction is available in ARMv7-A and ARMv7-R.

This MSR 32-bit Thumb instruction is available in ARMv7-A and ARMv7-R.

There are no 16-bit Thumb versions of these instructions.

#### See also

##### Reference:

- *SYS* on page 3-148
- *Condition codes* on page 3-186
- *ARM Architecture Reference Manual*,  
<http://infocenter.arm.com/help/topic/com.arm.doc.subset.arch.reference/index.html>.

### 3.10.5 MRS

Move to ARM register from system coprocessor register.

#### Syntax

`MRS{cond} Rn, coproc_register`

`MRS{cond} APSR_nzcv, special_register`

where:

*cond* is an optional condition code.

*coproc\_register*

is the name of the coprocessor register.

*special\_register*

is the name of the coprocessor register that can be written to APSR\_nzcv. This is only possible for the coprocessor register DBGDSCRint.

*Rn* is the ARM destination register. Do not use PC.

#### Usage

You can use this instruction to read CP14 or CP15 coprocessor registers, with the exception of write-only registers. A complete list of the applicable coprocessor register names is in the *ARMv7-AR Architecture Reference Manual*. For example:

```
MRS R1, SCTLR ; writes the contents of the CP15 coprocessor register SCTLR
               ; into R1
```

#### Architectures

This MRS ARM instruction is available in ARMv7-A and ARMv7-R.

This MRS 32-bit Thumb instruction is available in ARMv7-A and ARMv7-R.

There are no 16-bit Thumb versions of these instructions.

#### See also

#### Reference:

- *Condition codes* on page 3-186



- *ARM Architecture Reference Manual*,  
<http://infocenter.arm.com/help/topic/com.arm.doc.subset.arch.reference/index.html>.

### 3.10.6 SYS

Execute system coprocessor instruction.

#### Syntax

`SYS{cond} instruction{, Rn}`

where:

*cond* is an optional condition code.

*instruction* is the coprocessor instruction to execute.

*Rn* is an operand to the instruction. For instructions that take an argument, *Rn* is compulsory. For instructions that do not take an argument, *Rn* is optional and if it is not specified, R0 is used. Do not use PC.

#### Usage

You can use this instruction to execute special coprocessor instructions such as cache, branch predictor, and TLB operations. The instructions operate by writing to special write-only coprocessor registers. The instruction names are the same as the write-only coprocessor register names and are listed in the *ARMv7-AR Architecture Reference Manual*. For example:

```
SYS ICIALUIS ; invalidates all instruction caches Inner Shareable to Point
              ; of Unification and also flushes branch target cache.
```

#### Architectures

The SYS ARM instruction is available in ARMv7-A and ARMv7-R.

The SYS 32-bit Thumb instruction is available in ARMv7-A and ARMv7-R.

There are no 16-bit Thumb versions of these instructions.

#### See also

#### Reference:

- *Condition codes* on page 3-186.

### 3.10.7 LDC, LDC2, STC, and STC2

Transfer Data between memory and Coprocessor.

#### Syntax

*op*{L}{*cond*} *coproc*, *CRd*, [*Rn*]

*op*{L}{*cond*} *coproc*, *CRd*, [*Rn*, #{-}offset]{!}

*op*{L}{*cond*} *coproc*, *CRd*, [*Rn*], #{-}offset

*op*{L}{*cond*} *coproc*, *CRd*, *label*

where:

*op* is one of LDC, LDC2, STC, or STC2.

*cond* is an optional condition code.

In ARM code, *cond* is not allowed for LDC2 or STC2.

L is an optional suffix specifying a long transfer.

*coproc* is the name of the coprocessor the instruction is for. The standard name is *pn*, where *n* is an integer in the range 0 to 15.

*CRd* is the coprocessor register to load or store.

*Rn* is the register on which the memory address is based. If PC is specified, the value used is the address of the current instruction plus eight.

- is an optional minus sign. If - is present, the offset is subtracted from *Rn*. Otherwise, the offset is added to *Rn*.

*offset* is an expression evaluating to a multiple of 4, in the range 0 to 1020.

! is an optional suffix. If ! is present, the address including the offset is written back into *Rn*.

*label* is a word-aligned PC-relative expression.

*label* must be within 1020 bytes of the current instruction.

## Usage

The use of these instructions depends on the coprocessor. See the coprocessor documentation for details.

In Thumb-2EE, if the value in the base register is zero, execution branches to the NullCheck handler at HandlerBase - 4.

## Architectures

LDC and STC are available in all versions of the ARM architecture.

LDC2 and STC2 are available in ARMv5T and above.

These 32-bit Thumb instructions are available in ARMv6T2 and above.

There are no 16-bit Thumb versions of these instructions.

## Notes

Use of program relative addressing in the STC and STC2 instructions is deprecated.

## See also

### Concepts:

*Using the Assembler:*

- *Register-relative and PC-relative expressions* on page 8-9.

### Reference:

- *Condition codes* on page 3-186.

### 3.11 Miscellaneous instructions

This section contains the following subsections:

- *BKPT* on page 3-152  
Breakpoint.
- *SVC* on page 3-153  
Supervisor Call (formerly SWI).
- *MRS* on page 3-155  
Move the contents of the CPSR or SPSR to a general-purpose register.
- *MSR* on page 3-157  
Load specified fields of the CPSR or SPSR with an immediate value, or from the contents of a general-purpose register.
- *CPS* on page 3-160  
Change Processor State.
- *SMC* on page 3-162  
Secure Monitor Call (formerly SMI).
- *SETEND* on page 3-163  
Set the Endianness bit in the CPSR.
- *NOP* on page 3-164  
No Operation.
- *SEV*, *WFE*, *WFI*, and *YIELD* on page 3-165  
Set Event, Wait For Event, Wait for Interrupt, and Yield hint instructions.
- *DBG* on page 3-167  
Debug.
- *DMB*, *DSB*, and *ISB* on page 3-168  
Data Memory Barrier, Data Synchronization Barrier, and Instruction Synchronization Barrier hint instructions.
- *MAR* and *MRA* on page 3-171  
Transfer between two general-purpose registers and a 40-bit internal accumulator (XScale coprocessor 0 instructions).

### 3.11.1 BKPT

Breakpoint.

#### Syntax

BKPT #*imm*

where:

- imm* is an expression evaluating to an integer in the range:
- 0-65535 (a 16-bit value) in an ARM instruction
  - 0-255 (an 8-bit value) in a 16-bit Thumb instruction.

#### Usage

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.

In both ARM state and Thumb state, *imm* is ignored by the ARM hardware. However, a debugger can use it to store additional information about the breakpoint.

BKPT is an unconditional instruction. It must not have a condition code in ARM code. In Thumb code, the BKPT instruction does not need a condition code suffix because BKPT always executes irrespective of its condition code suffix.

#### Architectures

This ARM instruction is available in ARMv5T and above.

This 16-bit Thumb instruction is available in ARMv5T and above.

There is no 32-bit Thumb version of this instruction.

### 3.11.2 SVC

SuperVisor Call.

#### Syntax

`SVC{cond} #imm`

where:

*cond* is an optional condition code.

*imm* is an expression evaluating to an integer in the range:

- 0 to  $2^{24}-1$  (a 24-bit value) in an ARM instruction
- 0-255 (an 8-bit value) in a 16-bit Thumb instruction.

#### Usage

The SVC instruction causes an exception. This means that the processor mode changes to Supervisor, the CPSR is saved to the Supervisor mode SPSR, and execution branches to the SVC vector.

*imm* is ignored by the processor. However, it can be retrieved by the exception handler to determine what service is being requested.

---

#### Note

SVC was called SWI in earlier versions of the ARM assembly language. SWI instructions disassemble to SVC, with a comment to say that this was formerly SWI.

---

#### Condition flags

This instruction does not change the flags.

#### Architectures

This ARM instruction is available in all versions of the ARM architecture.

This 16-bit Thumb instruction is available in all T variants of the ARM architecture.

There is no 32-bit Thumb version of this instruction.

## See also

### Concepts

*Developing Software for ARM Processors:*

- Chapter 6 *Handling Processor Exceptions*.

### Reference:

- *Condition codes* on page 3-186.



### 3.11.3 MRS

Move the contents of a PSR to a general-purpose register.

#### Syntax

`MRS{cond} Rd, psr`

where:

*cond* is an optional condition code.

*Rd* is the destination register. *Rd* must not be PC.

*psr* is one of:

APSR on any processor, in any mode.

CPSR deprecated synonym for APSR and for use in Debug state, on any processor except ARMv7-M and ARMv6-M.

SPSR on any processor except ARMv7-M and ARMv6-M, in privileged software execution only.

*Mpsr* on ARMv7-M and ARMv6-M processors only.

*Mpsr* can be any of: IPSR, EPSR, IEPSPR, IAPSR, EAPSR, MSP, PSP, XPSR, PRIMASK, BASEPRI, BASEPRI\_MAX, FAULTMASK, or CONTROL.

#### Usage

Use MRS in combination with MSR as part of a read-modify-write sequence for updating a PSR, for example to change processor mode, or 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 make use of MRS/store and load/MSR instruction sequences.

#### SPSR

You must not attempt to access the SPSR when the processor is in User or System mode. This is your responsibility. The assembler cannot warn you about this, because it has no information about the processor mode at execution time.

If you attempt to access the SPSR when the processor is in User or System mode, the result is unpredictable.

## CPSR

The CPSR endianness bit (E) can be read in any privileged software execution.

The CPSR execution state bits, other than the E bit, can only be read when the processor is in Debug state, halting debug-mode. Otherwise, the execution state bits in the CPSR read as zero.

The condition flags can be read in any mode on any processor. Use APSR if you are only interested in accessing the condition code flags in User mode.

## Condition flags

This instruction does not change the flags.

## Architectures

This ARM instruction is available in all versions of the ARM architecture.

These 32-bit Thumb instructions are available in ARMv6T2 and above.

There is no 16-bit Thumb version of this instruction.

## See also

### Concepts

*Using the Assembler:*

- *Current Program Status Register* on page 3-23.

### Reference:

- *Condition codes* on page 3-186.

### 3.11.4 MSR

Load an immediate value, or the contents of a general-purpose register, into specified fields of a *Program Status Register* (PSR).

#### Syntax

`MSR{cond} APSR_flags, Rm`

where:

*cond* is an optional condition code.

*flags* specifies the APSR flags to be moved. *flags* can be one or more of:

- `nzcvq` ALU flags field mask, PSR[31:27] (User mode)
- `g` SIMD GE flags field mask, PSR[19:16] (User mode).

*Rm* is the source register.

#### Syntax (except ARMv7-M and ARMv6-M)

You can also use the following syntax on architectures other than ARMv7 and ARMv6M.

`MSR{cond} APSR_flags, #constant`

`MSR{cond} psr_fields, #constant`

`MSR{cond} psr_fields, Rm`

where:

*cond* is an optional condition code.

*flags* specifies the APSR flags to be moved. *flags* can be one or more of:

- `nzcvq` ALU flags field mask, PSR[31:27] (User mode)
- `g` SIMD GE flags field mask, PSR[19:16] (User mode).

*constant* is an expression evaluating to a numeric value. The value must correspond to an 8-bit pattern rotated by an even number of bits within a 32-bit word. Not available in Thumb.

*Rm* is the source register.

*psr* is one of:

- `CPSR` for use in Debug state, also deprecated synonym for APSR
- `SPSR` on any processor, in privileged software execution only.

<i>fields</i>	specifies the SPSR or CPSR fields to be moved. <i>fields</i> can be one or more of:
c	control field mask byte, PSR[7:0] (privileged software execution)
x	extension field mask byte, PSR[15:8] (privileged software execution)
s	status field mask byte, PSR[23:16] (privileged software execution)
f	flags field mask byte, PSR[31:24] (privileged software execution).

### Syntax (ARMv7-M and ARMv6-M only)

You can also use the following syntax on ARMv7 and ARMv6M.

`MSR{cond} psr, Rm`

where:

*cond* is an optional condition code.

*Rm* is the source register.

*psr* can be any of: APSR, IPSR, EPSR, IEPSR, IAPSR, EAPSR, XPSR, MSP, PSP, PRIMASK, BASEPRI, BASEPRI\_MAX, FAULTMASK, or CONTROL.

### Usage

In User mode:

- Use APSR to access condition flags, Q, or GE bits.
- Writes to unallocated, privileged or execution state bits in the CPSR are ignored. This ensures that User mode programs cannot change to privileged software execution.

If you access the SPSR when in User or System mode, the result is unpredictable.

### Condition flags

This instruction updates the flags explicitly if the `APSR_nzcvq` or `CPSR_f` field is specified.

### Architectures

This ARM instruction is available in all versions of the ARM architecture.

This 32-bit Thumb instruction is available in ARMv6T2 and above.

There is no 16-bit Thumb version of this instruction.

**See also****Reference:**

- *MRS* on page 3-155
- *Condition codes* on page 3-186.

### 3.11.5 CPS

CPS (Change Processor State) changes one or more of the mode, A, I, and F bits in the CPSR, without changing the other CPSR bits.

CPS is only allowed in privileged software execution, and has no effect in User mode.

CPS cannot be conditional, and is not allowed in an IT block.

#### Syntax

*CPSeffect iflags{, #mode}*

CPS *#mode*

where:

*effect* is one of:

- |    |                             |
|----|-----------------------------|
| IE | Interrupt or abort enable.  |
| ID | Interrupt or abort disable. |

*iflags* is a sequence of one or more of:

- |   |                                       |
|---|---------------------------------------|
| a | Enables or disables imprecise aborts. |
| i | Enables or disables IRQ interrupts.   |
| f | Enables or disables FIQ interrupts.   |

*mode* specifies the number of the mode to change to.

#### Condition flags

This instruction does not change the condition flags.

#### 16-bit instructions

The following forms of these instructions are available in Thumb code, and are 16-bit instructions:

- CPSIE *iflags*
- CPSID *iflags*

You cannot specify a mode change in a 16-bit Thumb instruction.

## Architectures

This ARM instruction is available in ARMv6 and above.

This 32-bit Thumb instruction are available in ARMv6T2 and above.

This 16-bit Thumb instruction is available in T variants of ARMv6 and above.

## Examples

```
CPSIE if      ; enable interrupts and fast interrupts
CPSID A       ; disable imprecise aborts
CPSID ai, #17 ; disable imprecise aborts and interrupts, and enter FIQ mode
CPS #16       ; enter User mode
```

### 3.11.6 SMC

Secure Monitor Call.

#### Syntax

`SMC{cond} #imm4`

where:

*cond* is an optional condition code.

*imm4* is a 4-bit immediate value. This is ignored by the ARM processor, but can be used by the SMC exception handler to determine what service is being requested.

#### Note

SMC was called SMI in earlier versions of the ARM assembly language. SMI instructions disassemble to SMC, with a comment to say that this was formerly SMI.

#### Architectures

This ARM instruction is available in implementations of ARMv6 and above, if they have the Security Extensions.

This 32-bit Thumb instruction is available in implementations of ARMv6T2 and above, if they have the Security Extensions.

There is no 16-bit Thumb version of this instruction.

#### See also

##### Reference:

- *Condition codes* on page 3-186
- *ARM Architecture Reference Manual*,  
<http://infocenter.arm.com/help/topic/com.arm.doc.subset.arch.reference/index.html>.



### 3.11.7 SETEND

Set the endianness bit in the CPSR, without affecting any other bits in the CPSR.

SETEND cannot be conditional, and is not allowed in an IT block.

#### Syntax

SETEND *specifier*

where:

<i>specifier</i>	is one of:
BE	Big-endian.
LE	Little-endian.

#### Usage

Use SETEND to access data of different endianness, for example, to access several big-endian DMA-formatted data fields from an otherwise little-endian application.

#### Architectures

This ARM instruction is available in ARMv6 and above.

This 16-bit Thumb instruction is available in T variants of ARMv6 and above, except the ARMv6-M and ARMv7-M profiles.

There is no 32-bit Thumb version of this instruction.

#### Example

```

SETEND BE          ; Set the CPSR E bit for big-endian accesses
LDR    r0, [r2, #header]
LDR    r1, [r2, #CRC32]
SETEND le          ; Set the CPSR E bit for little-endian accesses for the
                   ; rest of the application

```

### 3.11.8 NOP

No Operation.

#### Syntax

`NOP{cond}`

where:

*cond* is an optional condition code.

#### Usage

NOP does nothing. If NOP is not implemented as a specific instruction on your target architecture, the assembler treats it as a pseudo-instruction and generates an alternative instruction that does nothing, such as `MOV r0, r0` (ARM) or `MOV r8, r8` (Thumb).

NOP is not necessarily a time-consuming NOP. The processor might remove it from the pipeline before it reaches the execution stage.

You can use NOP for padding, for example to place the following instruction on a 64-bit boundary in ARM, or a 32-bit boundary in Thumb.

#### Architectures

This ARM instructions are available in ARMv6K and above.

This 32-bit Thumb instructions are available in ARMv6T2 and above.

This 16-bit Thumb instructions are available in ARMv6T2 and above.

NOP is available on all other ARM and Thumb architectures as a pseudo-instruction.

#### See also

#### Reference:

- *Condition codes* on page 3-186.

### 3.11.9 SEV, WFE, WFI, and YIELD

Set Event, Wait For Event, Wait for Interrupt, and Yield.

#### Syntax

SEV{*cond*}

WFE{*cond*}

WFI{*cond*}

YIELD{*cond*}

where:

*cond* is an optional condition code.

#### Usage

These are hint instructions. It is optional whether they are implemented or not. If any one of them is not implemented, it behaves as a NOP. The assembler produces a diagnostic message if the instruction executes as NOP on the target.

#### SEV

SEV causes an event to be signaled to all cores within a multiprocessor system. If SEV is implemented, WFE must also be implemented.

#### WFE

If the Event Register is not set, WFE suspends execution until one of the following events occurs:

- an IRQ interrupt, unless masked by the CPSR I-bit
- an FIQ interrupt, unless masked by the CPSR F-bit
- an Imprecise Data abort, unless masked by the CPSR A-bit
- a Debug Entry request, if Debug is enabled
- an Event signaled by another processor using the SEV instruction.

If the Event Register is set, WFE clears it and returns immediately.

If WFE is implemented, SEV must also be implemented.

#### WFI

WFI suspends execution until one of the following events occurs:

- an IRQ interrupt, regardless of the CPSR I-bit

- an FIQ interrupt, regardless of the CPSR F-bit
- an Imprecise Data abort, unless masked by the CPSR A-bit
- a Debug Entry request, regardless of whether Debug is enabled.

### ***YIELD***

YIELD indicates to the hardware that the current thread is performing a task, for example a spinlock, that can be swapped out. Hardware can use this hint to suspend and resume threads in a multithreading system.

### **Architectures**

These ARM instructions are available in ARMv6K and above.

These 32-bit Thumb instructions are available in ARMv6T2 and above.

These 16-bit Thumb instructions are available in ARMv6T2 and above.

SEV, WFE, WFI, and YIELD execute as NOP instructions in ARMv6T2.

### **See also**

#### **Reference:**

- *NOP* on page 3-164
- *Condition codes* on page 3-186.

### 3.11.10 DBG

Debug.

#### Syntax

DBG{*cond*} {*option*}

where:

*cond* is an optional condition code.

*option* is an optional limitation on the operation of the hint. The range is 0-15.

#### Usage

DBG is a hint instruction. It is optional whether they are implemented or not. If it is not implemented, it behaves as a NOP. The assembler produces a diagnostic message if the instruction executes as NOP on the target.

Debug hint provides a hint to debug and related systems. See their documentation for what use (if any) they make of this instruction.

#### Architectures

These ARM and 32-bit Thumb instructions are available in ARMv7.

There are no 16-bit Thumb versions of this instruction.

#### See also

##### Reference:

- *Condition codes* on page 3-186.

### 3.11.11 DMB, DSB, and ISB

Data Memory Barrier, Data Synchronization Barrier, and Instruction Synchronization Barrier.

#### Syntax

`DMB{cond} {option}`

`DSB{cond} {option}`

`ISB{cond} {option}`

where:

*cond* is an optional condition code.

*option* is an optional limitation on the operation of the hint.

#### Usage

##### **DMB**

Data Memory Barrier acts as a memory barrier. It ensures that all explicit memory accesses that appear in program order before the DMB instruction are observed before any explicit memory accesses that appear in program order after the DMB instruction. It does not affect the ordering of any other instructions executing on the processor.

Allowed values of *option* are:

SY	Full system DMB operation. This is the default and can be omitted.
ST	DMB operation that waits only for stores to complete.
ISH	DMB operation only to the inner shareable domain.
ISHST	DMB operation that waits only for stores to complete, and only to the inner shareable domain.
NSH	DMB operation only out to the point of unification.
NSHST	DMB operation that waits only for stores to complete and only out to the point of unification.
OSH	DMB operation only to the outer shareable domain.

OSHST          DMB operation that waits only for stores to complete, and only to the outer shareable domain.

### **DSB**

Data Synchronization Barrier acts as a special kind of memory barrier. No instruction in program order after this instruction executes until this instruction completes. This instruction completes when:

- All explicit memory accesses before this instruction complete.
- All Cache, Branch predictor and TLB maintenance operations before this instruction complete.

Allowed values of *option* are:

SY	Full system DSB operation. This is the default and can be omitted.
ST	DSB operation that waits only for stores to complete.
ISH	DSB operation only to the inner shareable domain.
ISHST	DSB operation that waits only for stores to complete, and only to the inner shareable domain.
NSH	DSB operation only out to the point of unification.
NSHST	DSB operation that waits only for stores to complete and only out to the point of unification.
OSH	DSB operation only to the outer shareable domain.
OSHST	DSB operation that waits only for stores to complete, and only to the outer shareable domain.

### **ISB**

Instruction Synchronization Barrier flushes the pipeline in the processor, so that all instructions following the ISB are fetched from cache or memory, after the instruction has been completed. It ensures that the effects of context altering operations, such as changing the ASID, or completed TLB maintenance operations, or branch predictor maintenance operations, as well as all changes to the CP15 registers, executed before the ISB instruction are visible to the instructions fetched after the ISB.

In addition, the ISB instruction ensures that any branches that appear in program order after it are always written into the branch prediction logic with the context that is visible after the ISB instruction. This is required to ensure correct execution of the instruction stream.

Allowed values of *option* are:

SY                    Full system ISB operation. This is the default, and can be omitted.

### Alias

The following alternative values of *option* are supported for DMB and DSB, but ARM recommends that you do not use them:

- SH is an alias for ISH
- SHST is an alias for ISHST
- UN is an alias for NSH
- UNST is an alias for NSHST

### Architectures

These ARM and 32-bit Thumb instructions are available in ARMv7.

There are no 16-bit Thumb versions of these instructions.

### See also

#### Reference:

- *Condition codes* on page 3-186.



### 3.11.12 MAR and MRA

Transfer between two general-purpose registers and a 40-bit internal accumulator.

#### Syntax

`MAR{cond} Acc, RdLo, RdHi`

`MRA{cond} RdLo, RdHi, Acc`

where:

*cond* is an optional condition code.

*Acc* is the internal accumulator. The standard name is *accx*, where *x* is an integer in the range 0 to *n*. The value of *n* depends on the processor. It is 0 for current processors.

*RdLo, RdHi* are general-purpose registers. *RdLo* and *RdHi* must not be the PC, and for MRA they must be different registers.

#### Usage

The MAR instruction copies the contents of *RdLo* to bits[31:0] of *Acc*, and the least significant byte of *RdHi* to bits[39:32] of *Acc*.

The MRA instruction:

- copies bits[31:0] of *Acc* to *RdLo*
- copies bits[39:32] of *Acc* to *RdHi* bits[7:0]
- sign extends the value by copying bit[39] of *Acc* to bits[31:8] of *RdHi*.

#### Architectures

These ARM coprocessor 0 instructions are only available in XScale processors.

There are no Thumb versions of these instructions.

#### Examples

```
MAR    acc0, r0, r1
MRA    r4, r5, acc0
MARNE  acc0, r9, r2
MRAGT  r4, r8, acc0
```

**See also**

**Reference:**

- *Condition codes* on page 3-186.

## 3.12 ThumbEE instructions

Apart from *ENTERX* and *LEAVEX*, these ThumbEE instructions are only accepted when the assembler has been switched into the ThumbEE state using the `--thumbx` command line option or the *THUMBX* directive.

This section contains the following subsections:

- *ENTERX* and *LEAVEX* on page 3-174  
Switch between Thumb state and ThumbEE state.
- *CHKA* on page 3-175  
Check array.
- *HB*, *HBL*, *HBLP*, and *HBP* on page 3-176  
Handler Branch, branches to a specified handler.

### 3.12.1 ENTERX and LEAVEX

Switch between Thumb state and ThumbEE state.

#### Syntax

ENTERX

LEAVEX

#### Usage

ENTERX causes a change from Thumb state to ThumbEE state, or has no effect in ThumbEE state.

LEAVEX causes a change from ThumbEE state to Thumb state, or has no effect in Thumb state.

Do not use ENTERX or LEAVEX in an IT block.

#### Architectures

These instructions are not available in the ARM instruction set.

These 32-bit Thumb and Thumb-2EE instructions are available in ARMv7, with Thumb-2EE support.

There are no 16-bit Thumb versions of these instructions.

#### See also

##### Reference:

- *ARM Architecture Reference Manual*,  
<http://infocenter.arm.com/help/topic/com.arm.doc.subset.arch.reference/index.html>.

### 3.12.2 CHKA

CHKA (Check Array) compares the unsigned values in two registers.

If the value in the first register is lower than, or the same as, the second, it copies the PC to the LR, and causes a branch to the IndexCheck handler.

#### Syntax

CHKA *Rn*, *Rm*

where:

*Rn* contains the array size. Do not use PC.

*Rm* contains the array index. Do not use SP or PC.

#### Architectures

This instruction is not available in ARM state.

This 16-bit ThumbEE instruction is only available in ARMv7, with Thumb-2EE support.

### 3.12.3 HB, HBL, HBLP, and HBP

Handler Branch, branches to a specified handler.

This instruction can optionally store a return address to the LR, pass a parameter to the handler, or both.

#### Syntax

HB{L} #*HandlerID*

HB{L}P #*imm*, #*HandlerID*

where:

L	is an optional suffix. If L is present, the instruction saves a return address in the LR.
P	is an optional suffix. If P is present, the instruction passes the value of <i>imm</i> to the handler in R8.
<i>imm</i>	is an immediate value. If L is present, <i>imm</i> must be in the range 0-31, otherwise <i>imm</i> must be in the range 0-7.
<i>HandlerID</i>	is the index number of the handler to be called. If P is present, <i>HandlerID</i> must be in the range 0-31, otherwise <i>HandlerID</i> must be in the range 0-255.

#### Architectures

These instructions are not available in ARM state.

These 16-bit ThumbEE instructions are only available in ThumbEE state, in ARMv7 with Thumb-2EE support.

### 3.13 Pseudo-instructions

The ARM assembler supports a number of pseudo-instructions that are translated into the appropriate combination of ARM, or Thumb instructions at assembly time.

The pseudo-instructions are described in the following sections:

- *ADRL pseudo-instruction* on page 3-178  
Load a PC-relative or register-relative address into a register (medium range, position independent)
- *MOV32 pseudo-instruction* on page 3-180  
Load a register with a 32-bit immediate value or an address (unlimited range, but not position independent). Available for ARMv6T2 and above only.
- *LDR pseudo-instruction* on page 3-182  
Load a register with a 32-bit immediate value or an address (unlimited range, but not position independent). Available for all ARM architectures.
- *UND pseudo-instruction* on page 3-185  
Generate an architecturally undefined instruction. Available for all ARM architectures.

### 3.13.1 ADRL pseudo-instruction

Load a PC-relative or register-relative address into a register. It is similar to the ADR instruction. ADRL can load a wider range of addresses than ADR because it generates two data processing instructions.

---

**Note**

---

ADRL is only available when assembling Thumb instructions ARMv6T2 and later.

---

#### Syntax

ADRL{*cond*} *Rd*, *label*

where:

*cond* is an optional condition code.

*Rd* is the register to load.

*label* is a PC-relative or register-relative expression.

#### Usage

ADRL always assembles to two 32-bit instructions. Even if the address can be reached in a single instruction, a second, redundant instruction is produced.

If the assembler cannot construct the address in two instructions, it generates an error message and the assembly fails. You can use the LDR pseudo-instruction for loading a wider range of addresses.

ADRL produces position-independent code, because the address is PC-relative or register-relative.

If *label* is PC-relative, it must evaluate to an address in the same assembler area as the ADRL pseudo-instruction.

If you use ADRL to generate a target for a BX or BLX instruction, it is your responsibility to set the Thumb bit (bit 0) of the address if the target contains Thumb instructions.



## Architectures and range

The available range depends on the instruction set in use:

<b>ARM</b>	±64KB to a byte or halfword-aligned address. ±256KB bytes to a word-aligned address.
<b>32-bit Thumb</b>	±1MB bytes to a byte, halfword, or word-aligned address.
<b>16-bit Thumb</b>	ADRL is not available.

The given range is relative to a point four bytes (in Thumb code) or two words (in ARM code) after the address of the current instruction. More distant addresses can be in range if the alignment is 16-bytes or more relative to this point.

## See also

### Concepts

*Using the Assembler:*

- *Register-relative and PC-relative expressions* on page 8-9
- *Load immediates into registers* on page 5-6.

### Reference:

- *LDR pseudo-instruction* on page 3-182
- *AREA* on page 6-81
- *Condition codes* on page 3-186.

### 3.13.2 MOV32 pseudo-instruction

Load a register with either:

- a 32-bit immediate value
- any address.

MOV32 always generates two 32-bit instructions, a MOV, MOV<sub>T</sub> pair. This allows you to load any 32-bit immediate, or to access the whole 32-bit address space.

#### Syntax

MOV32{*cond*} *Rd*, *expr*

where:

*cond* is an optional condition code.

*Rd* is the register to be loaded. *Rd* must not be SP or PC.

*expr* can be any one of the following:

<i>symbol</i>	A label in this or another program area.
<i>#constant</i>	Any 32-bit immediate value.
<i>symbol</i> + <i>constant</i>	A label plus a 32-bit immediate value.

#### Usage

The main purposes of the MOV32 pseudo-instruction are:

- To generate literal constants when an immediate value cannot be generated in a single instruction.
- To load a PC-relative or external address into a register. The address remains valid regardless of where the linker places the ELF section containing the MOV32.

#### ———— Note ————

An address loaded in this way is fixed at link time, so the code is *not* position-independent.

MOV32 sets the Thumb bit (bit 0) of the address if the label referenced is in Thumb code.

#### Architectures

This pseudo-instruction is available in ARMv6T2 and above in both ARM and Thumb.

**Examples**

```
MOV32 r3, #0xABCDEF12 ; loads 0xABCDEF12 into R3
MOV32 r1, Trigger+12   ; loads the address that is 12 bytes higher than
                        ; the address Trigger into R1
```

**See also****Reference:**

- *Condition codes* on page 3-186.

### 3.13.3 LDR pseudo-instruction

Load a register with either:

- a 32-bit immediate value
- an address.

---

**Note**

This section describes the LDR *pseudo*-instruction only, and not the LDR instruction.

---

#### Syntax

`LDR{cond}{.W} Rt, =expr`

`LDR{cond}{.W} Rt, =label_expr`

where:

*cond* is an optional condition code.

.W is an optional instruction width specifier.

*Rt* is the register to be loaded.

*expr* evaluates to a numeric value.

*label\_expr* is a PC-relative or external expression of an address in the form of a label plus or minus a numeric value.

#### Usage

When using the LDR pseudo-instruction:

- If the value of *expr* can be loaded with a valid MOV or MVN instruction, the assembler uses that instruction.
- If a valid MOV or MVN instruction cannot be used, or if the *label\_expr* syntax is used, the assembler places the constant in a literal pool and generates a PC-relative LDR instruction that reads the constant from the literal pool.

---

**Note**

— An address loaded in this way is fixed at link time, so the code is *not* position-independent.

— The address holding the constant remains valid regardless of where the linker places the ELF section containing the LDR instruction.

---

The assembler places the value of *label\_expr* in a literal pool and generates a PC-relative LDR instruction that loads the value from the literal pool.

If *label\_expr* is an external expression, or is not contained in the current section, the assembler places a linker relocation directive in the object file. The linker generates the address at link time.

If *label\_expr* is a local label, the assembler places a linker relocation directive in the object file and generates a symbol for that local label. The address is generated at link time. If the local label references Thumb code, the Thumb bit (bit 0) of the address is set.

The offset from the PC to the value in the literal pool must be less than  $\pm 4\text{KB}$  (ARM, 32-bit Thumb-2) or in the range 0 to +1KB (16-bit Thumb-2, pre-Thumb2 Thumb). You are responsible for ensuring that there is a literal pool within range.

If the label referenced is in Thumb code, the LDR pseudo-instruction sets the Thumb bit (bit 0) of *label\_expr*.

#### ————— Note —————

In *RealView Compilation Tools* (RVCT) v2.2, the Thumb bit of the address was not set. If you have code that relies on this behavior, use the command line option `--untyped_local_labels` to force the assembler not to set the Thumb bit when referencing labels in Thumb code.

## LDR in Thumb code

You can use the `.w` width specifier to force LDR to generate a 32-bit instruction in Thumb code on ARMv6T2 and above processors. LDR.w always generates a 32-bit instruction, even if the immediate value could be loaded in a 16-bit MOV, or there is a literal pool within reach of a 16-bit PC-relative load.

If the value to be loaded is not known in the first pass of the assembler, LDR without `.w` generates a 16-bit instruction in Thumb code, even if that results in a 16-bit PC-relative load for a value that could be generated in a 32-bit MOV or MVN instruction. However, if the value is known in the first pass, and it can be generated using a 32-bit MOV or MVN instruction, the MOV or MVN instruction is used.

The LDR pseudo-instruction never generates a 16-bit flag-setting MOV instruction. Use the `--diag_warning 1727` assembler command-line option to check when a 16-bit instruction could have been used.

You can use the MOV32 pseudo-instruction for generating immediate values or addresses without loading from a literal pool.

**Examples**

```

LDR    r3,=0xff0    ; loads 0xff0 into R3
                    ; => MOV.W r3,#0xff0
LDR    r1,=0xffff    ; loads 0xffff into R1
                    ; => LDR r1,[pc,offset_to_litpool]
                    ;
                    ;    ...
                    ;    litpool DCD 0xffff
LDR    r2,=pplace    ; loads the address of
                    ; pplace into R2
                    ; => LDR r2,[pc,offset_to_litpool]
                    ;
                    ;    ...
                    ;    litpool DCD pplace

```

**See also****Concepts**

*Using the Assembler:*

- *Numeric constants* on page 8-6
- *Register-relative and PC-relative expressions* on page 8-9
- *Local labels* on page 8-15
- *Load immediates into registers* on page 5-6
- *Load immediate 32-bit values to a register using LDR Rd, =const* on page 5-12.

**Reference:**

- *Memory access instructions* on page 3-12
- *LTORG* on page 6-20
- *MOV32 pseudo-instruction* on page 3-180
- *Condition codes* on page 3-186.

### 3.13.4 UND pseudo-instruction

Generate an architecturally undefined instruction. An attempt to execute an undefined instruction causes the Undefined instruction exception. Architecturally undefined instructions are expected to remain undefined.

#### Syntax

UND{*cond*}{.W} {#*expr*}

where:

*cond* is an optional condition code.

.W is an optional instruction width specifier.

*expr* evaluates to a numeric value. Table 3-10 shows the range and encoding of *expr* in the instruction, where Y shows the locations of the bits that encode for *expr* and V is the 4 bits that encode for the condition code. If *expr* is omitted, the value 0 is used.

**Table 3-10 Range and encoding of *expr***

Instruction	Encoding	Number of bits for <i>expr</i>	Range
ARM	0xV7FYYYFY	16	0-65535
32-bit Thumb	0xF7FYAYFY	12	0-4095
16-bit Thumb	0xDEYY	8	0-255

#### UND in Thumb code

You can use the .W width specifier to force UND to generate a 32-bit instruction in Thumb code on ARMv6T2 and above processors. UND.W always generates a 32-bit instruction, even if *expr* is in the range 0-255.

#### Disassembly

The encodings that this pseudo-instruction produces disassemble to DCI.

#### See also

#### Reference:

- *Condition codes* on page 3-186.

### 3.14 Condition codes

The instructions that can be conditional have an optional condition code, shown in syntax descriptions as {*cond*}. Table 3-11 shows the condition codes that you can use.

Table 3-11 Condition code suffixes

Suffix	Meaning
EQ	Equal
NE	Not equal
CS	Carry set (identical to HS)
HS	Unsigned higher or same (identical to CS)
CC	Carry clear (identical to LO)
LO	Unsigned lower (identical to CC)
MI	Minus or negative result
PL	Positive or zero result
VS	Overflow
VC	No overflow
HI	Unsigned higher
LS	Unsigned lower or same
GE	Signed greater than or equal
LT	Signed less than
GT	Signed greater than
LE	Signed less than or equal
AL	Always (this is the default)

———— **Note** ————

The precise meanings of the condition codes depend on whether the condition code flags were set by a VFP instruction or by an ARM data processing instruction.

**See also**

- *IT* on page 3-134



- *VMRS and VMSR* on page 4-17.

*Using the Assembler:*

- *Condition code meanings* on page 6-9
- *Conditional execution of NEON and VFP instructions* on page 9-11.



# Chapter 4

## NEON and VFP Programming

The following topics describe the assembly programming of NEON™ and the VFP coprocessor:

- *Instruction summary* on page 4-2
- *Instructions shared by NEON and VFP* on page 4-8
- *NEON logical and compare operations* on page 4-18
- *NEON general data processing instructions* on page 4-28
- *NEON shift instructions* on page 4-42
- *NEON general arithmetic instructions* on page 4-50
- *NEON multiply instructions* on page 4-66
- *NEON load and store element and structure instructions* on page 4-74
- *NEON and VFP pseudo-instructions* on page 4-82
- *VFP instructions* on page 4-91.

4.1 Instruction summary

This section provides a summary of the NEON and VFP instructions. Use it to locate individual instructions and pseudo-instructions. It contains:

- *NEON instructions*
- *Shared NEON and VFP instructions* on page 4-5
- *VFP instructions* on page 4-6.

4.1.1 NEON instructions

Table 4-1 shows a summary of NEON instructions. These instructions are not available in VFP.

Table 4-1 Location of NEON instructions

Mnemonic	Brief description	See
VABA, VABD	Absolute difference, Absolute difference and Accumulate	page 4-51
VABS	Absolute value	page 4-52
VACGE, VACGT	Absolute Compare Greater than or Equal, Greater Than	page 4-24
VACLE, VACLT	Absolute Compare Less than or Equal, Less Than (pseudo-instructions)	page 4-89
VADD	Add	page 4-53
VADDHN	Add, select High half	page 4-55
VAND	Bitwise AND	page 4-19
VAND	Bitwise AND (pseudo-instruction)	page 4-87
VBIC	Bitwise Bit Clear (register)	page 4-19
VBIC	Bitwise Bit Clear (immediate)	page 4-20
VBIF, VBIT, VBSL	Bitwise Insert if False, Insert if True, Select	page 4-22
VCEQ, VCLE, VCLT	Compare Equal, Less than or Equal, Compare Less Than	page 4-25
VCGE, VCGT	Compare Greater than or Equal, Greater Than	page 4-25
VCLE, VCLT	Compare Less than or Equal, Compare Less Than (pseudo-instruction)	page 4-90
VCLS, VC LZ, VCNT	Count Leading Sign bits, Count Leading Zeros, and Count set bits	page 4-61
VCVT	Convert fixed-point or integer to floating point, floating-point to integer or fixed-point	page 4-29
VCVT	Convert between half-precision and single-precision floating-point numbers	page 4-31

**Table 4-1 Location of NEON instructions (continued)**

<b>Mnemonic</b>	<b>Brief description</b>	<b>See</b>
VDUP	Duplicate scalar to all lanes of vector	page 4-32
VEOR	Bitwise Exclusive OR	page 4-19
VEXT	Extract	page 4-33
VFMA, VFMS	Fused Multiply Accumulate, Fused Multiply Subtract (vector)	page 4-71
VHADD, VHSUB	Halving Add, Halving Subtract	page 4-56
VLD	Vector Load	page 4-74
VMAX, VMIN	Maximum, Minimum	page 4-59
VMLA, VMLS	Multiply Accumulate, Multiply Subtract (vector)	page 4-67
VMLA, VMLS	Multiply Accumulate, Multiply Subtract (by scalar)	page 4-69
VMOV	Move (immediate)	page 4-34
VMOV	Move (register)	page 4-23
VMOVL, VMOV{U}N	Move Long, Move Narrow (register)	page 4-35
VMUL	Multiply (vector)	page 4-67
VMUL	Multiply (by scalar)	page 4-69
VMVN	Move Negative (immediate)	page 4-34
VNEG	Negate	page 4-52
VORN	Bitwise OR NOT	page 4-19
VORN	Bitwise OR NOT (pseudo-instruction)	page 4-87
VORR	Bitwise OR (register)	page 4-19
VORR	Bitwise OR (immediate)	page 4-20
VPADD, VPADAL	Pairwise Add, Pairwise Add and Accumulate	page 4-57
VPMAX, VPMIN	Pairwise Maximum, Pairwise Minimum	page 4-59
VQABS	Absolute value, saturate	page 4-52
VQADD	Add, saturate	page 4-53
VQDMLAL, VQDMLSL	Saturating Doubling Multiply Accumulate, and Multiply Subtract	page 4-72

**Table 4-1 Location of NEON instructions (continued)**

<b>Mnemonic</b>	<b>Brief description</b>	<b>See</b>
VQDMUL	Saturating Doubling Multiply	page 4-72
VQDMULH	Saturating Doubling Multiply returning High half	page 4-73
VQMOV{U}N	Saturating Move (register)	page 4-35
VQNEG	Negate, saturate	page 4-52
VQRDMULH	Saturating Doubling Multiply returning High half	page 4-73
VQRSHL	Shift Left, Round, saturate (by signed variable)	page 4-45
VQRSHR	Shift Right, Round, saturate (by immediate)	page 4-48
VQSHL	Shift Left, saturate (by immediate)	page 4-43
VQSHL	Shift Left, saturate (by signed variable)	page 4-45
VQSHR	Shift Right, saturate (by immediate)	page 4-48
VQSUB	Subtract, saturate	page 4-53
VRADDH	Add, select High half, Round	page 4-55
VRECPE	Reciprocal Estimate	page 4-62
VRECPS	Reciprocal Step	page 4-64
VREV	Reverse elements	page 4-36
VRHADD	Halving Add, Round	page 4-56
VRSHR, VRSRA	Shift Right and Round, Shift Right, Round, and Accumulate (by immediate)	page 4-46
VRSQRTE	Reciprocal Square Root Estimate	page 4-62
VRSQRTS	Reciprocal Square Root Step	page 4-64
VRSUBH	Subtract, select High half, Round	page 4-55
VSHL	Shift Left (by immediate)	page 4-43
VSHR	Shift Right (by immediate)	page 4-46
VSLI	Shift Left and Insert	page 4-49
VSRA	Shift Right, Accumulate (by immediate)	page 4-46
VSRI	Shift Right and Insert	page 4-49

**Table 4-1 Location of NEON instructions (continued)**

<b>Mnemonic</b>	<b>Brief description</b>	<b>See</b>
VST	Vector Store	page 4-74
VSUB	Subtract	page 4-53
VSUBH	Subtract, select High half	page 4-55
VSWP	Swap vectors	page 4-37
VTBL, VTBX	Vector table look-up	page 4-38
VTRN	Vector transpose	page 4-39
VTST	Test bits	page 4-27
VUZP, VZIP	Vector interleave and de-interleave	page 4-40

#### 4.1.2 Shared NEON and VFP instructions

Table 4-2 shows a summary of instructions that are common to NEON and VFP.

**Table 4-2 Location of shared NEON and VFP instructions**

<b>Mnemonic</b>	<b>Brief description</b>	<b>See</b>	<b>Op.</b>	<b>Arch.</b>
VLDM	Load multiple	page 4-11	-	All
VLDR	Load (see also <i>VLDR pseudo-instruction</i> on page 4-83)	page 4-9	Scalar	All
	Load (post-increment and pre-decrement)	page 4-84	Scalar	All
VMOV	Transfer from one ARM register to half of a doubleword register	page 4-15	Scalar	All
	Transfer from two ARM registers to a doubleword register	page 4-13	Scalar	VFPv2
	Transfer from half of a doubleword register to ARM register	page 4-15	Scalar	All
	Transfer from a doubleword register to two ARM registers	page 4-13	Scalar	VFPv2
	Transfer from single-precision to ARM register	page 4-16	Scalar	All
	Transfer from ARM register to single-precision	page 4-16	Scalar	All
VMRS	Transfer from NEON and VFP system register to ARM register	page 4-17	-	All
VMSR	Transfer from ARM register to NEON and VFP system register	page 4-17	-	All
VPOP	Pop VFP or NEON registers from full-descending stack	page 4-11	-	All

**Table 4-2 Location of shared NEON and VFP instructions (continued)**

<b>Mnemonic</b>	<b>Brief description</b>	<b>See</b>	<b>Op.</b>	<b>Arch.</b>
VPUH	Push VFP or NEON registers to full-descending stack	page 4-11	-	All
VSTM	Store multiple	page 4-11	-	All
VSTR	Store	page 4-9	Scalar	All
	Store (post-increment and pre-decrement)	page 4-84	Scalar	All

### 4.1.3 VFP instructions

Table 4-3 shows a summary of VFP instructions that are not available in NEON.

**Table 4-3 Location of VFP instructions**

<b>Mnemonic</b>	<b>Brief description</b>	<b>See</b>	<b>Op.</b>	<b>Arch.</b>
VABS	Absolute value	page 4-92	Vector	All
VADD	Add	page 4-94	Vector	All
VCMP	Compare	page 4-100	Scalar	All
VCVT	Convert between single-precision and double-precision	page 4-101	Scalar	All
	Convert between floating-point and integer	page 4-102	Scalar	All
	Convert between floating-point and fixed-point	page 4-103	Scalar	VFPv3
VCVTB, VCVTT	Convert between half-precision and single-precision floating-point	page 4-105	Scalar	Half-precision
VDIV	Divide	page 4-94	Vector	All
VFMA, VFMS	Fused multiply accumulate, Fused multiply subtract	page 4-98	Scalar	VFPv4
VFNMA, VFNMS	Fused multiply accumulate with negation, Fused multiply subtract with negation	page 4-98	Scalar	VFPv4
VMLA	Multiply accumulate	page 4-96	Vector	All
VMLS	Multiply subtract	page 4-96	Vector	All
VMOV	Insert floating-point immediate in single-precision or double-precision register (see also Table 4-2 on page 4-5)	page 4-106	Scalar	VFPv3
VMUL	Multiply	page 4-96	Vector	All



**Table 4-3 Location of VFP instructions (continued)**

<b>Mnemonic</b>	<b>Brief description</b>	<b>See</b>	<b>Op.</b>	<b>Arch.</b>
VNEG	Negate	page 4-92	Vector	All
VNMLA	Negated multiply accumulate	page 4-96	Vector	All
VNMLS	Negated multiply subtract	page 4-96	Vector	All
VNMUL	Negated multiply	page 4-96	Vector	All
VSQRT	Square Root	page 4-92	Vector	All
VSUB	Subtract	page 4-94	Vector	All

## 4.2 Instructions shared by NEON and VFP

This section contains the following subsections:

- *VLDR and VSTR* on page 4-9  
Extension register load and store.
- *VLDM, VSTM, VPOP, and VPUSH* on page 4-11  
Extension register load and store multiple.
- *VMOV (between two ARM registers and an extension register)* on page 4-13  
Transfer contents between two ARM registers and a 64-bit extension register.
- *VMOV (between an ARM register and a NEON scalar)* on page 4-15  
Transfer contents between an ARM register and a half of a 64-bit extension register.
- *VMOV (between one ARM register and single precision VFP)* on page 4-16  
Transfer contents between a 32-bit extension register and an ARM register.
- *VMRS and VMSR* on page 4-17  
Transfer contents between an ARM register and a NEON and VFP system register.

## 4.2.1 VLDR and VSTR

Extension register load and store.

### Syntax

`VLDR{cond}{.size} Fd, [Rn{, #offset}]`

`VSTR{cond}{.size} Fd, [Rn{, #offset}]`

`VLDR{cond}{.size} Fd, label`

`VSTR{cond}{.size} Fd, label`

where:

<i>cond</i>	is an optional condition code.
<i>size</i>	is an optional data size specifier. Must be 32 if <i>Fd</i> is an S register, or 64 otherwise.
<i>Fd</i>	is the extension register to be loaded or saved. For a NEON instruction, it must be a D register. For a VFP instruction, it can be either a D or S register.
<i>Rn</i>	is the ARM register holding the base address for the transfer.
<i>offset</i>	is an optional numeric expression. It must evaluate to a numeric value at assembly time. The value must be a multiple of 4, and lie in the range –1020 to +1020. The value is added to the base address to form the address used for the transfer.
<i>label</i>	is a PC-relative expression. <i>label</i> must be aligned on a word boundary within ±1KB of the current instruction.

### Usage

The VLDR instruction loads an extension register from memory. The VSTR instruction saves the contents of an extension register to memory.

One word is transferred if *Fd* is an S register (VFP only). Two words are transferred otherwise.

There is also an VLDR pseudo-instruction.

## See also

### Concepts

*Using the Assembler:*

- *Register-relative and PC-relative expressions* on page 8-9.

### Reference:

- *Condition codes* on page 3-186
- *VLDR pseudo-instruction* on page 4-83.

## 4.2.2 VLDM, VSTM, VPOP, and VPUSH

Extension register load multiple, store multiple, pop from stack, push onto stack.

### Syntax

*VLDM**mode*{*cond*} *Rn*{!}, *Registers*

*VSTM**mode*{*cond*} *Rn*{!}, *Registers*

*VPOP*{*cond*} *Registers*

*VPUSH*{*cond*} *Registers*

where:

<i>mode</i>	must be one of:
IA	meaning Increment address After each transfer. IA is the default, and can be omitted.
DB	meaning Decrement address Before each transfer.
EA	meaning Empty Ascending stack operation. This is the same as DB for loads, and the same as IA for saves.
FD	meaning Full Descending stack operation. This is the same as IA for loads, and the same as DB for saves.
<i>cond</i>	is an optional condition code.
<i>Rn</i>	is the ARM register holding the base address for the transfer.
!	is optional. ! specifies that the updated base address must be written back to <i>Rn</i> . If ! is not specified, <i>mode</i> must be IA.
<i>Registers</i>	is a list of consecutive extension registers enclosed in braces, { and }. The list can be comma-separated, or in range format. There must be at least one register in the list.  You can specify S, D, or Q registers, but they must not be mixed. The number of registers must not exceed 16 D registers, or 8 Q registers. If Q registers are specified, on disassembly they are shown as D registers.

### Note

*VPOP Registers* is equivalent to *VLDM sp!, Registers*.

*VPUSH Registers* is equivalent to *VSTMDB sp!, Registers*.

You can use either form of these instructions. They disassemble to *VPOP* and *VPUSH*.

## See also

### Concepts

*Using the Assembler:*

- *Stack implementation using LDM and STM* on page 5-28.

### Reference:

- *Condition codes* on page 3-186.

### 4.2.3 VMOV (between two ARM registers and an extension register)

Transfer contents between two ARM registers and a 64-bit extension register, or two consecutive 32-bit VFP registers.

#### Syntax

`VMOV{cond} Dm, Rd, Rn`

`VMOV{cond} Rd, Rn, Dm`

`VMOV{cond} Sm, Sm1, Rd, Rn`

`VMOV{cond} Rd, Rn, Sm, Sm1`

where:

*cond* is an optional condition code.

*Dm* is a 64-bit extension register.

*Sm* is a VFP 32-bit register.

*Sm1* is the next consecutive VFP 32-bit register after *Sm*.

*Rd, Rn* are the ARM registers. Do not use PC.

#### Usage

`VMOV Dm, Rd, Rn` transfers the contents of *Rd* into the low half of *Dm*, and the contents of *Rn* into the high half of *Dm*.

`VMOV Rd, Rn, Dm` transfers the contents of the low half of *Dm* into *Rd*, and the contents of the high half of *Dm* into *Rn*.

`VMOV Rd, Rn, Sm, Sm1` transfers the contents of *Sm* into *Rd*, and the contents of *Sm1* into *Rn*.

`VMOV Sm, Sm1, Rd, Rn` transfers the contents of *Rd* into *Sm*, and the contents of *Rn* into *Sm1*.

#### Architectures

The 64-bit instructions are available in:

- NEON
- VFPv2 and above.

The 2 x 32-bit instructions are available in VFPv2 and above.

**See also**

**Reference:**

- *Condition codes* on page 3-186.



#### 4.2.4 VMOV (between an ARM register and a NEON scalar)

Transfer contents between an ARM register and a NEON scalar.

##### Syntax

`VMOV{cond}{.size} Dn[x], Rd`

`VMOV{cond}{.datatype} Rd, Dn[x]`

where:

*cond* is an optional condition code.

*size* the data size. Can be 8, 16, or 32. If omitted, *size* is 32. For VFP instructions, *size* must be 32 or omitted.

*datatype* the data type. Can be U8, S8, U16, S16, or 32. If omitted, *datatype* is 32. For VFP instructions, *datatype* must be 32 or omitted.

*Dn*[*x*] is the NEON scalar.

*Rd* is the ARM register. *Rd* must not be PC.

##### Usage

`VMOV Rd, Dn[x]` transfers the contents of *Dn*[*x*] into the least significant byte, halfword, or word of *Rd*. The remaining bits of *Rd* are either zero or sign extended.

`VMOV Dn[x], Rd` transfers the contents of the least significant byte, halfword, or word of *Rd* into *Sn*.

##### See also

##### Concepts

*Using the Assembler:*

- *NEON scalars* on page 9-22.

##### Reference:

- *Condition codes* on page 3-186.

#### 4.2.5 VMOV (between one ARM register and single precision VFP)

Transfer contents between a single-precision floating-point register and an ARM register.

##### Syntax

VMOV{*cond*} *Rd*, *Sn*

VMOV{*cond*} *Sn*, *Rd*

where:

*cond* is an optional condition code.

*Sn* is the VFP single-precision register.

*Rd* is the ARM register. *Rd* must not be PC.

##### Usage

VMOV *Rd*, *Sn* transfers the contents of *Sn* into *Rd*.

VMOV *Sn*, *Rd* transfers the contents of *Rd* into *Sn*.

##### See also

##### Reference:

- *Condition codes* on page 3-186.

## 4.2.6 VMRS and VMSR

Transfer contents between an ARM register and a NEON and VFP system register.

### Syntax

`VMRS{cond} Rd, extsysreg`

`VMSR{cond} extsysreg, Rd`

where:

*cond* is an optional condition code.

*extsysreg* is the NEON and VFP system register, usually FPSCR, FPSID, or FPEXC.

*Rd* is the ARM register. *Rd* must not be PC.

It can be APSR\_nzcv, if *extsysreg* is FPSCR. In this case, the floating-point status flags are transferred into the corresponding flags in the ARM APSR.

### Usage

The VMRS instruction transfers the contents of *extsysreg* into *Rd*.

The VMSR instruction transfers the contents of *Rd* into *extsysreg*.

#### Note

These instructions stall the ARM until all current NEON or VFP operations complete.

### Examples

```
VMRS    r2, FPSID
VMRS    APSR_nzcv, FPSCR    ; transfer FP status register to ARM APSR
VMSR    FPSCR, r4
```

### See also

#### Concepts

*Using the Assembler:*

- *NEON and VFP system registers* on page 9-25.

#### Reference:

- *Condition codes* on page 3-186.

## 4.3 NEON logical and compare operations

This section contains the following subsections:

- *VAND, VBIC, VEOR, VORN, and VORR (register)* on page 4-19  
Bitwise AND, Bit Clear, Exclusive OR, OR Not, and OR (register).
- *VBIC and VORR (immediate)* on page 4-20  
Bitwise Bit Clear and OR (immediate).
- *VBIF, VBIT, and VBSL* on page 4-22  
Bitwise Insert if False, Insert if True, and Select.
- *VMOV, VMVN (register)* on page 4-23  
Move, and Move NOT.
- *VACGE and VACGT* on page 4-24  
Compare Absolute.
- *VCEQ, VCGE, VCGT, VCLE, and VCLT* on page 4-25  
Compare.
- *VTST* on page 4-27  
Test bits.

### 4.3.1 VAND, VBIC, VEOR, VORN, and VORR (register)

VAND (Bitwise AND), VBIC (Bit Clear), VEOR (Bitwise Exclusive OR), VORN (Bitwise OR NOT), and VORR (Bitwise OR) instructions perform bitwise logical operations between two registers, and place the results in the destination register.

#### Syntax

*Vop{cond}{.datatype} {Qd}, Qn, Qm*

*Vop{cond}{.datatype} {Dd}, Dn, Dm*

where:

*op* must be one of:

AND	Logical AND
ORR	Logical OR
EOR	Logical exclusive OR
BIC	Logical AND complement
ORN	Logical OR complement.

*cond* is an optional condition code.

*datatype* is an optional data type. The assembler ignores *datatype*.

*Qd, Qn, Qm* specifies the destination register, the first operand register, and the second operand register, for a quadword operation.

*Dd, Dn, Dm* specifies the destination register, the first operand register, and the second operand register, for a doubleword operation.

#### Note

VORR with the same register for both operands is a VMOV instruction. You can use VORR in this way, but disassembly of the resulting code produces the VMOV syntax.

#### See also

#### Reference:

- *VMOV, VMVN (register)* on page 4-23
- *Condition codes* on page 3-186.

4.3.2 VBIC and VORR (immediate)

VBIC (Bit Clear immediate) takes each element of the destination vector, performs a bitwise AND Complement with an immediate value, and returns the result into the destination vector.

VORR (Bitwise OR immediate) takes each element of the destination vector, performs a bitwise OR with an immediate value, and returns the result into the destination vector.

Syntax

*Vop{cond}.datatype Qd, #imm*

*Vop{cond}.datatype Dd, #imm*

where:

- op* must be either BIC or ORR.
- cond* is an optional condition code.
- datatype* must be either I8, I16, I32, or I64.
- Qd* or *Dd* is the NEON register for the source and result.
- imm* is the immediate value.

Immediate values

You can either specify *imm* as a pattern which the assembler repeats to fill the destination register, or you can directly specify the immediate value (that conforms to the pattern) in full. The pattern for *imm* depends on *datatype* as shown in Table 4-4:

Table 4-4 Patterns for immediate value	
I16	I32
0x00XY	0x000000XY
0xXY00	0x0000XY00
	0x00XY0000
	0xXY000000

If you use the I8 or I64 datatypes, the assembler will convert it to either the I16 or I32 instruction to match the pattern of *imm*. If the immediate value does not match any of the patterns in Table 4-4, the assembler generates an error.

**See also****Reference:**

- *VAND and VORN (immediate)* on page 4-87
- *Condition codes* on page 3-186.

### 4.3.3 VBIF, VBIT, and VBSL

VBIT (Bitwise Insert if True) inserts each bit from the first operand into the destination if the corresponding bit of the second operand is 1, otherwise leaves the destination bit unchanged.

VBIF (Bitwise Insert if False) inserts each bit from the first operand into the destination if the corresponding bit of the second operand is 0, otherwise leaves the destination bit unchanged.

VBSL (Bitwise Select) selects each bit for the destination from the first operand if the corresponding bit of the destination is 1, or from the second operand if the corresponding bit of the destination is 0.

#### Syntax

*Vop*{*cond*}.{*datatype*} {*Qd*}, *Qn*, *Qm*

*Vop*{*cond*}.{*datatype*} {*Dd*}, *Dn*, *Dm*

where:

*op* must be one of BIT, BIF, or BSL.

*cond* is an optional condition code.

*datatype* is an optional datatype. The assembler ignores *datatype*.

*Qd*, *Qn*, *Qm* specifies the destination register, the first operand register, and the second operand register, for a quadword operation.

*Dd*, *Dn*, *Dm* specifies the destination register, the first operand register, and the second operand register, for a doubleword operation.

#### See also

#### Reference:

- *Condition codes* on page 3-186.



#### 4.3.4 VMOV, VMVN (register)

Vector Move (register) copies a value from the source register into the destination register.

Vector Move Not (register) inverts the value of each bit from the source register and places the results into the destination register.

##### Syntax

`VMOV{cond}{.datatype} Qd, Qm`

`VMOV{cond}{.datatype} Dd, Dm`

`VMVN{cond}{.datatype} Qd, Qm`

`VMVN{cond}{.datatype} Dd, Dm`

where:

*cond* is an optional condition code.

*datatype* is an optional datatype. The assembler ignores *datatype*.

*Qd*, *Qm* specifies the destination vector and the source vector, for a quadword operation.

*Dd*, *Dm* specifies the destination vector and the source vector, for a doubleword operation.

##### See also

##### Reference:

- *Condition codes* on page 3-186.

### 4.3.5 VACGE and VACGT

Vector Absolute Compare takes the absolute value of each element in a vector, and compares it with the absolute value of the corresponding element of a second vector. If the condition is true, the corresponding element in the destination vector is set to all ones. Otherwise, it is set to all zeros.

#### Syntax

$VACop\{cond\}.F32 \{Qd\}, Qn, Qm$

$VACop\{cond\}.F32 \{Dd\}, Dn, Dm$

where:

*op* must be one of:

GE	Absolute Greater than or Equal
GT	Absolute Greater Than.

*cond* is an optional condition code.

*Qd, Qn, Qm* specifies the destination register, the first operand register, and the second operand register, for a quadword operation.

*Dd, Dn, Dm* specifies the destination register, the first operand register, and the second operand register, for a doubleword operation.

The result datatype is I32.

#### See also

#### Reference:

- *VACLE and VACLT* on page 4-89
- *Condition codes* on page 3-186.

### 4.3.6 VCEQ, VCGE, VCGT, VCLE, and VCLT

Vector Compare takes the value of each element in a vector, and compares it with the value of the corresponding element of a second vector, or zero. If the condition is true, the corresponding element in the destination vector is set to all ones. Otherwise, it is set to all zeros.

#### Syntax

$\text{VCop}\{\text{cond}\}.\text{datatype } \{Qd\}, Qn, Qm$

$\text{VCop}\{\text{cond}\}.\text{datatype } \{Dd\}, Dn, Dm$

$\text{VCop}\{\text{cond}\}.\text{datatype } \{Qd\}, Qn, \#0$

$\text{VCop}\{\text{cond}\}.\text{datatype } \{Dd\}, Dn, \#0$

where:

*op* must be one of:

EQ	Equal
GE	Greater than or Equal
GT	Greater Than
LE	Less than or Equal (only if the second operand is #0)
LT	Less Than (only if the second operand is #0).

*cond* is an optional condition code.

*datatype* must be one of:

- I8, I16, I32, or F32 for EQ
- S8, S16, S32, U8, U16, U32, or F32 for GE, GT, LE, or LT (except #0 form)
- S8, S16, S32, or F32 for GE, GT, LE, or LT (#0 form).

The result datatype is:

- I32 for operand datatypes I32, S32, U32, or F32
- I16 for operand datatypes I16, S16, or U16
- I8 for operand datatypes I8, S8, or U8.

*Qd, Qn, Qm* specifies the destination register, the first operand register, and the second operand register, for a quadword operation.

*Dd, Dn, Dm* specifies the destination register, the first operand register, and the second operand register, for a doubleword operation.

*#0* replaces *Qm* or *Dm* for comparisons with zero.

## See also

### Reference:

- *VCLE and VCLT* on page 4-90
- *Condition codes* on page 3-186.

### 4.3.7 VTST

VTST (Vector Test Bits) takes each element in a vector, and bitwise logical ANDs them with the corresponding element of a second vector. If the result is not zero, the corresponding element in the destination vector is set to all ones. Otherwise, it is set to all zeros.

#### Syntax

`VTST{cond}.size {Qd}, Qn, Qm`

`VTST{cond}.size {Dd}, Dn, Dm`

where:

*cond* is an optional condition code.

*size* must be one of 8, 16, or 32.

*Qd, Qn, Qm* specifies the destination register, the first operand register, and the second operand register, for a quadword operation.

*Dd, Dn, Dm* specifies the destination register, the first operand register, and the second operand register, for a doubleword operation.

#### See also

#### Reference:

- *Condition codes* on page 3-186.

## 4.4 NEON general data processing instructions

This section contains the following subsections:

- *VCVT (between fixed-point or integer, and floating-point)* on page 4-29  
Vector convert between fixed-point or integer and floating-point.
- *VCVT (between half-precision and single-precision floating-point)* on page 4-31  
Vector convert between half-precision and single-precision floating-point.
- *VDUP* on page 4-32  
Duplicate scalar to all lanes of vector.
- *VEXT* on page 4-33  
Extract.
- *VMOV, VMVN (immediate)* on page 4-34  
Move and Move Negative (immediate).
- *VMOVL, V{Q}MOVN, VQMOVUN* on page 4-35  
Move (register).
- *VREV* on page 4-36  
Reverse elements within a vector.
- *VSWP* on page 4-37  
Swap vectors.
- *VTBL, VTBX* on page 4-38  
Vector table look-up.
- *VTRN* on page 4-39  
Vector transpose.
- *VUZP, VZIP* on page 4-40  
Vector interleave and de-interleave.

#### 4.4.1 VCVT (between fixed-point or integer, and floating-point)

VCVT (Vector Convert) converts each element in a vector in one of the following ways, and places the results in the destination vector:

- from floating-point to integer
- from integer to floating-point
- from floating-point to fixed-point
- from fixed-point to floating-point.

##### Syntax

`VCVT{cond}.type Qd, Qm {, #fbits}`

`VCVT{cond}.type Dd, Dm {, #fbits}`

where:

*cond* is an optional condition code.

*type* specifies the data types for the elements of the vectors. It must be one of:

S32.F32 floating-point to signed integer or fixed-point

U32.F32 floating-point to unsigned integer or fixed-point

F32.S32 signed integer or fixed-point to floating-point

F32.U32 unsigned integer or fixed-point to floating-point

*Qd, Qm* specifies the destination vector and the operand vector, for a quadword operation.

*Dd, Dm* specifies the destination vector and the operand vector, for a doubleword operation.

*fbits* if present, specifies the number of fraction bits in the fixed point number. Otherwise, the conversion is between floating-point and integer. *fbits* must lie in the range 0-32. If *fbits* is omitted, the number of fraction bits is 0.

##### Rounding

Integer or fixed-point to floating-point conversions use round to nearest.

Floating-point to integer or fixed-point conversions use round towards zero.

**See also**

**Reference:**

- *Condition codes* on page 3-186.



#### 4.4.2 VCVT (between half-precision and single-precision floating-point)

VCVT (Vector Convert), with half-precision extension, converts each element in a vector in one of the following ways, and places the results in the destination vector:

- from half-precision floating-point to single-precision floating-point (F32.F16)
- from single-precision floating-point to half-precision floating-point (F16.F32).

##### Syntax

`VCVT{cond}.F32.F16 Qd, Dm`

`VCVT{cond}.F16.F32 Dd, Qm`

where:

*cond* is an optional condition code.

*Qd*, *Dm* specifies the destination vector for the single-precision results and the half-precision operand vector.

*Dd*, *Qm* specifies the destination vector for half-precision results and the single-precision operand vector.

##### Architectures

This instruction is only available in NEON systems with the half-precision extension.

##### See also

##### Reference:

- *Condition codes* on page 3-186.

### 4.4.3 VDUP

VDUP (Vector Duplicate) duplicates a scalar into every element of the destination vector. The source can be a NEON scalar or an ARM register.

#### Syntax

`VDUP{cond}.size Qd, Dm[x]`

`VDUP{cond}.size Dd, Dm[x]`

`VDUP{cond}.size Qd, Rm`

`VDUP{cond}.size Dd, Rm`

where:

*cond* is an optional condition code.

*size* must be 8, 16, or 32.

*Qd* specifies the destination register for a quadword operation.

*Dd* specifies the destination register for a doubleword operation.

*Dm[x]* specifies the NEON scalar.

*Rm* specifies the ARM register. *Rm* must not be the R15.

#### See also

#### Reference:

- *Condition codes* on page 3-186.

4.4.4 VEXT

VEXT (Vector Extract) extracts 8-bit elements from the bottom end of the second operand vector and the top end of the first, concatenates them, and places the result in the destination vector. See Figure 4-1 for an example.

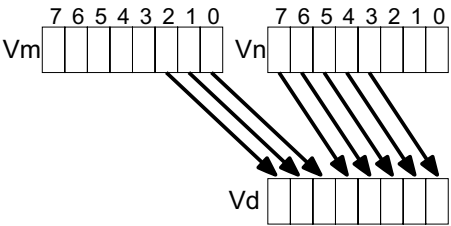


Figure 4-1 Operation of doubleword VEXT for imm = 3

Syntax

VEXT{cond}.8 {Qd}, Qn, Qm, #imm

VEXT{cond}.8 {Dd}, Dn, Dm, #imm

where:

- cond* is an optional condition code.
- Qd, Qn, Qm* specifies the destination register, the first operand register, and the second operand register, for a quadword operation.
- Dd, Dn, Dm* specifies the destination register, the first operand register, and the second operand register, for a doubleword operation.
- imm* is the number of 8-bit elements to extract from the bottom of the second operand vector, in the range 0-7 for doubleword operations, or 0-15 for quadword operations.

VEXT pseudo-instruction

You can specify a datatype of 16, 32, or 64 instead of 8. In this case, #imm refers to halfwords, words, or doublewords instead of referring to bytes, and the allowed ranges are correspondingly reduced.

See also

Reference:

- Condition codes on page 3-186.

4.4.5 VMOV, VMVN (immediate)

VMOV (Vector Move) and VMVN (Vector Move Negative) immediate generate an immediate value into the destination register.

Syntax

*Vop{cond}.datatype Qd, #imm*

*Vop{cond}.datatype Dd, #imm*

where:

- op* must be either MOV or MVN.
- cond* is an optional condition code.
- datatype* must be one of I8, I16, I32, I64, or F32.
- Qd* or *Dd* is the NEON register for the result.
- imm* is an immediate value of the type specified by *datatype*. This is replicated to fill the destination register.

Table 4-5 Available immediate values

datatype	VMOV	VMVN
I8	0xXY	-
I16	0x00XY, 0xXY00	0xFFXY, 0xXYFF
I32	0x000000XY, 0x0000XY00, 0x00XY0000, 0xXY000000 0x0000XYFF, 0x00XYFFFF	0xFFFFFX, 0xFFFFXYFF, 0xFFXYFFFF, 0xXYFFFFFF 0xFFFFXY00, 0xFFXY0000
I64	byte masks, 0xGGHHJJKKLLMMNNPP <sup>a</sup>	-
F32	floating-point numbers <sup>b</sup>	-

- a. Each of 0xGG, 0xHH, 0xJJ, 0xKK, 0xLL, 0xMM, 0xNN, and 0xPP must be either 0x00 or 0xFF.
- b. Any number that can be expressed as  $\pm n \cdot 2^{-r}$ , where *n* and *r* are integers,  $16 \leq n \leq 31$ ,  $0 \leq r \leq 7$ .

See also

Reference:

- *Condition codes* on page 3-186.

#### 4.4.6 VMOVL, V{Q}MOVN, VQMOVUN

VMOVL (Vector Move Long) takes each element in a doubleword vector, sign or zero extends them to twice their original length, and places the results in a quadword vector.

VMOVN (Vector Move and Narrow) copies the least significant half of each element of a quadword vector into the corresponding elements of a doubleword vector.

VQMOVN (Vector Saturating Move and Narrow) copies each element of the operand vector to the corresponding element of the destination vector. The result element is half the width of the operand element, and values are saturated to the result width.

VQMOVUN (Vector Saturating Move and Narrow, signed operand with Unsigned result) copies each element of the operand vector to the corresponding element of the destination vector. The result element is half the width of the operand element, and values are saturated to the result width.

##### Syntax

VMOVL{*cond*}.*datatype* *Qd*, *Dm*

V{Q}MOVN{*cond*}.*datatype* *Dd*, *Qm*

VQMOVUN{*cond*}.*datatype* *Dd*, *Qm*

where:

*Q* if present, specifies that the results are saturated.

*cond* is an optional condition code.

*datatype* must be one of:

S8, S16, S32	for VMOVL
U8, U16, U62	for VMOVL
I16, I32, I64	for VMOVN
S16, S32, S64	for VQMOVN or VQMOVUN
U16, U32, U64	for VQMOVN.

*Qd*, *Dm* specifies the destination vector and the operand vector for VMOVL.

*Dd*, *Qm* specifies the destination vector and the operand vector for V{Q}MOV{U}N.

##### See also

##### Reference:

- *Condition codes* on page 3-186.

#### 4.4.7 VREV

VREV16 (Vector Reverse within halfwords) reverses the order of 8-bit elements within each halfword of the vector, and places the result in the corresponding destination vector.

VREV32 (Vector Reverse within words) reverses the order of 8-bit or 16-bit elements within each word of the vector, and places the result in the corresponding destination vector.

VREV64 (Vector Reverse within doublewords) reverses the order of 8-bit, 16-bit, or 32-bit elements within each doubleword of the vector, and places the result in the corresponding destination vector.

##### Syntax

$VREVn\{cond\}.size\ Qd, Qm$

$VREVn\{cond\}.size\ Dd, Dm$

where:

$n$  must be one of 16, 32, or 64.

$cond$  is an optional condition code.

$size$  must be one of 8, 16, or 32, and must be less than  $n$ .

$Qd, Qm$  specifies the destination vector and the operand vector, for a quadword operation.

$Dd, Dm$  specifies the destination vector and the operand vector, for a doubleword operation.

##### See also

##### Reference:

- *Condition codes* on page 3-186.

#### 4.4.8 VSWP

VSWP (Vector Swap) exchanges the contents of two vectors. The vectors can be either doubleword or quadword. There is no distinction between data types.

##### Syntax

VSWP{*cond*}.{*datatype*} *Qd*, *Qm*

VSWP{*cond*}.{*datatype*} *Dd*, *Dm*

where:

*cond* is an optional condition code.

*datatype* is an optional datatype. The assembler ignores *datatype*.

*Qd*, *Qm* specifies the vectors for a quadword operation.

*Dd*, *Dm* specifies the vectors for a doubleword operation.

##### See also

##### Reference:

- *Condition codes* on page 3-186.

#### 4.4.9 VTBL, VTBX

VTBL (Vector Table Lookup) uses byte indexes in a control vector to look up byte values in a table and generate a new vector. Indexes out of range return 0.

VTBX (Vector Table Extension) works in the same way, except that indexes out of range leave the destination element unchanged.

##### Syntax

*Vop*{*cond*}.8 *Dd*, *list*, *Dm*

where:

*op* must be either TBL or TBX.

*cond* is an optional condition code.

*Dd* specifies the destination vector.

*list* Specifies the vectors containing the table. It must be one of:

- {*Dn*}
- {*Dn*, *D(n+1)*}
- {*Dn*, *D(n+1)*, *D(n+2)*}
- {*Dn*, *D(n+1)*, *D(n+2)*, *D(n+3)*}
- {*Qn*, *Q(n+1)*}.

All the registers in *list* must be in the range D0-D31 or Q0-Q15 and must not wraparound the end of the register bank. For example {D31,D0,D1} is not allowed. If *list* contains Q registers, they disassemble to the equivalent D registers.

*Dm* specifies the index vector.

##### See also

##### Reference:

- *Condition codes* on page 3-186.



#### 4.4.10 VTRN

VTRN (Vector Transpose) treats the elements of its operand vectors as elements of 2 x 2 matrices, and transposes the matrices. Figure 4-2 and Figure 4-3 show examples of the operation of VTRN.

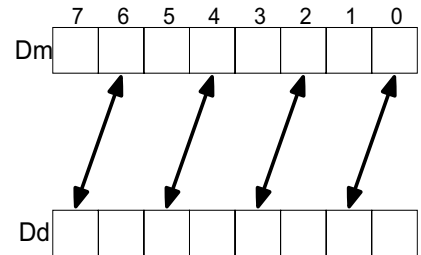


Figure 4-2 Operation of doubleword VTRN.8

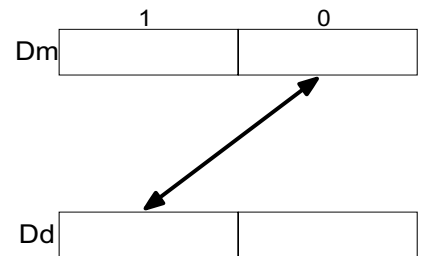


Figure 4-3 Operation of doubleword VTRN.32

#### Syntax

`VTRN{cond}.size Qd, Qm`

`VTRN{cond}.size Dd, Dm`

where:

*cond* is an optional condition code.

*size* must be one of 8, 16, or 32.

*Qd, Qm* specifies the vectors, for a quadword operation.

*Dd, Dm* specifies the vectors, for a doubleword operation.

**See also****Reference:**

- *Condition codes* on page 3-186.

**4.4.11 VUZP, VZIP**

VZIP (Vector Zip) interleaves the elements of two vectors.

VUZP (Vector Unzip) de-interleaves the elements of two vectors.

De-interleaving is the inverse process of interleaving.

**Syntax**

*Vop{cond}.size Qd, Qm*

*Vop{cond}.size Dd, Dm*

where:

*op* must be either UZP or ZIP.

*cond* is an optional condition code.

*size* must be one of 8, 16, or 32.

*Qd, Qm* specifies the vectors, for a quadword operation.

*Dd, Dm* specifies the vectors, for a doubleword operation.

**———— Note ————**

The following are all the same instruction:

- *VZIP.32 Dd, Dm*
- *VUZP.32 Dd, Dm*
- *VTRN.32 Dd, Dm*

The instruction is disassembled as *VTRN.32 Dd, Dm*.

**See also****Reference:**

- *De-interleaving an array of 3-element structures* on page 4-74
- *VTRN* on page 4-39

- *Condition codes* on page 3-186.

## 4.5 NEON shift instructions

This section contains the following subsections:

- *VSHL, VQSHL, VQSHLU, and VSHLL (by immediate)* on page 4-43  
Shift Left by immediate value.
- *V{Q}{R}SHL (by signed variable)* on page 4-45  
Shift left by signed variable.
- *V{R}SHR{N}, V{R}SRA (by immediate)* on page 4-46  
Shift Right by immediate value.
- *VQ{R}SHR{U}N (by immediate)* on page 4-48  
Shift Right by immediate value, and saturate.
- *VSLI and VSRI* on page 4-49  
Shift Left and Insert, and Shift Right and Insert.

#### 4.5.1 VSHL, VQSHL, VQSHLU, and VSHLL (by immediate)

Vector Shift Left (by immediate) instructions take each element in a vector of integers, left shift them by an immediate value, and place the results in the destination vector.

For VSHL (Vector Shift Left), bits shifted out of the left of each element are lost.

For VQSHL (Vector Saturating Shift Left) and VQSHLU (Vector Saturating Shift Left Unsigned), the sticky QC flag (FPSCR bit[27]) is set if saturation occurs.

For VSHLL (Vector Shift Left Long), values are sign or zero extended.

##### Syntax

$V\{Q\}SHL\{U\}\{cond\}.datatype\ Qd, Qm, \#imm$

$V\{Q\}SHL\{U\}\{cond\}.datatype\ Dd, Dm, \#imm$

$VSHLL\{cond\}.datatype\ Qd, Dm, \#imm$

where:

*Q* if present, indicates that if any of the results overflow, they are saturated.

*U* only allowed if *Q* is also present. Indicates that the results are unsigned even though the operands are signed.

*cond* is an optional condition code.

*datatype* must be one of:

I8, I16, I32, I64	for VSHL
S8, S16, S32	for VSHLL, VQSHL, or VQSHLU
U8, U16, U32	for VSHLL or VQSHL
S64	for VQSHL or VQSHLU
U64	for VQSHL.

*Qd, Qm* are the destination and operand vectors, for a quadword operation.

*Dd, Dm* are the destination and operand vectors, for a doubleword operation.

*Qd, Dm* are the destination and operand vectors, for a long operation.

*imm* is the immediate value specifying the size of the shift, in the range:

- 1 to  $\text{size}(\text{datatype})$  for VSHLL
- 1 to  $(\text{size}(\text{datatype}) - 1)$  for VSHL, VQSHL, or VQSHLU.

0 is permitted, but the resulting code disassembles to VMOV or VMOVL.

**See also**

**Reference:**

- *Condition codes* on page 3-186.

### 4.5.2 V{Q}{R}SHL (by signed variable)

VSHL (Vector Shift Left by signed variable) takes each element in a vector, shifts them by a value from the least significant byte of the corresponding element of a second vector, and places the results in the destination vector. If the shift value is positive, the operation is a left shift. Otherwise, it is a right shift.

The results can be optionally saturated, rounded, or both. The sticky QC flag (FPSCR bit[27]) is set if saturation occurs.

#### Syntax

$V\{Q\}\{R\}SHL\{cond\}.datatype\ \{Qd\},\ Qm,\ Qn$

$V\{Q\}\{R\}SHL\{cond\}.datatype\ \{Dd\},\ Dm,\ Dn$

where:

<i>Q</i>	if present, indicates that If any of the results overflow, they are saturated.
<i>R</i>	if present, indicates that each result is rounded. Otherwise, each result is truncated.
<i>cond</i>	is an optional condition code.
<i>datatype</i>	must be one of S8, S16, S32, S64, U8, U16, U32, or U64.
<i>Qd, Qm, Qn</i>	are the destination vector, the first operand vector, and the second operand vector, for a quadword operation.
<i>Dd, Dm, Dn</i>	are the destination vector, the first operand vector, and the second operand vector, for a doubleword operation.

#### See also

#### Reference:

- *Condition codes* on page 3-186.

### 4.5.3 V{R}SHR{N}, V{R}SRA (by immediate)

V{R}SHR{N} (Vector Shift Right by immediate value) takes each element in a vector, right shifts them by an immediate value, and places the results in the destination vector. The results can be optionally rounded, or narrowed, or both.

V{R}SRA (Vector Shift Right by immediate value and Accumulate) takes each element in a vector, right shifts them by an immediate value, and accumulates the results into the destination vector. The results can be optionally rounded.

#### Syntax

V{R}SHR{cond}.datatype {Qd}, Qm, #imm

V{R}SHR{cond}.datatype {Dd}, Dm, #imm

V{R}SRA{cond}.datatype {Qd}, Qm, #imm

V{R}SRA{cond}.datatype {Dd}, Dm, #imm

V{R}SHRN{cond}.datatype Dd, Qm, #imm

where:

**R** if present, indicates that the results are rounded. Otherwise, the results are truncated.

**cond** is an optional condition code.

**datatype** must be one of:

S8, S16, S32, S64	for V{R}SHR or V{R}SRA
U8, U16, U32, U64	for V{R}SHR or V{R}SRA
I16, I32, I64	for V{R}SHRN.

**Qd, Qm** are the destination vector and the operand vector, for a quadword operation.

**Dd, Dm** are the destination vector and the operand vector, for a doubleword operation.

**Dd, Qm** are the destination vector and the operand vector, for a narrow operation.

**imm** is the immediate value specifying the size of the shift, in the range 0 to (size(datatype) – 1).



**See also**

**Reference:**

- *Condition codes* on page 3-186.

#### 4.5.4 VQ{R}SHR{U}N (by immediate)

VQ{R}SHR{U}N (Vector Saturating Shift Right, Narrow, by immediate value, with optional Rounding) takes each element in a quadword vector of integers, right shifts them by an immediate value, and places the results in a doubleword vector.

The sticky QC flag (FPSCR bit[27]) is set if saturation occurs.

##### Syntax

VQ{R}SHR{U}N{*cond*}.*datatype* *Dd*, *Qm*, #*imm*

where:

<i>R</i>	if present, indicates that the results are rounded. Otherwise, the results are truncated.
<i>U</i>	if present, indicates that the results are unsigned, although the operands are signed. Otherwise, the results are the same type as the operands.
<i>cond</i>	is an optional condition code.
<i>datatype</i>	must be one of: S16, S32, S64      for VQ{R}SHRN or VQ{R}SHRUN U16, U32, U64      for VQ{R}SHRN only.
<i>Dd</i> , <i>Qm</i>	are the destination vector and the operand vector.
<i>imm</i>	is the immediate value specifying the size of the shift, in the range 0 to (size( <i>datatype</i> ) – 1).

##### See also

##### Reference:

- *Condition codes* on page 3-186.

### 4.5.5 VSLI and VSRI

VSLI (Vector Shift Left and Insert) takes each element in a vector, left shifts them by an immediate value, and inserts the results in the destination vector. Bits shifted out of the left of each element are lost.

VSRI (Vector Shift Right and Insert) takes each element in a vector, right shifts them by an immediate value, and inserts the results in the destination vector. Bits shifted out of the right of each element are lost.

#### Syntax

*Vop{cond}.size {Qd}, Qm, #imm*

*Vop{cond}.size {Dd}, Dm, #imm*

where:

<i>op</i>	must be either SLI or SRI.
<i>cond</i>	is an optional condition code.
<i>size</i>	must be one of 8, 16, 32, or 64.
<i>Qd, Qm</i>	are the destination vector and the operand vector, for a quadword operation.
<i>Dd, Dm</i>	are the destination vector and the operand vector, for a doubleword operation.
<i>imm</i>	is the immediate value specifying the size of the shift, in the range: <ul style="list-style-type: none"> <li>• 0 to (<i>size</i> – 1) for VSLI</li> <li>• 1 to <i>size</i> for VSRI.</li> </ul>

#### See also

#### Reference:

- *Condition codes* on page 3-186.

## 4.6 NEON general arithmetic instructions

This section contains the following subsections:

- *VABA{L}* and *VABD{L}* on page 4-51  
Vector Absolute Difference and Accumulate, and Absolute Difference.
- *V{Q}ABS* and *V{Q}NEG* on page 4-52  
Vector Absolute value, and Negate.
- *V{Q}ADD*, *VADDL*, *VADDW*, *V{Q}SUB*, *VSUBL*, and *VSUBW* on page 4-53  
Vector Add and Subtract.
- *V{R}ADDHN* and *V{R}SUBHN* on page 4-55  
Vector Add selecting High half, and Subtract selecting High Half.
- *V{R}HADD* and *VHSUB* on page 4-56  
Vector Halving Add and Subtract.
- *VPADD{L}*, *VPADAL* on page 4-57  
Vector Pairwise Add, Add and Accumulate.
- *VMAX*, *VMIN*, *VPMAX*, and *VPMIN* on page 4-59  
Vector Maximum, Minimum, Pairwise Maximum, and Pairwise Minimum.
- *VCLS*, *VCLZ*, and *VCNT* on page 4-61  
Vector Count Leading Sign bits, Count Leading Zeros, and Count set bits.
- *VRECPE* and *VRSQRTPE* on page 4-62  
Vector Reciprocal Estimate and Reciprocal Square Root Estimate.
- *VRECPS* and *VRSQRTS* on page 4-64  
Vector Reciprocal Step and Reciprocal Square Root Step.

#### 4.6.1 VABA{L} and VABD{L}

VABA (Vector Absolute Difference and Accumulate) subtracts the elements of one vector from the corresponding elements of another vector, and accumulates the absolute values of the results into the elements of the destination vector.

VABD (Vector Absolute Difference) subtracts the elements of one vector from the corresponding elements of another vector, and places the absolute values of the results into the elements of the destination vector.

Long versions of both instructions are available.

##### Syntax

*Vop{cond}.datatype {Qd}, Qn, Qm*

*Vop{cond}.datatype {Dd}, Dn, Dm*

*VopL{cond}.datatype Qd, Dn, Dm*

where:

*op* must be either ABA or ABD.

*cond* is an optional condition code.

*datatype* must be one of:

- S8, S16, S32, U8, U16, or U32 for VABA, VABAL, or VABDL
- S8, S16, S32, U8, U16, U32 or F32 for VABD.

*Qd, Qn, Qm* are the destination vector, the first operand vector, and the second operand vector, for a quadword operation.

*Dd, Dn, Dm* are the destination vector, the first operand vector, and the second operand vector, for a doubleword operation.

*Qd, Dn, Dm* are the destination vector, the first operand vector, and the second operand vector, for a long operation.

##### See also

##### Reference:

- *Condition codes* on page 3-186.

#### 4.6.2 V{Q}ABS and V{Q}NEG

VABS (Vector Absolute) takes the absolute value of each element in a vector, and places the results in a second vector. (The floating-point version only clears the sign bit.)

VNEG (Vector Negate) negates each element in a vector, and places the results in a second vector. (The floating-point version only inverts the sign bit.)

Saturating versions of both instructions are available. The sticky QC flag (FPSCR bit[27]) is set if saturation occurs.

##### Syntax

$V\{Q\}op\{cond\}.datatype\ Qd,\ Qm$

$V\{Q\}op\{cond\}.datatype\ Dd,\ Dm$

where:

$Q$  if present, indicates that If any of the results overflow, they are saturated.

$op$  must be either ABS or NEG.

$cond$  is an optional condition code.

$datatype$  must be one of:

S8, S16, S32	for VABS, VNEG, VQABS, or VQNEG
F32	for VABS and VNEG only.

$Qd,\ Qm$  are the destination vector and the operand vector, for a quadword operation.

$Dd,\ Dm$  are the destination vector and the operand vector, for a doubleword operation.

##### See also

##### Reference:

- *Condition codes* on page 3-186.

### 4.6.3 V{Q}ADD, VADDL, VADDW, V{Q}SUB, VSUBL, and VSUBW

VADD (Vector Add) adds corresponding elements in two vectors, and places the results in the destination vector.

VSUB (Vector Subtract) subtracts the elements of one vector from the corresponding elements of another vector, and places the results in the destination vector.

VADD and VSUB have these forms:

- Saturating. The sticky QC flag (FPSCR bit[27]) is set if saturation occurs.
- Long.
- Wide.

#### Syntax

$V\{Q\}op\{cond\}.datatype \{Qd\}, Qn, Qm$  ; Saturating instruction

$V\{Q\}op\{cond\}.datatype \{Dd\}, Dn, Dm$  ; Saturating instruction

$VopL\{cond\}.datatype Qd, Dn, Dm$  ; Long instruction

$VopW\{cond\}.datatype \{Qd\}, Qn, Dm$  ; Wide instruction

where:

*Q* if present, indicates that if any of the results overflow, they are saturated.

*op* must be either ADD or SUB.

*cond* is an optional condition code.

*datatype* must be one of:

I8, I16, I32, I64, F32 for VADD or VSUB

S8, S16, S32 for VQADD, VQSUB, VADDL, VADDW, VSUBL, or VSUBW

U8, U16, U32 for VQADD, VQSUB, VADDL, VADDW, VSUBL, or VSUBW

S64, U64 for VQADD or VQSUB.

*Qd, Qn, Qm* are the destination vector, the first operand vector, and the second operand vector, for a quadword operation.

*Dd, Dn, Dm* are the destination vector, the first operand vector, and the second operand vector, for a doubleword operation.

*Qd, Dn, Dm* are the destination vector, the first operand vector, and the second operand vector, for a long operation.

$Qd$ ,  $Qn$ ,  $Dm$  are the destination vector, the first operand vector, and the second operand vector, for a wide operation.

**See also**

**Reference:**

- *Condition codes* on page 3-186.



#### 4.6.4 V{R}ADDHN and V{R}SUBHN

V{R}ADDH (Vector Add and Narrow, selecting High half) adds corresponding elements in two vectors, selects the most significant halves of the results, and places the final results in the destination vector. Results can be either rounded or truncated.

V{R}SUBH (Vector Subtract and Narrow, selecting High half) subtracts the elements of one vector from the corresponding elements of another vector, selects the most significant halves of the results, and places the final results in the destination vector. Results can be either rounded or truncated.

##### Syntax

V{R}*op*HN{*cond*}.*datatype* *Dd*, *Qn*, *Qm*

where:

<i>R</i>	if present, indicates that each result is rounded. Otherwise, each result is truncated.
<i>op</i>	must be either ADD or SUB.
<i>cond</i>	is an optional condition code.
<i>datatype</i>	must be one of I16, I32, or I64.
<i>Dd</i> , <i>Qn</i> , <i>Qm</i>	are the destination vector, the first operand vector, and the second operand vector.

##### See also

##### Reference:

- *Condition codes* on page 3-186.

#### 4.6.5 V{R}HADD and VHSUB

VHADD (Vector Halving Add) adds corresponding elements in two vectors, shifts each result right one bit, and places the results in the destination vector. Results can be either rounded or truncated.

VHSUB (Vector Halving Subtract) subtracts the elements of one vector from the corresponding elements of another vector, shifts each result right one bit, and places the results in the destination vector. Results are always truncated.

##### Syntax

`V{R}HADD{cond}.datatype {Qd}, Qn, Qm`

`V{R}HADD{cond}.datatype {Dd}, Dn, Dm`

`VHSUB{cond}.datatype {Qd}, Qn, Qm`

`VHSUB{cond}.datatype {Dd}, Dn, Dm`

where:

**R** if present, indicates that each result is rounded. Otherwise, each result is truncated.

**cond** is an optional condition code.

**datatype** must be one of S8, S16, S32, U8, U16, or U32.

**Qd, Qn, Qm** are the destination vector, the first operand vector, and the second operand vector, for a quadword operation.

**Dd, Dn, Dm** are the destination vector, the first operand vector, and the second operand vector, for a doubleword operation.

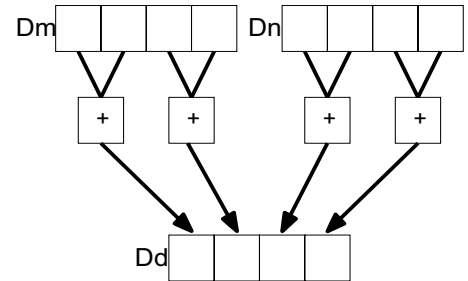
##### See also

##### Reference:

- *Condition codes* on page 3-186.

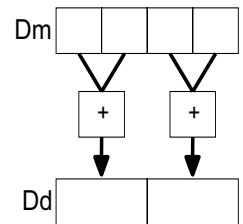
#### 4.6.6 VPADD{L}, VPADAL

VPADD (Vector Pairwise Add) adds adjacent pairs of elements of two vectors, and places the results in the destination vector.



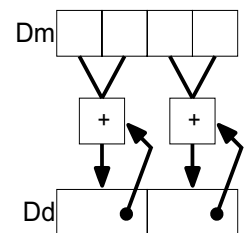
**Figure 4-4 Example of operation of VPADD (in this case, for data type I16)**

VPADDL (Vector Pairwise Add Long) adds adjacent pairs of elements of a vector, sign or zero extends the results to twice their original width, and places the final results in the destination vector.



**Figure 4-5 Example of operation of doubleword VPADDL (in this case, for data type S16)**

VPADAL (Vector Pairwise Add and Accumulate Long) adds adjacent pairs of elements of a vector, and accumulates the absolute values of the results into the elements of the destination vector.



**Figure 4-6 Example of operation of VPADAL (in this case for data type S16)**

**Syntax**

$\text{VPADD}\{\text{cond}\}.\text{datatype } \{Dd\}, Dn, Dm$

$\text{VPopL}\{\text{cond}\}.\text{datatype } Qd, Qm$

$\text{VPopL}\{\text{cond}\}.\text{datatype } Dd, Dm$

where:

*op* must be either ADD or ADA.

*cond* is an optional condition code.

*datatype* must be one of:

I8, I16, I32, F32	for VPADD
S8, S16, S32	for VPADDL or VPADAL
U8, U16, U32	for VPADDL or VPADAL.

*Dd, Dn, Dm* are the destination vector, the first operand vector, and the second operand vector, for a VPADD instruction.

*Qd, Qm* are the destination vector and the operand vector, for a quadword VPADDL or VPADAL.

*Dd, Dm* are the destination vector and the operand vector, for a doubleword VPADDL or VPADAL.

**See also****Reference:**

- *Condition codes* on page 3-186.

#### 4.6.7 VMAX, VMIN, VPMAX, and VPMIN

VMAX (Vector Maximum) compares corresponding elements in two vectors, and copies the larger of each pair into the corresponding element in the destination vector.

VMIN (Vector Minimum) compares corresponding elements in two vectors, and copies the smaller of each pair into the corresponding element in the destination vector.

VPMAX (Vector Pairwise Maximum) compares adjacent pairs of elements in two vectors, and copies the larger of each pair into the corresponding element in the destination vector. Operands and results must be doubleword vectors.

VPMIN (Vector Pairwise Minimum) compares adjacent pairs of elements in two vectors, and copies the smaller of each pair into the corresponding element in the destination vector. Operands and results must be doubleword vectors.

##### Syntax

*Vop{cond}.datatype Qd, Qn, Qm*

*Vop{cond}.datatype Dd, Dn, Dm*

*VPop{cond}.datatype Dd, Dn, Dm*

where:

*op* must be either MAX or MIN.

*cond* is an optional condition code.

*datatype* must be one of S8, S16, S32, U8, U16, U32, or F32.

*Qd, Qn, Qm* are the destination vector, the first operand vector, and the second operand vector, for a quadword operation.

*Dd, Dn, Dm* are the destination vector, the first operand vector, and the second operand vector, for a doubleword operation.

##### Floating-point maximum and minimum

$\max(+0.0, -0.0) = +0.0$ .

$\min(+0.0, -0.0) = -0.0$

If any input is a NaN, the corresponding result element is the default NaN.

## See also

### Reference:

- *Condition codes* on page 3-186
- *VPADD{L}, VPADAL* on page 4-57.

#### 4.6.8 VCLS, VCLZ, and VCNT

VCLS (Vector Count Leading Sign bits) counts the number of consecutive bits following the topmost bit, that are the same as the topmost bit, in each element in a vector, and places the results in a second vector.

VCLZ (Vector Count Leading Zeros) counts the number of consecutive zeros, starting from the top bit, in each element in a vector, and places the results in a second vector.

VCNT (Vector Count set bits) counts the number of bits that are one in each element in a vector, and places the results in a second vector.

##### Syntax

*Vop{cond}.datatype Qd, Qm*

*Vop{cond}.datatype Dd, Dm*

where:

*op* must be one of CLS, CLZ, or CNT.

*cond* is an optional condition code.

*datatype* must be one of:

- S8, S16, or S32 for CLS.
- I8, I16, or I32 for CLZ.
- I8 for CNT.

*Qd, Qm* are the destination vector and the operand vector, for a quadword operation.

*Dd, Dm* are the destination vector and the operand vector, for a doubleword operation.

##### See also

##### Reference:

- *Condition codes* on page 3-186.

4.6.9 VRECPE and VRSQRTE

VRECPE (Vector Reciprocal Estimate) finds an approximate reciprocal of each element in a vector, and places the results in a second vector.

VRSQRTE (Vector Reciprocal Square Root Estimate) finds an approximate reciprocal square root of each element in a vector, and places the results in a second vector.

Syntax

*Vop{cond}.datatype Qd, Qm*

*Vop{cond}.datatype Dd, Dm*

where:

- op* must be either RECPE or RSQRTE.
- cond* is an optional condition code.
- datatype* must be either U32 or F32.
- Qd, Qm* are the destination vector and the operand vector, for a quadword operation.
- Dd, Dm* are the destination vector and the operand vector, for a doubleword operation.

Results for out-of-range inputs

Table 4-6 shows the results where input values are out of range.

Table 4-6 Results for out-of-range inputs

	Operand element (VRECPE)	Operand element (VRSQRTE)	Result element
Integer	<= 0x7FFFFFFF	<= 0x3FFFFFFF	0xFFFFFFFF
Floating-point	NaN	NaN, Negative Normal, Negative Infinity	Default NaN
	Negative 0, Negative Denormal	Negative 0, Negative Denormal	Negative Infinity <sup>a</sup>
	Positive 0, Positive Denormal	Positive 0, Positive Denormal	Positive Infinity <sup>a</sup>
	Positive infinity	Positive infinity	Positive 0
	Negative infinity		Negative 0

a. The Division by Zero exception bit in the FPSCR (FPSCR[1]) is set



**See also**

**Reference:**

- *Condition codes* on page 3-186.

4.6.10 VRECPS and VRSQRTS

VRECPS (Vector Reciprocal Step) multiplies the elements of one vector by the corresponding elements of another vector, subtracts each of the results from 2, and places the final results into the elements of the destination vector.

VRSQRTS (Vector Reciprocal Square Root Step) multiplies the elements of one vector by the corresponding elements of another vector, subtracts each of the results from 3, divides these results by two, and places the final results into the elements of the destination vector.

Syntax

*Vop{cond}.F32 {Qd}, Qn, Qm*

*Vop{cond}.F32 {Dd}, Dn, Dm*

where:

- op* must be either RECPS or RSQRTS.
- cond* is an optional condition code.
- Qd, Qn, Qm* are the destination vector, the first operand vector, and the second operand vector, for a quadword operation.
- Dd, Dn, Dm* are the destination vector, the first operand vector, and the second operand vector, for a doubleword operation.

Results for out-of-range inputs

Table 4-7 shows the results where input values are out of range.

Table 4-7 Results for out-of-range inputs

1st operand element	2nd operand element	Result element (VRECPS)	Result element (VRSQRTS)
NaN	-	Default NaN	Default NaN
-	NaN	Default NaN	Default NaN
+/- 0.0 or denormal	+/- infinity	2.0	1.5
+/- infinity	+/- 0.0 or denormal	2.0	1.5

**Usage**

The Newton-Raphson iteration:

$$x_{n+1} = x_n(2 - dx_n)$$

converges to  $(1/d)$  if  $x_0$  is the result of VRECPE applied to  $d$ .

The Newton-Raphson iteration:

$$x_{n+1} = x_n(3 - dx_n^2)/2$$

converges to  $(1/\sqrt{d})$  if  $x_0$  is the result of VRSQRTE applied to  $d$ .

**See also****Reference:**

- *Condition codes* on page 3-186.

## 4.7 NEON multiply instructions

This section contains the following subsections:

- *VMUL<sub>{L}</sub>, VMLA<sub>{L}</sub>, and VMLS<sub>{L}</sub>* on page 4-67.  
Vector Multiply, Multiply Accumulate, and Multiply Subtract.
- *VMUL<sub>{L}</sub>, VMLA<sub>{L}</sub>, and VMLS<sub>{L}</sub> (by scalar)* on page 4-69.  
Vector Multiply, Multiply Accumulate, and Multiply Subtract (by scalar).
- *VFMA, VFMS* on page 4-71.  
Vector Fused Multiply Accumulate and Vector Fused Multiply Subtract.
- *VQDMULL, VQDMLAL, and VQDMLSL (by vector or by scalar)* on page 4-72  
Vector Saturating Doubling Multiply, Multiply Accumulate, and Multiply Subtract (by vector or scalar).
- *VQ<sub>{R}</sub>DMULH (by vector or by scalar)* on page 4-73  
Vector Saturating Doubling Multiply returning High half (by vector or scalar).

#### 4.7.1 VMUL{L}, VMLA{L}, and VMLS{L}

VMUL (Vector Multiply) multiplies corresponding elements in two vectors, and places the results in the destination vector.

VMLA (Vector Multiply Accumulate) multiplies corresponding elements in two vectors, and accumulates the results into the elements of the destination vector.

VMLS (Vector Multiply Subtract) multiplies corresponding elements in two vectors, subtracts the results from corresponding elements of the destination vector, and places the final results in the destination vector.

##### Syntax

*Vop{cond}.datatype {Qd}, Qn, Qm*

*Vop{cond}.datatype {Dd}, Dn, Dm*

*VopL{cond}.datatype Qd, Dn, Dm*

where:

*op* must be one of:

MUL	Multiply
MLA	Multiply Accumulate
MLS	Multiply Subtract.

*cond* is an optional condition code.

*datatype* must be one of:

I8, I16, I32, F32	for VMUL, VMLA, or VMLS
S8, S16, S32	for VMULL, VMLAL, or VMLS�
U8, U16, U32	for VMULL, VMLAL, or VMLS�
P8	for VMUL or VMULL.

*Qd, Qn, Qm* are the destination vector, the first operand vector, and the second operand vector, for a quadword operation.

*Dd, Dn, Dm* are the destination vector, the first operand vector, and the second operand vector, for a doubleword operation.

*Qd, Dn, Dm* are the destination vector, the first operand vector, and the second operand vector, for a long operation.

## See also

### Concepts

*Using the Assembler:*

- *Polynomial arithmetic over  $\{0,1\}$*  on page 9-24.

### Reference:

- *Condition codes* on page 3-186.

4.7.2 VMUL{L}, VMLA{L}, and VMLS{L} (by scalar)

VMUL (Vector Multiply by scalar) multiplies each element in a vector by a scalar, and places the results in the destination vector.

VMLA (Vector Multiply Accumulate) multiplies each element in a vector by a scalar, and accumulates the results into the corresponding elements of the destination vector.

VMLS (Vector Multiply Subtract) multiplies each element in a vector by a scalar, and subtracts the results from the corresponding elements of the destination vector, and places the final results in the destination vector.

Syntax

```
Vop{cond}.datatype {Qd}, Qn, Dm[x]
Vop{cond}.datatype {Dd}, Dn, Dm[x]
VopL{cond}.datatype Qd, Dn, Dm[x]
```

where:

<i>op</i>	must be one of:	
	MUL	Multiply
	MLA	Multiply Accumulate
	MLS	Multiply Subtract.
<i>cond</i>	is an optional condition code.	
<i>datatype</i>	must be one of:	
	I16, I32, F32	for VMUL, VMLA, or VMLS
	S16, S32	for VMULL, VMLAL, or VMLSL
	U16, U32	for VMULL, VMLAL, or VMLSL.
<i>Qd, Qn</i>	are the destination vector and the first operand vector, for a quadword operation.	
<i>Dd, Dn</i>	are the destination vector and the first operand vector, for a doubleword operation.	
<i>Qd, Dn</i>	are the destination vector and the first operand vector, for a long operation.	
<i>Dm[x]</i>	is the scalar holding the second operand.	

**See also**

**Reference:**

- *Condition codes* on page 3-186.



### 4.7.3 VFMA, VFMS

VFMA (Vector Fused Multiply Accumulate) multiplies corresponding elements in the two operand vectors, and accumulates the results into the elements of the destination vector. The result of the multiply is not rounded before the accumulation.

VFMS (Vector Fused Multiply Subtract) multiplies corresponding elements in the two operand vectors, then subtracts the products from the corresponding elements of the destination vector, and places the final results in the destination vector. The result of the multiply is not rounded before the subtraction.

#### Syntax

*Vop{cond}.F32 {Qd}, Qn, Qm*

*Vop{cond}.F32 {Dd}, Dn, Dm*

*Vop{cond}.F64 {Dd}, Dn, Dm*

*Vop{cond}.F32 {Sd}, Sn, Sm*

where:

*op* is one of FMA or FMS.

*cond* is an optional condition code.

*Sd, Sn, Sm* are the destination and operand vectors for word operation.

*Dd, Dn, Dm* are the destination and operand vectors for doubleword operation.

*Qd, Qn, Qm* are the destination and operand vectors for quadword operation.

#### See also

#### Reference:

- *Condition codes* on page 3-186
- *VMUL{L}, VMLA{L}, and VMLS{L}* on page 4-67.

#### 4.7.4 VQDMULL, VQDMLAL, and VQDMLSL (by vector or by scalar)

Vector Saturating Doubling Multiply instructions multiply their operands and double the results. VQDMULL places the results in the destination register. VQDMLAL adds the results to the values in the destination register. VQDMLSL subtracts the results from the values in the destination register.

If any of the results overflow, they are saturated. The sticky QC flag (FPSCR bit[27]) is set if saturation occurs.

##### Syntax

$VQDopL\{cond\}.datatype\ Qd, Dn, Dm$

$VQDopL\{cond\}.datatype\ Qd, Dn, Dm[x]$

where:

*op* must be one of:

MUL	Multiply
MLA	Multiply Accumulate
MLS	Multiply Subtract.

*cond* is an optional condition code.

*datatype* must be either S16 or S32.

*Qd, Dn* are the destination vector and the first operand vector.

*Dm* is the vector holding the second operand, for a *by vector* operation.

*Dm[x]* is the scalar holding the second operand, for a *by scalar* operation.

##### See also

##### Reference:

- *Condition codes* on page 3-186.

#### 4.7.5 VQ{R}DMULH (by vector or by scalar)

Vector Saturating Doubling Multiply instructions multiply their operands and double the results. They return only the high half of the results.

If any of the results overflow, they are saturated. The sticky QC flag (FPSCR bit[27]) is set if saturation occurs.

##### Syntax

$VQ\{R\}DMULH\{cond\}.datatype\ \{Qd\},\ Qn,\ Qm$

$VQ\{R\}DMULH\{cond\}.datatype\ \{Dd\},\ Dn,\ Dm$

$VQ\{R\}DMULH\{cond\}.datatype\ \{Qd\},\ Qn,\ Dm[x]$

$VQ\{R\}DMULH\{cond\}.datatype\ \{Dd\},\ Dn,\ Dm[x]$

where:

<i>R</i>	if present, indicates that each result is rounded. Otherwise, each result is truncated.
<i>cond</i>	is an optional condition code.
<i>datatype</i>	must be either S16 or S32.
<i>Qd, Qn</i>	are the destination vector and the first operand vector, for a quadword operation.
<i>Dd, Dn</i>	are the destination vector and the first operand vector, for a doubleword operation.
<i>Qm</i> or <i>Dm</i>	is the vector holding the second operand, for a <i>by vector</i> operation.
<i>Dm[x]</i>	is the scalar holding the second operand, for a <i>by scalar</i> operation.

##### See also

##### Reference:

- *Condition codes* on page 3-186.

## 4.8 NEON load and store element and structure instructions

This section contains the following subsections:

- *Interleaving.*
- *Alignment restrictions in load and store, element and structure instructions on page 4-75.*
- *VLDn and VSTn (single n-element structure to one lane) on page 4-76.*

This is used for almost all data accesses. A normal vector can be loaded ( $n = 1$ ).

- *VLDn (single n-element structure to all lanes) on page 4-78.*
- *VLDn and VSTn (multiple n-element structures) on page 4-80.*

### 4.8.1 Interleaving

Many instructions in this group provide interleaving when structures are stored to memory, and de-interleaving when structures are loaded from memory. Figure 4-7 shows an example of de-interleaving. Interleaving is the inverse process.

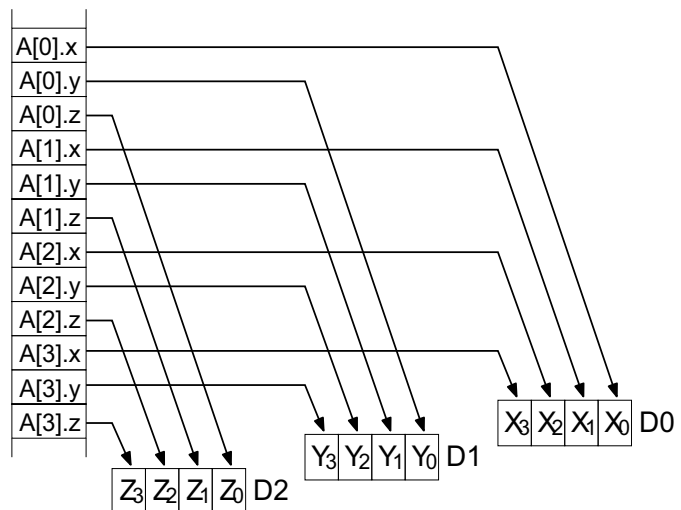


Figure 4-7 De-interleaving an array of 3-element structures

## 4.8.2 Alignment restrictions in load and store, element and structure instructions

Many of these instructions allow memory alignment restrictions to be specified. When the alignment is not specified in the instruction, the alignment restriction is controlled by the A bit (SCTLR bit[1]):

- if the A bit is 0, there are no alignment restrictions (except for strongly ordered or device memory, where accesses must be element aligned or the result is unpredictable)
- if the A bit is 1, accesses must be element aligned.

If an address is not correctly aligned, an alignment fault occurs.

### See also

### Reference

- *ARM Architecture Reference Manual*,  
<http://infocenter.arm.com/help/topic/com.arm.doc.subset.arch.reference/index.html>.

4.8.3 VLDn and VSTn (single n-element structure to one lane)

Vector Load single *n*-element structure to one lane. It loads one *n*-element structure from memory into one or more NEON registers. Elements of the register that are not loaded are unaltered.

Vector Store single *n*-element structure to one lane. It stores one *n*-element structure into memory from one or more NEON registers.

Syntax

```
Vopn{cond}.datatype list, [Rn{@align}}{!}  
Vopn{cond}.datatype list, [Rn{@align}], Rm
```

where:

- op* must be either LD or ST.
- n* must be one of 1, 2, 3, or 4.
- cond* is an optional condition code.
- datatype* see Table 4-8.
- list* specifies the NEON register list. See Table 4-8 for options.
- Rn* is the ARM register containing the base address. *Rn* cannot be PC.
- align* specifies an optional alignment. See Table 4-8 for options.
- ! if ! is present, *Rn* is updated to (*Rn* + the number of bytes transferred by the instruction). The update occurs after all the loads or stores have taken place.
- Rm* is an ARM register containing an offset from the base address. If *Rm* is present, *Rn* is updated to (*Rn* + *Rm*) *after* the address is used to access memory. *Rm* cannot be SP or PC.

Table 4-8 Permitted combinations of parameters

<i>n</i>	<i>datatype</i>	<i>list</i> <sup>a</sup>	<i>align</i> <sup>b</sup>	alignment
1	8	{Dd[x]}	-	Standard only
	16	{Dd[x]}	@16	2-byte
	32	{Dd[x]}	@32	4-byte

**Table 4-8 Permitted combinations of parameters (continued)**

<i>n</i>	<i>datatype</i>	<i>list</i> <sup>a</sup>	<i>align</i> <sup>b</sup>	<i>alignment</i>
2	8	{Dd[x], D(d+1)[x]}	@16	2-byte
		{Dd[x], D(d+1)[x]}	@32	4-byte
	16	{Dd[x], D(d+2)[x]}	@32	4-byte
		{Dd[x], D(d+1)[x]}	@64	8-byte
	32	{Dd[x], D(d+2)[x]}	@64	8-byte
		{Dd[x], D(d+1)[x]}	@64	8-byte
3	8	{Dd[x], D(d+1)[x], D(d+2)[x]}	-	Standard only
	16 or 32	{Dd[x], D(d+1)[x], D(d+2)[x]}	-	Standard only
		{Dd[x], D(d+2)[x], D(d+4)[x]}	-	Standard only
4	8	{Dd[x], D(d+1)[x], D(d+2)[x], D(d+3)[x]}	@32	4-byte
	16	{Dd[x], D(d+1)[x], D(d+2)[x], D(d+3)[x]}	@64	8-byte
		{Dd[x], D(d+2)[x], D(d+4)[x], D(d+6)[x]}	@64	8-byte
	32	{Dd[x], D(d+1)[x], D(d+2)[x], D(d+3)[x]}	@64 or @128	8-byte or 16-byte
		{Dd[x], D(d+2)[x], D(d+4)[x], D(d+6)[x]}	@64 or @128	8-byte or 16-byte

a. Every register in the list must be in the range D0-D31.

b. *align* can be omitted. In this case, standard alignment rules apply, see *Alignment restrictions in load and store, element and structure instructions* on page 4-75.

## See also

## Reference:

- *Condition codes* on page 3-186.

4.8.4 VLDn (single *n*-element structure to all lanes)

Vector Load single *n*-element structure to all lanes. It loads multiple copies of one *n*-element structure from memory into one or more NEON registers.

Syntax

```
VLDn{cond}.datatype list, [Rn{@align}]{!}  
VLDn{cond}.datatype list, [Rn{@align}], Rm
```

where:

- n* must be one of 1, 2, 3, or 4.
- cond* is an optional condition code.
- datatype* see Table 4-9 .
- list* specifies the NEON register list. See Table 4-9 for options.
- Rn* is the ARM register containing the base address. *Rn* cannot be PC.
- align* specifies an optional alignment. See Table 4-9 for options.
- ! if ! is present, *Rn* is updated to (*Rn* + the number of bytes transferred by the instruction). The update occurs after all the loads or stores have taken place.
- Rm* is an ARM register containing an offset from the base address. If *Rm* is present, *Rn* is updated to (*Rn* + *Rm*) *after* the address is used to access memory. *Rm* cannot be SP or PC.

Table 4-9 Permitted combinations of parameters

<i>n</i>	<i>datatype</i>	<i>list</i> <sup>a</sup>	<i>align</i> <sup>b</sup>	alignment
1	8	{Dd[]}	-	Standard only
		{Dd[],D(d+1)[]}	-	Standard only
	16	{Dd[]}	@16	2-byte
		{Dd[],D(d+1)[]}	@16	2-byte
	32	{Dd[]}	@32	4-byte
		{Dd[],D(d+1)[]}	@32	4-byte
2	8	{Dd[], D(d+1)[]}	@8	byte



Table 4-9 Permitted combinations of parameters (continued)

<i>n</i>	<i>datatype</i>	<i>list</i> <sup>a</sup>	<i>align</i> <sup>b</sup>	<i>alignment</i>
16	8	{Dd[], D(d+2)[]}	@8	byte
		{Dd[], D(d+1)[]}	@16	2-byte
		{Dd[], D(d+2)[]}	@16	2-byte
	32	{Dd[], D(d+1)[]}	@32	4-byte
		{Dd[], D(d+2)[]}	@32	4-byte
3	8, 16, or 32	{Dd[], D(d+1)[], D(d+2)[]}	-	Standard only
		{Dd[], D(d+2)[], D(d+4)[]}	-	Standard only
4	8	{Dd[], D(d+1)[], D(d+2)[], D(d+3)[]}	@32	4-byte
		{Dd[], D(d+2)[], D(d+4)[], D(d+6)[]}	@32	4-byte
	16	{Dd[], D(d+1)[], D(d+2)[], D(d+3)[]}	@64	8-byte
		{Dd[], D(d+2)[], D(d+4)[], D(d+6)[]}	@64	8-byte
	32	{Dd[], D(d+1)[], D(d+2)[], D(d+3)[]}	@64 or @128	8-byte or 16-byte
		{Dd[], D(d+2)[], D(d+4)[], D(d+6)[]}	@64 or @128	8-byte or 16-byte

- a. Every register in the list must be in the range D0-D31.
- b. *align* can be omitted. In this case, standard alignment rules apply, see *Alignment restrictions in load and store, element and structure instructions* on page 4-75.

See also

Reference:

- *Condition codes* on page 3-186.

4.8.5 VLDn and VSTn (multiple *n*-element structures)

Vector Load multiple *n*-element structures. It loads multiple *n*-element structures from memory into one or more NEON registers, with de-interleaving (unless *n* == 1). Every element of each register is loaded.

Vector Store multiple *n*-element structures. It stores multiple *n*-element structures to memory from one or more NEON registers, with interleaving (unless *n* == 1). Every element of each register is stored.

Syntax

```
Vopn{cond}.datatype list, [Rn{@align}]{!}  
Vopn{cond}.datatype list, [Rn{@align}], Rm
```

where:

- op* must be either LD or ST.
- n* must be one of 1, 2, 3, or 4.
- cond* is an optional condition code.
- datatype* see Table 4-10 for options.
- list* specifies the NEON register list. See Table 4-10 for options.
- Rn* is the ARM register containing the base address. *Rn* cannot be PC.
- align* specifies an optional alignment. See Table 4-10 for options.
- ! if ! is present, *Rn* is updated to (*Rn* + the number of bytes transferred by the instruction). The update occurs after all the loads or stores have taken place.
- Rm* is an ARM register containing an offset from the base address. If *Rm* is present, *Rn* is updated to (*Rn* + *Rm*) *after* the address is used to access memory. *Rm* cannot be SP or PC.

Table 4-10 Permitted combinations of parameters

<i>n</i>	<i>datatype</i>	<i>list</i> <sup>a</sup>	<i>align</i> <sup>b</sup>	<i>alignment</i>
1	8, 16, 32, or 64	{Dd}	@64	8-byte
		{Dd, D(d+1)}	@64 or @128	8-byte or 16-byte
		{Dd, D(d+1), D(d+2)}	@64	8-byte

Table 4-10 Permitted combinations of parameters (continued)

<i>n</i>	<i>datatype</i>	<i>list</i> <sup>a</sup>	<i>align</i> <sup>b</sup>	<i>alignment</i>
2	8, 16, or 32	{Dd, D(d+1), D(d+2), D(d+3)}	@64, @128, or @256	8-byte, 16-byte, or 32-byte
		{Dd, D(d+1)}	@64, @128	8-byte or 16-byte
		{Dd, D(d+2)}	@64, @128	8-byte or 16-byte
		{Dd, D(d+1), D(d+2), D(d+3)}	@64, @128, or @256	8-byte, 16-byte, or 32-byte
3	8, 16, or 32	{Dd, D(d+1), D(d+2)}	@64	8-byte
		{Dd, D(d+2), D(d+4)}	@64	8-byte
4	8, 16, or 32	{Dd, D(d+1), D(d+2), D(d+3)}	@64, @128, or @256	8-byte, 16-byte, or 32-byte
		{Dd, D(d+2), D(d+4), D(d+6)}	@64, @128, or @256	8-byte, 16-byte, or 32-byte

- a. Every register in the list must be in the range D0-D31.
- b. *align* can be omitted. In this case, standard alignment rules apply, see *Alignment restrictions in load and store, element and structure instructions* on page 4-75.

See also

Reference:

- *Condition codes* on page 3-186.

## 4.9 NEON and VFP pseudo-instructions

This section contains the following subsections:

- *VLDR pseudo-instruction* on page 4-83 (NEON and VFP)
- *VLDR and VSTR (post-increment and pre-decrement)* on page 4-84 (NEON and VFP)
- *VMOV2* on page 4-86 (NEON only)
- *VAND and VORN (immediate)* on page 4-87 (NEON only)
- *VACLE and VACLT* on page 4-89 (NEON only)
- *VCLE and VCLT* on page 4-90 (NEON only).

### 4.9.1 VLDR pseudo-instruction

The VLDR pseudo-instruction loads a constant value into every element of a 64-bit NEON vector, or into a VFP single-precision or double-precision register.

———— **Note** ————

This section describes the VLDR *pseudo*-instruction only.

#### Syntax

VLDR{*cond*}.*datatype* *Dd*,=*constant*

VLDR{*cond*}.*datatype* *Sd*,=*constant*

where:

*datatype* must be one of:

<i>In</i>	NEON only
<i>Sn</i>	NEON only
<i>Un</i>	NEON only
F32	NEON or VFP
F64	VFP only

*n* must be one of 8, 16, 32, or 64.

*cond* is an optional condition code.

*Dd* or *Sd* is the extension register to be loaded.

*constant* is an immediate value of the appropriate type for *datatype*.

#### Usage

If an instruction (for example, *VMOV*) is available that can generate the constant directly into the register, the assembler uses it. Otherwise, it generates a doubleword literal pool entry containing the constant and loads the constant using a VLDR instruction.

#### See also

#### Reference:

- *VLDR and VSTR* on page 4-9
- *Condition codes* on page 3-186.

## 4.9.2 VLDR and VSTR (post-increment and pre-decrement)

Pseudo-instructions that load or store extension registers with post-increment and pre-decrement.

---

### Note

---

There are also VLDR and VSTR instructions without post-increment and pre-decrement.

---

### Syntax

`op{cond}{.size} Fd, [Rn], #offset` ; post-increment

`op{cond}{.size} Fd, [Rn, #-offset]!` ; pre-decrement

where:

*op* can be:

- VLDR - load extension register from memory
- VSTR - store contents of extension register to memory.

*cond* is an optional condition code.

*size* is an optional data size specifier. Must be 32 if *Fd* is an S register, or 64 if *Fd* is a D register.

*Fd* is the extension register to be loaded or saved. For a NEON instruction, it must be a doubleword (*Dd*) register. For a VFP instruction, it can be either a double precision (*Dd*) or a single precision (*Sd*) register.

*Rn* is the ARM register holding the base address for the transfer.

*offset* is a numeric expression that must evaluate to a numeric value at assembly time. The value must be 4 if *Fd* is an S register, or 8 if *Fd* is a D register.

### Usage

The post-increment instruction increments the base address in the register by the offset value, after the transfer. The pre-decrement instruction decrements the base address in the register by the offset value, and then performs the transfer using the new address in the register. These pseudo-instructions assemble to VLDM or VSTM instructions.

### See also

#### Reference:

- *VLDR and VSTR* on page 4-9

- *VLDM, VSTM, VPOP, and VPUSH* on page 4-11
- *Condition codes* on page 3-186.

### 4.9.3 VMOV2

The VMOV2 pseudo-instruction generates an immediate value and places it in every element of a NEON vector, without loading a value from a literal pool. It always assembles to exactly two instructions.

VMOV2 can generate any 16-bit immediate value, and a restricted range of 32-bit and 64-bit immediate values.

#### Syntax

`VMOV2{cond}.datatype Qd, #constant`

`VMOV2{cond}.datatype Dd, #constant`

where:

*datatype* must be one of:

- I8, I16, I32, or I64
- S8, S16, S32, or S64
- U8, U16, U32, or U64
- F32.

*cond* is an optional condition code.

*Qd* or *Dd* is the extension register to be loaded.

*constant* is an immediate value of the appropriate type for *datatype*.

#### Usage

VMOV2 typically assembles to a VMOV or VMVN instruction, followed by a VBIC or VORR instruction.

#### See also

##### Reference:

- *VMOV, VMVN (immediate)* on page 4-34
- *VBIC and VORR (immediate)* on page 4-20
- *Condition codes* on page 3-186.



#### 4.9.4 VAND and VORN (immediate)

VAND (Bitwise AND immediate) takes each element of the destination vector, performs a bitwise AND with an immediate value, and returns the result into the destination vector.

VORN (Bitwise OR NOT immediate) takes each element of the destination vector, performs a bitwise OR Complement with an immediate value, and returns the result into the destination vector.

---

##### Note

On disassembly, these pseudo-instructions are disassembled to the corresponding VBIC and VORR instructions, with the complementary immediate values.

---

#### Syntax

*Vop{cond}.datatype Qd, #imm*

*Vop{cond}.datatype Dd, #imm*

where:

<i>op</i>	must be either VAND or VORN.
<i>cond</i>	is an optional condition code.
<i>datatype</i>	must be either I8, I16, I32, or I64.
<i>Qd</i> or <i>Dd</i>	is the NEON register for the result.
<i>imm</i>	is the immediate value.

#### Immediate values

If *datatype* is I16, the immediate value must have one of the following forms:

- 0xFFXY
- 0xXYFF.

If *datatype* is I32, the immediate value must have one of the following forms:

- 0xFFFFFFXY
- 0xFFFFXYFF
- 0xFFXYFFFF
- 0xXYFFFFFF.

## See also

### Reference:

- *VBIC and VORR (immediate)* on page 4-20
- *Condition codes* on page 3-186.

### 4.9.5 VACLE and VACLT

Vector Absolute Compare takes the absolute value of each element in a vector, and compares it with the absolute value of the corresponding element of a second vector. If the condition is true, the corresponding element in the destination vector is set to all ones. Otherwise, it is set to all zeros.

---

#### Note

---

On disassembly, these pseudo-instructions are disassembled to the corresponding VACGE and VACGT instructions, with the operands reversed.

---

#### Syntax

`VACop{cond}.datatype {Qd}, Qn, Qm`

`VACop{cond}.datatype {Dd}, Dn, Dm`

where:

<i>op</i>	must be one of:
LE	Absolute Less than or Equal
LT	Absolute Less Than.
<i>cond</i>	is an optional condition code.
<i>datatype</i>	must be F32.
<i>Qd</i> or <i>Dd</i>	is the NEON register for the result. The result datatype is I32.
<i>Qn</i> or <i>Dn</i>	is the NEON register holding the first operand.
<i>Qm</i> or <i>Dm</i>	is the NEON register holding the second operand.

#### See also

#### Reference:

- *Condition codes* on page 3-186
- *VACGE and VACGT* on page 4-24.

## 4.9.6 VCLE and VCLT

Vector Compare takes the value of each element in a vector, and compares it with the value of the corresponding element of a second vector, or zero. If the condition is true, the corresponding element in the destination vector is set to all ones. Otherwise, it is set to all zeros.

---

### Note

---

On disassembly, these pseudo-instructions are disassembled to the corresponding VCGE and VCGT instructions, with the operands reversed.

---

### Syntax

`VCop{cond}.datatype {Qd}, Qn, Qm`

`VCop{cond}.datatype {Dd}, Dn, Dm`

where:

*op* must be one of:

LE	Less than or Equal
LT	Less Than.

*cond* is an optional condition code.

*datatype* must be one of S8, S16, S32, U8, U16, U32, or F32.

*Qd* or *Dd* is the NEON register for the result.

The result datatype is:

- I32 for operand datatypes I32, S32, U32, or F32
- I16 for operand datatypes I16, S16, or U16
- I8 for operand datatypes I8, S8, or U8.

*Qn* or *Dn* is the NEON register holding the first operand.

*Qm* or *Dm* is the NEON register holding the second operand.

### See also

#### Reference:

- *Condition codes* on page 3-186
- *VCLE and VCLT*.

## 4.10 VFP instructions

This section contains the following subsections:

- *VABS, VNEG, and VSQRT* on page 4-92  
Floating-point absolute value, negate, and square root.
- *VADD, VSUB, and VDIV* on page 4-94  
Floating-point add, subtract, and divide.
- *VMUL, VMLA, VMLS, VNMUL, VNMLA, and VNMLS* on page 4-96  
Floating-point multiply and multiply accumulate, with optional negation.
- *VFMA, VFMS, VFNMA, VFNMS* on page 4-98  
Fused floating-point multiply accumulate and fused floating-point multiply subtract, with optional negation.
- *VCMP* on page 4-100  
Floating-point compare.
- *VCVT (between single-precision and double-precision)* on page 4-101  
Convert between single-precision and double-precision.
- *VCVT (between floating-point and integer)* on page 4-102  
Convert between floating-point and integer.
- *VCVT (between floating-point and fixed-point)* on page 4-103  
Convert between floating-point and fixed-point.
- *VCVTB, VCVTT (half-precision extension)* on page 4-105  
Convert between half-precision and single-precision floating-point.
- *VMOV* on page 4-106  
Insert a floating-point immediate value in a single-precision or double-precision register.

### 4.10.1 VABS, VNEG, and VSQRT

Floating-point absolute value, negate, and square root.

These instructions can be scalar, vector, or mixed.

#### Syntax

$Vop\{cond\}.F32\ Sd, Sm$

$Vop\{cond\}.F64\ Dd, Dm$

where:

$op$  is one of ABS, NEG, or Sqrt.

$cond$  is an optional condition code.

$Sd, Sm$  are the single-precision registers for the result and operand.

$Dd, Dm$  are the double-precision registers for the result and operand.

#### Usage

The VABS instruction takes the contents of  $Sm$  or  $Dm$ , clears the sign bit, and places the result in  $Sd$  or  $Dd$ . This gives the absolute value.

The VNEG instruction takes the contents of  $Sm$  or  $Dm$ , changes the sign bit, and places the result in  $Sd$  or  $Dd$ . This gives the negation of the value.

The VSQRT instruction takes the square root of the contents of  $Sm$  or  $Dm$ , and places the result in  $Sd$  or  $Dd$ .

In the case of a VABS and VNEG instruction, if the operand is a NaN, the sign bit is determined in each case as above, but no exception is produced.

#### Floating-point exceptions

VABS and VNEG instructions cannot produce any exceptions.

VSQRT instructions can produce Invalid Operation or Inexact exceptions.

#### See also

##### Concepts

*Using the Assembler:*

- *Control of scalar, vector, and mixed operations* on page 9-41.

**Reference:**

- *Condition codes* on page 3-186.

### 4.10.2 VADD, VSUB, and VDIV

Floating-point add, subtract, and divide.

These instructions can be scalar, vector, or mixed.

#### Syntax

*Vop{cond}.F32 {Sd}, Sn, Sm*

*Vop{cond}.F64 {Dd}, Dn, Dm*

where:

*op* is one of ADD, SUB, or DIV.

*cond* is an optional condition code.

*Sd, Sn, Sm* are the single-precision registers for the result and operands.

*Dd, Dn, Dm* are the double-precision registers for the result and operands.

#### Usage

The VADD instruction adds the values in the operand registers and places the result in the destination register.

The VSUB instruction subtracts the value in the second operand register from the value in the first operand register, and places the result in the destination register.

The VDIV instruction divides the value in the first operand register by the value in the second operand register, and places the result in the destination register.

#### Floating-point exceptions

VADD and VSUB instructions can produce Invalid Operation, Overflow, or Inexact exceptions.

VDIV operations can produce Division by Zero, Invalid Operation, Overflow, Underflow, or Inexact exceptions.

#### See also

#### Concepts

*Using the Assembler:*

- *Control of scalar, vector, and mixed operations* on page 9-41.



**Reference:**

- *Condition codes* on page 3-186.

### 4.10.3 VMUL, VMLA, VMLS, VNMUL, VNMLA, and VNMLS

Floating-point multiply and multiply accumulate, with optional negation.

These instructions can be scalar, vector, or mixed.

#### Syntax

$V\{N\}MUL\{cond\}.F32 \{Sd,\} Sn, Sm$

$V\{N\}MUL\{cond\}.F64 \{Dd,\} Dn, Dm$

$V\{N\}MLA\{cond\}.F32 Sd, Sn, Sm$

$V\{N\}MLA\{cond\}.F64 Dd, Dn, Dm$

$V\{N\}MLS\{cond\}.F32 Sd, Sn, Sm$

$V\{N\}MLS\{cond\}.F64 Dd, Dn, Dm$

where:

*N* negates the final result.

*cond* is an optional condition code.

*Sd, Sn, Sm* are the single-precision registers for the result and operands.

*Dd, Dn, Dm* are the double-precision registers for the result and operands.

#### Usage

The VMUL operation multiplies the values in the operand registers and places the result in the destination register.

The VMLA operation multiplies the values in the operand registers, adds the value in the destination register, and places the final result in the destination register.

The VMLS operation multiplies the values in the operand registers, subtracts the result from the value in the destination register, and places the final result in the destination register.

In each case, the final result is negated if the N option is used.

#### Floating-point exceptions

These instructions can produce Invalid Operation, Overflow, Underflow, Inexact, or Input Denormal exceptions.

**See also****Concepts**

*Using the Assembler:*

- *Control of scalar, vector, and mixed operations* on page 9-41.

**Reference:**

- *Condition codes* on page 3-186.

#### 4.10.4 VFMA, VFMS, VFNMA, VFNMS

Fused floating-point multiply accumulate and fused floating-point multiply subtract with optional negation.

These instructions are always scalar.

##### Syntax

$VF\{N\}op\{cond\}.F64 \{Dd\}, Dn, Dm$

$VF\{N\}op\{cond\}.F32 \{Sd\}, Sn, Sm$

where:

*op* is one of MA or MS.

*N* negates the final result.

*cond* is an optional condition code.

*Sd, Sn, Sm* are the single-precision registers for the result and operands.

*Dd, Dn, Dm* are the double-precision registers for the result and operands.

*Qd, Qn, Qm* are the double-precision registers for the result and operands.

##### Usage

VFMA multiplies the values in the operand registers, adds the value in the destination register, and places the final result in the destination register. The result of the multiply is not rounded before the accumulation.

VFMS multiplies the values in the operand registers, subtracts the product from the value in the destination register, and places the final result in the destination register. The result of the multiply is not rounded before the subtraction.

In each case, the final result is negated if the *N* option is used.

##### Floating-point exceptions

These instructions can produce Input Denormal, Invalid Operation, Overflow, Underflow, or Inexact exceptions.

**See also****Concepts**

*Using the Assembler:*

- *Control of scalar, vector, and mixed operations* on page 9-41.

**Reference:**

- *Condition codes* on page 3-186
- *VMUL, VMLA, VMLS, VNMUL, VNMLA, and VNMLS* on page 4-96.

### 4.10.5 VCMP

Floating-point compare.

VCMP is always scalar.

#### Syntax

`VCMP{cond}.F32 Sd, Sm`

`VCMP{cond}.F32 Sd, #0`

`VCMP{cond}.F64 Dd, Dm`

`VCMP{cond}.F64 Dd, #0`

where:

*cond* is an optional condition code.

*Sd, Sm* are the single-precision registers holding the operands.

*Dd, Dm* are the double-precision registers holding the operands.

#### Usage

The VCMP instruction subtracts the value in the second operand register (or 0 if the second operand is #0) from the value in the first operand register, and sets the VFP condition flags on the result.

#### Floating-point exceptions

VCMP instructions can produce Invalid Operation exceptions.

#### See also

#### Reference:

- *Condition codes* on page 3-186.

#### 4.10.6 VCVT (between single-precision and double-precision)

Convert between single-precision and double-precision numbers.

VCVT is always scalar.

##### Syntax

$\text{VCVT}\{\text{cond}\}.\text{F64}.\text{F32 } Dd, Sm$

$\text{VCVT}\{\text{cond}\}.\text{F32}.\text{F64 } Sd, Dm$

where:

*cond* is an optional condition code.

*Dd* is a double-precision register for the result.

*Sm* is a single-precision register holding the operand.

*Sd* is a single-precision register for the result.

*Dm* is a double-precision register holding the operand.

##### Usage

These instructions convert the single-precision value in *Sm* to double-precision and places the result in *Dd*, or the double-precision value in *Dm* to single-precision and place the result in *Sd*.

##### Floating-point exceptions

These instructions can produce Invalid Operation, Input Denormal, Overflow, Underflow, or Inexact exceptions.

##### See also

##### Reference:

- *Condition codes* on page 3-186.

#### 4.10.7 VCVT (between floating-point and integer)

Convert between floating-point numbers and integers.

VCVT is always scalar.

##### Syntax

`VCVT{R}{cond}.type.F64 Sd, Dm`

`VCVT{R}{cond}.type.F32 Sd, Sm`

`VCVT{cond}.F64.type Dd, Sm`

`VCVT{cond}.F32.type Sd, Sm`

where:

*R* makes the operation use the rounding mode specified by the FPSCR. Otherwise, the operation rounds towards zero.

*cond* is an optional condition code.

*type* can be either U32 (unsigned 32-bit integer) or S32 (signed 32-bit integer).

*Sd* is a single-precision register for the result.

*Dd* is a double-precision register for the result.

*Sm* is a single-precision register holding the operand.

*Dm* is a double-precision register holding the operand.

##### Usage

The first two forms of this instruction convert from floating-point to integer.

The third and fourth forms convert from integer to floating-point.

##### Floating-point exceptions

These instructions can produce Input Denormal, Invalid Operation, or Inexact exceptions.

##### See also

##### Reference:

- *Condition codes* on page 3-186.



#### 4.10.8 VCVT (between floating-point and fixed-point)

Convert between floating-point and fixed-point numbers.

VCVT is always scalar.

##### Syntax

`VCVT{cond}.type.F64 Dd, Dd, #fbits`

`VCVT{cond}.type.F32 Sd, Sd, #fbits`

`VCVT{cond}.F64.type Dd, Dd, #fbits`

`VCVT{cond}.F32.type Sd, Sd, #fbits`

where:

*cond* is an optional condition code.

*type* can be any one of:

S16	16-bit signed fixed-point number
U16	16-bit unsigned fixed-point number
S32	32-bit signed fixed-point number
U32	32-bit unsigned fixed-point number.

*Sd* is a single-precision register for the operand and result.

*Dd* is a double-precision register for the operand and result.

*fbits* is the number of fraction bits in the fixed-point number, in the range 0-16 if *type* is S16 or U16, or in the range 1-32 if *type* is S32 or U32.

##### Usage

The first two forms of this instruction convert from floating-point to fixed-point.

The third and fourth forms convert from fixed-point to floating-point.

In all cases the fixed-point number is contained in the least significant 16 or 32 bits of the register.

##### Floating-point exceptions

These instructions can produce Input Denormal, Invalid Operation, or Inexact exceptions.

**See also**

**Reference:**

- *Condition codes* on page 3-186.

#### 4.10.9 VCVTB, VCVTT (half-precision extension)

Converts between half-precision and single-precision floating-point numbers in the following ways:

- VCVTB uses the bottom half (bits[15:0]) of the single word register to obtain or store the half-precision value
- VCVTT uses the top half (bits[31:16]) of the single word register to obtain or store the half-precision value.

VCVTB and VCVTT are always scalar.

##### Syntax

`VCVTB{cond}.type Sd, Sm`

`VCVTT{cond}.type Sd, Sm`

where:

*cond* is an optional condition code.

*type* can be any one of:

F32.F16 convert from half-precision to single-precision

F16.F32 convert from single-precision to half-precision.

*Sd* is a single word register for the result.

*Sm* is a single word register for the operand.

##### Architectures

The instructions are only available in VFPv3 systems with the half-precision extension.

##### Floating-point exceptions

These instructions can produce Input Denormal, Invalid Operation, Overflow, Underflow, or Inexact exceptions.

##### See also

##### Reference:

- *Condition codes* on page 3-186.

#### 4.10.10 VMOV

Insert a floating-point immediate value in a single-precision or double-precision register, or copy one register into another register.

This instruction is always scalar.

##### Syntax

`VMOV{cond}.F32 Sd, #imm`

`VMOV{cond}.F64 Dd, #imm`

`VMOV{cond}.F32 Sd, Sm`

`VMOV{cond}.F64 Dd, Dm`

where:

<i>cond</i>	is an optional condition code.
<i>Sd</i>	is the single-precision destination register.
<i>Dd</i>	is the double-precision destination register.
<i>imm</i>	is the floating-point immediate value.
<i>Sm</i>	is the single-precision source register.
<i>Dm</i>	is the double-precision source register.

##### Immediate values

Any number that can be expressed as  $\pm n * 2^{-r}$ , where  $n$  and  $r$  are integers,  $16 \leq n \leq 31$ ,  $0 \leq r \leq 7$ .

##### Architectures

The instructions that copy immediate constants are available in VFPv3.

The instructions that copy from register are available on all VFP systems.

##### See also

##### Reference:

- *Condition codes* on page 3-186.

# Chapter 5

## Wireless MMX Technology Instructions

The following topics describe support for Wireless MMX Technology instructions:

- *Introduction* on page 5-2
- *ARM support for Wireless MMX technology* on page 5-3
- *Wireless MMX instructions* on page 5-7
- *Wireless MMX pseudo-instructions* on page 5-9.

## 5.1 Introduction

Marvell Wireless MMX Technology is a set of *Single Instruction Multiple Data* (SIMD) instructions available on selected XScale processors that improve the performance of some multimedia applications. Wireless MMX Technology uses 64-bit registers to enable it to operate on multiple data elements in a packed format.

The assembler supports Marvell Wireless MMX Technology instructions to assemble code to run on the PXA270 processor. This processor implements ARMv5TE architecture, with MMX extensions. Wireless MMX Technology uses ARM coprocessors 0 and 1 to support its instruction set and data types. ARM Compiler toolchain supports Wireless MMX Technology Control and *Single Instruction Multiple Data* (SIMD) Data registers, and include new directives for Wireless MMX Technology development. There is also enhanced support for load and store instructions.

When using the assembler, be aware that:

- Wireless MMX Technology instructions are only assembled if you specify the supported processor (`armasm --cpu PXA270`).
- The PXA270 processor supports code written in ARM or Thumb only.
- Most Wireless MMX Technology instructions can be executed conditionally, depending on the state of the ARM flags. The Wireless MMX Technology condition codes are identical to the ARM condition codes.

Wireless MMX 2 Technology is an upgraded version of Wireless MMX Technology.

This contains information on the Wireless MMX Technology support provided by the assembler in the ARM Compiler toolchain. It does not provide a detailed description of the Wireless MMX Technology. *Wireless MMX Technology Developer Guide* contains information about the programmers' model and a full description of the Wireless MMX Technology instruction set.

### See also

### Reference

- *Wireless MMX Technology Developer Guide*.

## 5.2 ARM support for Wireless MMX technology

This section gives information on the assembler support for Wireless MMX and MMX 2 Technology. It describes:

- *Directives, WRN and WCN*
- *Frame directives*
- *Wireless MMX load and store instructions on page 5-4*
- *Wireless MMX Technology and XScale instructions on page 5-5.*

### 5.2.1 Directives, WRN and WCN

Directives are available to support Wireless MMX Technology:

<b>WCN</b>	Defines a name for a specified Control register, for example: speed WCN wcgr0 ; defines speed as a symbol for control reg 0
<b>WRN</b>	Defines a name for a specified SIMD Data register, for example: rate WRN wr6 ; defines rate as a symbol for data reg 6

Avoid conflicting uses of the same register under different names. Do not use any of the predefined register and coprocessor names.

### 5.2.2 Frame directives

Wireless MMX Technology registers can be used with FRAME directives in the usual way to add debug information into your object files. Be aware of the following restrictions:

- A warning is given if you try to push Wireless MMX Technology registers wR0 - wR9 or wCGR0 - wCGR3 onto the stack.
- Wireless MMX Technology registers cannot be used as address offsets.

### 5.2.3 Wireless MMX load and store instructions

Load and store byte, halfword, word or doublewords to and from Wireless MMX coprocessor registers.

#### Syntax

*op*<type>{*cond*} *wRd*, [*Rn*, #{-}*offset*]{!}

*op*<type>{*cond*} *wRd*, [*Rn*] {, #{-}*offset*}

*opW*{*cond*} *wRd*, *label*

*opW wCd*, [*Rn*, #{-}*offset*]{!}

*opW wCd*, [*Rn*] {, #{-}*offset*}

*opD*{*cond*} *wRd*, *label*

*opD wRd*, [*Rn*, {-}*Rm* {, LSL #*imm4*}]{!} ; MMX2 only

*opD wRd*, [*Rn*], {-}*Rm* {, LSL #*imm4*} ; MMX2 only

where:

*op* can be either:

WLDR	Load Wireless MMX Register
WSTR	Store Wireless MMX Register.

<type> can be any one of:

B	Byte
H	Halfword
W	Word
D	Doubleword.

*cond* is an optional condition code.

*wRd* is the Wireless MMX SIMD data register to load or save.

*wCd* is the Wireless MMX Status and Control register to load or save.

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

*offset* is an immediate offset. If offset is omitted, the instruction is a zero offset instruction.

! is an optional suffix. If ! is present, the instruction is a pre-indexed instruction.



<i>label</i>	is a PC-relative expression. <i>label</i> must be within +/- 1020 bytes of the current instruction.
<i>Rm</i>	is a register containing a value to be used as the offset. <i>Rm</i> must not be PC.
<i>imm4</i>	contains the number of bits to shift <i>Rm</i> left, in the range 0-15.

### Loading constants into SIMD registers

The assembler also supports the WLD<sub>RW</sub> and WLD<sub>RD</sub> literal load pseudo-instructions, for example:

```
WLDRW wr0, =0x114
```

Be aware that:

- The assembler cannot load byte and halfword literals. These produce a downgradable error. If downgraded, the instruction is converted to a WLD<sub>RW</sub> and a 32-bit literal is generated. This is the same as a byte literal load, but uses a 32-bit word instead.
- If the literal to be loaded is zero, and the destination is a SIMD Data register, the assembler converts the instruction to a WZERO.
- Doubleword loads that are not 8-byte aligned are unpredictable.

### 5.2.4 Wireless MMX Technology and XScale instructions

Wireless MMX Technology instructions overlap with XScale instructions. To avoid conflicts, the assembler has the following restrictions:

- You cannot mix the XScale instructions with Wireless MMX Technology instructions in the same assembly.
- Wireless MMX Technology TMIA instructions have a MIA mnemonic that overlaps with the XScale MIA instructions. Be aware that:
  - MIA acc0, *Rm*, *Rs* is accepted in XScale, but faulted in Wireless MMX Technology.
  - MIA wr0, *Rm*, *Rs* and TMIA wr0, *Rm*, *Rs* are accepted in Wireless MMX Technology.

— TMIA acc0, Rm, Rs is faulted in XScale (XScale has no TMIA instruction).

### See also

### Concepts

*Using the Assembler:*

- *Predeclared XScale register names* on page 3-17
- *Register-relative and PC-relative expressions* on page 8-9.

### Reference

- *Condition codes* on page 3-186
- *MIA, MIAPH, and MIAxy* on page 3-105
- *MAR and MRA* on page 3-171
- *Frame directives* on page 6-50
- *FRAME PUSH* on page 6-55
- *FRAME ADDRESS* on page 6-52
- *FRAME RETURN ADDRESS* on page 6-59.

### 5.3 Wireless MMX instructions

Table 5-1 gives a list of the Wireless MMX Technology instruction set. The instructions are described in *Wireless MMX Technology Developer Guide*. Wireless MMX Technology registers are indicated by *wRn*, *wRd*, and ARM registers are shown as *Rn*, *Rd*.

**Table 5-1 Wireless MMX Technology instructions**

Mnemonic	Example
TANDC	TANDCB r15
TBCST	TBCSTB wr15, r1
TEXTRC	TEXTRCB r15, #0
TEXTRM	TEXTRMUBCS r3, wr7, #7
TINSR	TINSRB wr6, r11, #0
TMIA, TMIAPH, TMIAxy	TMIANE wr1, r2, r3 TMIAPH wr4, r5, r6 TMIABB wr4, r5, r6 MIAPHNE wr4, r5, r6
TMOVMSK	TMOVMSKBNE r14, wr15
TORC	TORCB r15
WACC	WACCBGE wr1, wr2
WADD	WADDBGE wr1, wr2, wr13
WALIGNI, WALIGNR	WALIGNI wr7, wr6, wr5, #3 WALIGNR0 wr4, wr8, wr12
WAND, WANDN	WAND wr1, wr2, wr3 WANDN wr5, wr5, wr9
WAVG2	WAVG2B wr3, wr6, wr9 WAVG2BR wr4, wr7, wr10
WCMP EQ	WCMP EQB wr0, wr4, wr2
WCMPGT	WCMPGTUB wr0, wr4, wr2
WLDR	WLDRB wr1, [r2, #0]
WMAC	WMACU wr3, wr4, wr5
WMADD	WMADDU wr3, wr4, wr5

Table 5-1 Wireless MMX Technology instructions (continued)

Mnemonic	Example
WMAX, WMIN	WMAXUB wr0, wr4, wr2 WMINSB wr0, wr4, wr2
WMUL	WMULUL wr4, wr2, wr3
WOR	WOR wr3, wr1, wr4
WPACK	WPACKHUS wr2, wr7, wr1
WROR	WRORH wr3, wr1, wr4
WSAD	WSADB wr3, wr5, wr8
WSHUFH	WSHUFH wr8, wr15, #17
WSLL, WSRL	WSLLH wr3, wr1, wr4 WSRLHG wr3, wr1, wcgr0
WSRA	WSRAH wr3, wr1, wr4 WSRAHG wr3, wr1, wcgr0
WSTR	WSTRB wr1, [r2, #0] WSTRW wc1, [r2, #0]
WSUB	WSUBBGE wr1, wr2, wr13
WUNPCKEH, WUNPCKEL	WUNPCKEHUB wr0, wr4 WUNPCKELSB wr0, wr4
WUNPCKIH, WUNPCKIL	WUNPCKIHB wr0, wr4, wr2 WUNPCKILH wr1, wr5, wr3
WXOR	WXOR wr3, wr1, wr4

See also

Reference

- *Wireless MMX pseudo-instructions* on page 5-9
- *Wireless MMX Technology Developer Guide*.

## 5.4 Wireless MMX pseudo-instructions

Table 5-2 gives an overview of the Wireless MMX Technology pseudo-instructions. These instructions are described in the *Wireless MMX Technology Developer Guide*.

**Table 5-2 Wireless MMX Technology pseudo-instructions**

Mnemonic	Brief description	Example	
TMCRR	Moves the contents of source register, <i>Rn</i> , to Control register, <i>wCn</i> . Maps onto the ARM MCR coprocessor instruction (page 3-141).	TMCRR	wc1, r10
TMCRR	Moves the contents of two source registers, <i>RnLo</i> and <i>RnHi</i> , to destination register, <i>wRd</i> . Do not use R15 for either <i>RnLo</i> or <i>RnHi</i> . Maps onto the ARM MCRR coprocessor instruction (page 3-141).	TMCRR	wr4, r5, r6
TMRC	Moves the contents of Control register, <i>wCn</i> , to destination register, <i>Rd</i> . Do not use R15 for <i>Rd</i> . Maps onto the ARM MRC coprocessor instruction (page 3-143).	TMRC	r1, wc2
TMRRRC	Moves the contents of source register, <i>wRn</i> , to two destination registers, <i>RdLo</i> and <i>RdHi</i> . Do not use R15 for either destination register. <i>RdLo</i> and <i>RdHi</i> must be distinct registers, otherwise the result is unpredictable. Maps onto the ARM MRRC coprocessor instruction (page 3-143).	TMRRRC	r1, r0, wr2
WMOV	Moves the contents of source register, <i>wRn</i> , to destination register, <i>wRd</i> . This instruction is a form of WOR (see Table 5-1 on page 5-7).	WMOV	wr1, wr8
WZERO	Zeros destination register, <i>wRd</i> . This instruction is a form of WANDN (see Table 5-1 on page 5-7).	WZERO	wr1

### See also

### Reference

- *Wireless MMX Technology Developer Guide*
- Chapter 3 *ARM and Thumb Instructions*.



# Chapter 6

## Directives Reference

The following topics describe the directives that are provided by the ARM assembler, `armasm`:

- *Alphabetical list of directives* on page 6-2
- *Symbol definition directives* on page 6-4
- *Data definition directives* on page 6-18
- *Assembly control directives* on page 6-39
- *Frame directives* on page 6-50
- *Reporting directives* on page 6-67
- *Instruction set and syntax selection directives* on page 6-74
- *Miscellaneous directives* on page 6-77.

———— **Note** —————

None of these directives are available in the inline assemblers in the ARM C and C++ compilers.

—————

## 6.1 Alphabetical list of directives

Table 6-1 shows a complete list of the directives. Use it to locate individual directives.

**Table 6-1 Location of directives**

Directive	See	Directive	See	Directive	See
ALIGN	page 6-78	EXPORT <i>or</i> GLOBAL	page 6-91	MACRO <i>and</i> MEND	page 6-40
ARM <i>and</i> CODE32	page 6-75	EXPORTAS	page 6-93	MAP	page 6-21
AREA	page 6-81	EXTERN	page 6-95	MEND <i>see</i> MACRO	page 6-40
ASSERT	page 6-67	FIELD	page 6-22	MEXIT	page 6-44
ATTR	page 6-85	FRAME ADDRESS	page 6-52	NOFP	page 6-100
CN	page 6-14	FRAME POP	page 6-54	OPT	page 6-71
CODE16	page 6-75	FRAME PUSH	page 6-55	PRESERVE8 <i>see</i> REQUIRE8	page 6-101
COMMON	page 6-37	FRAME REGISTER	page 6-57	PROC <i>see</i> FUNCTION	page 6-65
CP	page 6-15	FRAME RESTORE	page 6-58	QN	page 6-16
DATA	page 6-38	FRAME SAVE	page 6-60	RELOC	page 6-10
DCB	page 6-25	FRAME STATE REMEMBER	page 6-61	REQUIRE	page 6-100
DCD <i>and</i> DCDU	page 6-26	FRAME STATE RESTORE	page 6-62	REQUIRE8 <i>and</i> PRESERVE8	page 6-101
DCDO	page 6-28	FRAME UNWIND ON <i>or</i> OFF	page 6-63	RLIST	page 6-13
DCFD <i>and</i> DCFDU	page 6-29	FUNCTION <i>or</i> PROC	page 6-65	RN	page 6-12
DCFS <i>and</i> DCFSU	page 6-31	GBLA, GBLL, <i>and</i> GBLS	page 6-5	ROUT	page 6-102
DCI	page 6-32	GET <i>or</i> INCLUDE	page 6-94	SETA, SETL, <i>and</i> SETS	page 6-8
DCQ <i>and</i> DCQU	page 6-34	GLOBAL <i>see</i> EXPORT	page 6-91	SN	page 6-16
DCW <i>and</i> DCWU	page 6-36	IF, ELSE, ENDIF, <i>and</i> ELIF	page 6-45	SPACE <i>or</i> FILL	page 6-23
DN	page 6-16	IMPORT	page 6-95	SUBT	page 6-73
ELIF, ELSE <i>see</i> IF	page 6-45	INCBIN	page 6-98	THUMB	page 6-75



**Table 6-1 Location of directives (continued)**

<b>Directive</b>	<b>See</b>	<b>Directive</b>	<b>See</b>	<b>Directive</b>	<b>See</b>
END	page 6-87	INCLUDE <i>see</i> GET	page 6-94	THUMBX	page 6-75
ENDFUNC <i>or</i> ENDP	page 6-66	INFO	page 6-69	TTL	page 6-73
ENDIF <i>see</i> IF	page 6-45	KEEP	page 6-99	WHILE <i>and</i> WEND	page 6-49
ENTRY	page 6-87	LCLA, LCLL, <i>and</i> LCLS	page 6-7		
EQU	page 6-89	LTORG	page 6-20		

## 6.2 Symbol definition directives

This section describes the following directives:

- *GBLA*, *GBLL*, and *GBLS* on page 6-5  
Declare a global arithmetic, logical, or string variable.
- *LCLA*, *LCLL*, and *LCLS* on page 6-7  
Declare a local arithmetic, logical, or string variable.
- *SETA*, *SETL*, and *SETS* on page 6-8  
Set the value of an arithmetic, logical, or string variable.
- *RELOC* on page 6-10  
Encode an ELF relocation in an object file.
- *RN* on page 6-12  
Define a name for a specified register.
- *RLIST* on page 6-13  
Define a name for a set of general-purpose registers.
- *CN* on page 6-14  
Define a coprocessor register name.
- *CP* on page 6-15  
Define a coprocessor name.
- *QN*, *DN*, and *SN* on page 6-16  
Define a double-precision or single-precision VFP register name.

### 6.2.1 GBLA, GBLL, and GBLS

The GBLA directive declares a global arithmetic variable, and initializes its value to 0.

The GBLL directive declares a global logical variable, and initializes its value to {FALSE}.

The GBLS directive declares a global string variable and initializes its value to a null string, "".

#### Syntax

*<gb1x> variable*

where:

*<gb1x>* is one of GBLA, GBLL, or GBLS.

*variable* is the name of the variable. *variable* must be unique among symbols within a source file.

#### Usage

Using one of these directives for a variable that is already defined re-initializes the variable to the same values given above.

The scope of the variable is limited to the source file that contains it.

Set the value of the variable with a SETA, SETL, or SETS directive.

Global variables can also be set with the --predefine assembler command-line option.

Examples

Example 6-1 declares a variable `objectsize`, sets the value of `objectsize` to `0xFF`, and then uses it later in a `SPACE` directive.

Example 6-1

---

```
objectsize    GBLA    objectsize    ; declare the variable name
              SETA    0xFF          ; set its value
              .
              .                  ; other code
              .
              SPACE   objectsize    ; quote the variable
```

---

Example 6-2 shows how to declare and set a variable when you invoke `armasm`. Use this when you want to set the value of a variable at assembly time. `--pd` is a synonym for `--predefine`.

Example 6-2

---

```
armasm --predefine "objectsize SETA 0xFF" sourcefile -o objectfile
```

---

See also

Reference:

- *SETA, SETL, and SETS* on page 6-8
- *LCLA, LCLL, and LCLS* on page 6-7
- *Assembler command line options* on page 2-3.

## 6.2.2 LCLA, LCLL, and LCLS

The LCLA directive declares a local arithmetic variable, and initializes its value to 0.

The LCLL directive declares a local logical variable, and initializes its value to {FALSE}.

The LCLS directive declares a local string variable, and initializes its value to a null string, "".

### Syntax

```
<lc1x> variable
```

where:

<lc1x> is one of LCLA, LCLL, or LCLS.

*variable* is the name of the variable. *variable* must be unique within the macro that contains it.

### Usage

Using one of these directives for a variable that is already defined re-initializes the variable to the same values given above.

The scope of the variable is limited to a particular instantiation of the macro that contains it.

Set the value of the variable with a SETA, SETL, or SETS directive.

### Example

```
MACRO                                ; Declare a macro
$label message $a                    ; Macro prototype line
LCLS err                             ; Declare local string
                                     ; variable err.
err SETS "error no: "                ; Set value of err
$label ; code
INFO 0, "err":CC::STR:$a             ; Use string
MEND
```

### See also

#### Reference:

- *SETA, SETL, and SETS* on page 6-8
- *MACRO and MEND* on page 6-40
- *GBLA, GBLR, and GBL* on page 6-5.

### 6.2.3 SETA, SETL, and SETS

The SETA directive sets the value of a local or global arithmetic variable.

The SETL directive sets the value of a local or global logical variable.

The SETS directive sets the value of a local or global string variable.

#### Syntax

*variable* <setx> *expr*

where:

<setx> is one of SETA, SETL, or SETS.

*variable* is the name of a variable declared by a GBLA, GBLL, GBLS, LCLA, LCLL, or LCLS directive.

*expr* is an expression that is:

- numeric, for SETA
- logical, for SETL
- string, for SETS.

#### Usage

You must declare *variable* using a global or local declaration directive before using one of these directives.

You can also predefine variable names on the command line.

#### Examples

	GBLA	VersionNumber
VersionNumber	SETA	21
	GBLL	Debug
Debug	SETL	{TRUE}
	GBLS	VersionString
VersionString	SETS	"Version 1.0"

#### See also

##### Concepts:

*Using the Assembler:*

- *Numeric expressions* on page 8-20

- *Logical expressions* on page 8-25
- *String expressions* on page 8-18.

**Reference:**

- *Assembler command line options* on page 2-3
- *LCLA, LCLL, and LCLS* on page 6-7
- *GBLA, GBLL, and GBLS* on page 6-5.

## 6.2.4 RELOC

The RELOC directive explicitly encodes an ELF relocation in an object file.

### Syntax

RELOC *n*, *symbol*

RELOC *n*

where:

*n* must be in the range 0 to 255.

*symbol* can be any PC-relative label.

### Usage

Use RELOC *n*, *symbol* to create a relocation with respect to the address labeled by *symbol*.

If used immediately after an ARM or Thumb instruction, RELOC results in a relocation at that instruction. If used immediately after a DCB, DCW, or DCD, or any other data generating directive, RELOC results in a relocation at the start of the data. Any addend to be applied must be encoded in the instruction or in the data.

If the assembler has already emitted a relocation at that place, the relocation is updated with the details in the RELOC directive, for example:

```
DCD    sym2 ; R_ARM_ABS32 to sym32
RELOC  55  ; ... makes it R_ARM_ABS32_NOI
```

RELOC is faulted in all other cases, for example, after any non-data generating directive, LTORG, ALIGN, or as the first thing in an AREA.

Use RELOC *n* to create a relocation with respect to the anonymous symbol, that is, symbol 0 of the symbol table. If you use RELOC *n* without a preceding assembler generated relocation, the relocation is with respect to the anonymous symbol.

### Examples

```
IMPORT  impsym
LDR     r0,[pc,#-8]
RELOC   4, impsym
DCD     0
RELOC   2, sym
DCD     0,1,2,3,4 ; the final word is relocated
RELOC   38,sym2   ; R_ARM_TARGET1
```



## See also

## Reference

- *Application Binary Interface for the ARM Architecture*,  
<http://infocenter.arm.com/help/topic/com.arm.doc.subset.swdev.abi/index.html>.

## 6.2.5 RN

The RN directive defines a register name for a specified register.

### Syntax

*name* RN *expr*

where:

*name* is the name to be assigned to the register. *name* cannot be the same as any of the predefined names.

*expr* evaluates to a register number from 0 to 15.

### Usage

Use RN to allocate convenient names to registers, to help you to remember what you use each register for. Be careful to avoid conflicting uses of the same register under different names.

### Examples

```
regname    RN    11 ; defines regname for register 11
sqr4       RN    r6 ; defines sqr4 for register 6
```

### See also

#### Reference:

*Using the Assembler:*

- *Predeclared core register names* on page 3-15
- *Predeclared extension register names* on page 3-16
- *Predeclared XScale register names* on page 3-17
- *Predeclared coprocessor names* on page 3-19.

## 6.2.6 RLIST

The RLIST (register list) directive gives a name to a set of general-purpose registers.

### Syntax

```
name RLIST {list-of-registers}
```

where:

*name* is the name to be given to the set of registers. *name* cannot be the same as any of the predefined names.

*list-of-registers*

is a comma-delimited list of register names and register ranges. The register list must be enclosed in braces.

### Usage

Use RLIST to give a name to a set of registers to be transferred by the LDM or STM instructions.

LDM and STM always put the lowest physical register numbers at the lowest address in memory, regardless of the order they are supplied to the LDM or STM instruction. If you have defined your own symbolic register names it can be less apparent that a register list is not in increasing register order.

Use the `--diag_warning 1206` assembler option to ensure that the registers in a register list are supplied in increasing register order. If registers are not supplied in increasing register order, a warning is issued.

### Example

```
Context RLIST {r0-r6,r8,r10-r12,pc}
```

### See also

#### Reference:

*Using the Assembler:*

- *Predeclared core register names* on page 3-15
- *Predeclared extension register names* on page 3-16
- *Predeclared XScale register names* on page 3-17
- *Predeclared coprocessor names* on page 3-19.

## 6.2.7 CN

The CN directive defines a name for a coprocessor register.

### Syntax

*name* CN *expr*

where:

*name* is the name to be defined for the coprocessor register. *name* cannot be the same as any of the predefined names.

*expr* evaluates to a coprocessor register number from 0 to 15.

### Usage

Use CN to allocate convenient names to registers, to help you remember what you use each register for.

#### ———— Note ————

Avoid conflicting uses of the same register under different names.

The names c0 to c15 are predefined.

### Example

```
power    CN    6           ; defines power as a symbol for
                           ; coprocessor register 6
```

### See also

#### Reference:

*Using the Assembler:*

- *Predeclared core register names* on page 3-15
- *Predeclared extension register names* on page 3-16
- *Predeclared XScale register names* on page 3-17
- *Predeclared coprocessor names* on page 3-19.

## 6.2.8 CP

The CP directive defines a name for a specified coprocessor. The coprocessor number must be within the range 0 to 15.

### Syntax

*name* CP *expr*

where:

*name* is the name to be assigned to the coprocessor. *name* cannot be the same as any of the predefined names.

*expr* evaluates to a coprocessor number from 0 to 15.

### Usage

Use CP to allocate convenient names to coprocessors, to help you to remember what you use each one for.

#### ————— Note —————

Avoid conflicting uses of the same coprocessor under different names.

The names p0 to p15 are predefined for coprocessors 0 to 15.

### Example

```
dmu    CP 6      ; defines dmu as a symbol for
                ; coprocessor 6
```

### See also

#### Reference:

*Using the Assembler:*

- *Predeclared core register names* on page 3-15
- *Predeclared extension register names* on page 3-16
- *Predeclared XScale register names* on page 3-17
- *Predeclared coprocessor names* on page 3-19.

### 6.2.9 QN, DN, and SN

The QN directive defines a name for a specified 128-bit extension register.

The DN directive defines a name for a specified 64-bit extension register.

The SN directive defines a name for a specified single-precision VFP register.

#### Syntax

*name directive* *expr*{*.type*}{[*x*]}

where:

*directive* is QN, DN, or SN.

*name* is the name to be assigned to the extension register. *name* cannot be the same as any of the predefined names.

*expr* Can be:

- an expression that evaluates to a number in the range:
  - 0-15 if you are using DN in VFPv2 or QN in NEON
  - 0-31 otherwise.
- a predefined register name, or a register name that has already been defined in a previous directive.

*type* is any NEON or VFP datatype.

[*x*] is only available for NEON code. [*x*] is a scalar index into a register.

*type* and [*x*] are *Extended notation*.

#### Usage

Use QN, DN, or SN to allocate convenient names to extension registers, to help you to remember what you use each one for.

#### ————— Note —————

Avoid conflicting uses of the same register under different names.

You cannot specify a vector length in a DN or SN directive.

## Examples

```
energy DN 6 ; defines energy as a symbol for
            ; VFP double-precision register 6
mass SN 16 ; defines mass as a symbol for
            ; VFP single-precision register 16
```

## Extended notation examples

```
varA DN d1.U16
varB DN d2.U16
varC DN d3.U16
      VADD varA,varB,varC ; VADD.U16 d1,d2,d3
index DN d4.U16[0]
result QN q5.I32
      VMULL result,varA,index ; VMULL.U16 q5,d1,d3[2]
```

## See also

### Reference:

*Using the Assembler:*

- *Predeclared core register names* on page 3-15
- *Predeclared extension register names* on page 3-16
- *Predeclared XScale register names* on page 3-17
- *Predeclared coprocessor names* on page 3-19
- *Extended notation* on page 9-23
- *Extended notation examples*
- *NEON and VFP data types* on page 9-14
- *VFP directives and vector notation* on page 9-43.

## 6.3 Data definition directives

This section describes the following directives to allocate memory, define data structures, set initial contents of memory:

- *LTORG* on page 6-20  
Set an origin for a literal pool.
- *MAP* on page 6-21  
Set the origin of a storage map.
- *FIELD* on page 6-22  
Define a field within a storage map.
- *SPACE* or *FILL* on page 6-23  
Allocate a zeroed block of memory.
- *DCB* on page 6-25  
Allocate bytes of memory, and specify the initial contents.
- *DCD* and *DCDU* on page 6-26  
Allocate words of memory, and specify the initial contents.
- *DCDO* on page 6-28  
Allocate words of memory, and specify the initial contents as offsets from the static base register.
- *DCFD* and *DCFDU* on page 6-29  
Allocate doublewords of memory, and specify the initial contents as double-precision floating-point numbers.
- *DCFS* and *DCFSU* on page 6-31  
Allocate words of memory, and specify the initial contents as single-precision floating-point numbers.
- *DCI* on page 6-32  
Allocate words of memory, and specify the initial contents. Mark the location as code not data.
- *DCQ* and *DCQU* on page 6-34  
Allocate doublewords of memory, and specify the initial contents as 64-bit integers.
- *DCW* and *DCWU* on page 6-36



Allocate halfwords of memory, and specify the initial contents.

- *COMMON* on page 6-37

Allocate a block of memory at a symbol, and specify the alignment.

- *DATA* on page 6-38

Mark data within a code section. Obsolete, for backwards compatibility only.

### 6.3.1 LTORG

The LTORG directive instructs the assembler to assemble the current literal pool immediately.

#### Syntax

LTORG

#### Usage

The assembler assembles the current literal pool at the end of every code section. The end of a code section is determined by the AREA directive at the beginning of the following section, or the end of the assembly.

These default literal pools can sometimes be out of range of some LDR, VLDR, and WLDL pseudo-instructions. Use LTORG to ensure that a literal pool is assembled within range.

Large programs can require several literal pools. Place LTORG directives after unconditional branches or subroutine return instructions so that the processor does not attempt to execute the constants as instructions.

The assembler word-aligns data in literal pools.

#### Example

```

      AREA    Example, CODE, READONLY
start BL      func1
func1                                ; function body
      ; code
      LDR     r1,=0x55555555 ; => LDR R1, [pc, #offset to Literal Pool 1]
      ; code
      MOV     pc,lr          ; end function
      LTORG                                ; Literal Pool 1 contains literal &55555555.
data  SPACE   4200           ; Clears 4200 bytes of memory,
                                ; starting at current location.
      END                                ; Default literal pool is empty.
```

#### See also

#### Reference:

- *LDR pseudo-instruction* on page 3-182
- *VLDR pseudo-instruction* on page 4-83
- *Wireless MMX load and store instructions* on page 5-4.

## 6.3.2 MAP

The MAP directive sets the origin of a storage map to a specified address. The storage-map location counter, {VAR}, is set to the same address. ^ is a synonym for MAP.

### Syntax

MAP *expr*{, *base-register*}

where:

*expr* is a numeric or PC-relative expression:

- If *base-register* is not specified, *expr* evaluates to the address where the storage map starts. The storage map location counter is set to this address.
- If *expr* is PC-relative, you must have defined the label before you use it in the map. The map requires the definition of the label during the first pass of the assembler.

*base-register*

specifies a register. If *base-register* is specified, the address where the storage map starts is the sum of *expr*, and the value in *base-register* at runtime.

### Usage

Use the MAP directive in combination with the FIELD directive to describe a storage map.

Specify *base-register* to define register-relative labels. The base register becomes implicit in all labels defined by following FIELD directives, until the next MAP directive. The register-relative labels can be used in load and store instructions.

The MAP directive can be used any number of times to define multiple storage maps.

The {VAR} counter is set to zero before the first MAP directive is used.

### Examples

```
MAP    0, r9
MAP    0xff, r9
```

### See also

#### Reference:

- *FIELD* on page 6-22.

### 6.3.3 FIELD

The FIELD directive describes space within a storage map that has been defined using the MAP directive. # is a synonym for FIELD.

#### Syntax

```
{label} FIELD expr
```

where:

*label* is an optional label. If specified, *label* is assigned the value of the storage location counter, {VAR}. The storage location counter is then incremented by the value of *expr*.

*expr* is an expression that evaluates to the number of bytes to increment the storage counter.

#### Usage

If a storage map is set by a MAP directive that specifies a *base-register*, the base register is implicit in all labels defined by following FIELD directives, until the next MAP directive. These register-relative labels can be quoted in load and store instructions.

#### Examples

The following example shows how register-relative labels are defined using the MAP and FIELD directives.

```
MAP    0,r9      ; set {VAR} to the address stored in R9
FIELD  4         ; increment {VAR} by 4 bytes
Lab FIELD 4      ; set Lab to the address [R9 + 4]
        ; and then increment {VAR} by 4 bytes
LDR    r0,Lab    ; equivalent to LDR r0,[r9,#4]
```

#### See also

#### Reference:

- *MAP* on page 6-21.

### 6.3.4 SPACE or FILL

The SPACE directive reserves a zeroed block of memory. % is a synonym for SPACE.

The FILL directive reserves a block of memory to fill with the given value.

#### Syntax

```
{label} SPACE expr
```

```
{label} FILL expr{,value{,valuesize}}
```

where:

*label* is an optional label.

*expr* evaluates to the number of bytes to fill or zero.

*value* evaluates to the value to fill the reserved bytes with. *value* is optional and if omitted, it is 0. *value* must be 0 in a NOINIT area.

*valuesize* is the size, in bytes, of *value*. It can be any of 1, 2, or 4. *valuesize* is optional and if omitted, it is 1.

#### Usage

Use the ALIGN directive to align any code following a SPACE or FILL directive.

#### Example

```

        AREA    MyData, DATA, READWRITE
data1    SPACE  255      ; defines 255 bytes of zeroed store
data2    FILL   50,0xAB,1 ; defines 50 bytes containing 0xAB

```

#### See also

##### Concept:

*Using the Assembler:*

- *Numeric expressions* on page 8-20.

##### Reference:

- *DCB* on page 6-25
- *DCD and DCDU* on page 6-26
- *DCDO* on page 6-28

- *DCW and DCWU* on page 6-36
- *ALIGN* on page 6-78.

### 6.3.5 DCB

The DCB directive allocates one or more bytes of memory, and defines the initial runtime contents of the memory. = is a synonym for DCB.

#### Syntax

```
{label} DCB expr{,expr}...
```

where:

*expr* is either:

- a numeric expression that evaluates to an integer in the range –128 to 255.
- a quoted string. The characters of the string are loaded into consecutive bytes of store.

#### Usage

If DCB is followed by an instruction, use an ALIGN directive to ensure that the instruction is aligned.

#### Example

Unlike C strings, ARM assembler strings are not nul-terminated. You can construct a nul-terminated C string using DCB as follows:

```
C_string DCB "C_string",0
```

#### See also

##### Concept:

*Using the Assembler:*

- *Numeric expressions* on page 8-20.

##### Reference:

- *DCD and DCDU* on page 6-26
- *DCQ and DCQU* on page 6-34
- *DCW and DCWU* on page 6-36
- *SPACE or FILL* on page 6-23
- *ALIGN* on page 6-78.

### 6.3.6 DCD and DCDU

The DCD directive allocates one or more words of memory, aligned on four-byte boundaries, and defines the initial runtime contents of the memory.

& is a synonym for DCD.

DCDU is the same, except that the memory alignment is arbitrary.

#### Syntax

```
{label} DCD{U} expr{,expr}
```

where:

*expr* is either:

- a numeric expression.
- a PC-relative expression.

#### Usage

DCD inserts up to three bytes of padding before the first defined word, if necessary, to achieve four-byte alignment.

Use DCDU if you do not require alignment.

#### Examples

```
data1 DCD 1,5,20 ; Defines 3 words containing
                ; decimal values 1, 5, and 20
data2 DCD mem06 + 4 ; Defines 1 word containing 4 +
                ; the address of the label mem06
        AREA MyData, DATA, READWRITE
        DCB 255 ; Now misaligned ...
data3 DCDU 1,5,20 ; Defines 3 words containing
                ; 1, 5 and 20, not word aligned
```

#### See also

##### Concept:

*Using the Assembler:*

- *Numeric expressions* on page 8-20.

##### Reference:

- *DCB* on page 6-25
- *DCI* on page 6-32



- *DCW and DCWU* on page 6-36
- *DCQ and DCQU* on page 6-34
- *SPACE or FILL* on page 6-23.

### 6.3.7 DCDO

The DCDO directive allocates one or more words of memory, aligned on four-byte boundaries, and defines the initial runtime contents of the memory as an offset from the *static base register*, sb (R9).

#### Syntax

```
{label} DCDO expr{,expr}...
```

where:

*expr* is a register-relative expression or label. The base register must be sb.

#### Usage

Use DCDO to allocate space in memory for static base register relative relocatable addresses.

#### Example

```
IMPORT externsym
DCDO    externsym    ; 32-bit word relocated by offset of
                    ; externsym from base of SB section.
```

### 6.3.8 DCFD and DCFDU

The DCFD directive allocates memory for word-aligned double-precision floating-point numbers, and defines the initial runtime contents of the memory. Double-precision numbers occupy two words and must be word aligned to be used in arithmetic operations.

DCFDU is the same, except that the memory alignment is arbitrary.

#### Syntax

```
{label} DCFD{U} fpliteral{, fpliteral}...
```

where:

*fpliteral* is a double-precision floating-point literal.

#### Usage

The assembler inserts up to three bytes of padding before the first defined number, if necessary, to achieve four-byte alignment.

Use DCFDU if you do not require alignment.

The word order used when converting *fpliteral* to internal form is controlled by the floating-point architecture selected. You cannot use DCFD or DCFDU if you select the `--fpu none` option.

The range for double-precision numbers is:

- maximum 1.79769313486231571e+308
- minimum 2.22507385850720138e-308.

#### Examples

```
DCFD    1E308, -4E-100
DCFUDU  10000, -.1, 3.1E26
```

#### See also

##### Concept:

*Using the Assembler:*

- *Floating-point literals* on page 8-23.

**Reference:**

- *DCFS and DCFSU* on page 6-31.

### 6.3.9 DCFS and DCFSU

The DCFS directive allocates memory for word-aligned single-precision floating-point numbers, and defines the initial runtime contents of the memory. Single-precision numbers occupy one word and must be word aligned to be used in arithmetic operations.

DCFSU is the same, except that the memory alignment is arbitrary.

#### Syntax

```
{label} DCFS{U} fpliteral{, fpliteral}...
```

where:

*fpliteral* is a single-precision floating-point literal.

#### Usage

DCFS inserts up to three bytes of padding before the first defined number, if necessary to achieve four-byte alignment.

Use DCFSU if you do not require alignment.

The range for single-precision values is:

- maximum 3.40282347e+38
- minimum 1.17549435e-38.

#### Examples

```
DCFS    1E3, -4E-9
DCFSU   1.0, -.1, 3.1E6
```

#### See also

##### Concept:

*Using the Assembler:*

- *Floating-point literals* on page 8-23.

##### Reference:

- *DCFD and DCFDU* on page 6-29.

### 6.3.10 DCI

In ARM code, the DCI directive allocates one or more words of memory, aligned on four-byte boundaries, and defines the initial runtime contents of the memory.

In Thumb code, the DCI directive allocates one or more halfwords of memory, aligned on two-byte boundaries, and defines the initial runtime contents of the memory.

#### Syntax

```
{label} DCI{.W} expr{,expr}
```

where:

*expr* is a numeric expression.

*.W* if present, indicates that four bytes must be inserted in Thumb code.

#### Usage

The DCI directive is very like the DCD or DCW directives, but the location is marked as code instead of data. Use DCI when writing macros for new instructions not supported by the version of the assembler you are using.

In ARM code, DCI inserts up to three bytes of padding before the first defined word, if necessary, to achieve four-byte alignment. In Thumb code, DCI inserts an initial byte of padding, if necessary, to achieve two-byte alignment.

You can use DCI to insert a bit pattern into the instruction stream. For example, use:

```
DCI 0x46c0
```

to insert the Thumb operation MOV r8,r8.

#### Example macro

```
MACRO          ; this macro translates newinstr Rd,Rm
                ; to the appropriate machine code
newinst    $Rd,$Rm
DCI        0xe16f0f10 :OR: ($Rd:SHL:12) :OR: $Rm
MEND
```

#### Thumb-2 example

```
DCI.W 0xf3af8000 ; inserts 32-bit NOP, 2-byte aligned.
```

**See also****Concept:**

*Using the Assembler:*

- *Numeric expressions* on page 8-20.

**Reference:**

- *DCD and DCDU* on page 6-26
- *DCW and DCWU* on page 6-36.

### 6.3.11 DCQ and DCQU

The DCQ directive allocates one or more eight-byte blocks of memory, aligned on four-byte boundaries, and defines the initial runtime contents of the memory.

DCQU is the same, except that the memory alignment is arbitrary.

#### Syntax

```
{label} DCQ{U} {-}literal{,{-}literal}...
```

where:

*literal* is a 64-bit numeric literal.

The range of numbers permitted is 0 to  $2^{64}-1$ .

In addition to the characters normally permitted in a numeric literal, you can prefix *literal* with a minus sign. In this case, the range of numbers permitted is  $-2^{63}$  to  $-1$ .

The result of specifying  $-n$  is the same as the result of specifying  $2^{64}-n$ .

#### Usage

DCQ inserts up to three bytes of padding before the first defined eight-byte block, if necessary, to achieve four-byte alignment.

Use DCQU if you do not require alignment.

#### Examples

```

data      AREA      MiscData, DATA, READWRITE
          DCQ        -225,2_101      ; 2_101 means binary 101.
          DCQU       number+4        ; number must already be defined.
```

#### See also

##### Concept:

*Using the Assembler:*

- *Numeric literals* on page 8-21.

##### Reference:

- *DCB* on page 6-25
- *DCD and DCDU* on page 6-26
- *DCW and DCWU* on page 6-36



- *SPACE or FILL* on page 6-23.

### 6.3.12 DCW and DCWU

The DCW directive allocates one or more halfwords of memory, aligned on two-byte boundaries, and defines the initial runtime contents of the memory.

DCWU is the same, except that the memory alignment is arbitrary.

#### Syntax

```
{label} DCW{U} expr{,expr}...
```

where:

*expr* is a numeric expression that evaluates to an integer in the range –32768 to 65535.

#### Usage

DCW inserts a byte of padding before the first defined halfword if necessary to achieve two-byte alignment.

Use DCWU if you do not require alignment.

#### Examples

```
data    DCW    -225,2*number ; number must already be defined
        DCWU   number+4
```

#### See also

##### Concept:

*Using the Assembler:*

- *Numeric expressions* on page 8-20.

##### Reference:

- *DCB* on page 6-25
- *DCD and DCDU* on page 6-26
- *DCQ and DCQU* on page 6-34
- *SPACE or FILL* on page 6-23.

### 6.3.13 COMMON

The **COMMON** directive allocates a block of memory, of the defined size, at the specified symbol. You specify how the memory is aligned. If alignment is omitted, the default alignment is 4. If size is omitted, the default size is 0.

You can access this memory as you would any other memory, but no space is allocated in object files.

#### Syntax

```
COMMON symbol{, size{, alignment}} {[attr]}
```

where:

*symbol* is the symbol name. The symbol name is case-sensitive.

*size* is the number of bytes to reserve.

*alignment* is the alignment.

*attr* can be any one of:

**DYNAMIC** sets the ELF symbol visibility to STV\_DEFAULT.

**PROTECTED** sets the ELF symbol visibility to STV\_PROTECTED.

**HIDDEN** sets the ELF symbol visibility to STV\_HIDDEN.

**INTERNAL** sets the ELF symbol visibility to STV\_INTERNAL.

#### Usage

The linker allocates the required space as zero initialized memory during the link stage. You cannot define, **IMPORT** or **EXPORT** a symbol that has already been created by the **COMMON** directive. In the same way, if a symbol has already been defined or used with the **IMPORT** or **EXPORT** directive, you cannot use the same symbol for the **COMMON** directive.

#### Example

```
LDR      r0, =xyz
COMMON   xyz,255,4 ; defines 255 bytes of ZI store, word-aligned
```

#### Incorrect examples

```
COMMON   foo,4,4
COMMON   bar,4,4
foo DCD   0 ; cannot define label with same name as COMMON
IMPORT   bar ; cannot import label with same name as COMMON
```

### **6.3.14 DATA**

The DATA directive is no longer required. It is ignored by the assembler.

## 6.4 Assembly control directives

This section describes the following directives to control conditional assembly, looping, inclusions, and macros:

- *MACRO* and *MEND* on page 6-40
- *MEXIT* on page 6-44
- *IF*, *ELSE*, *ENDIF*, and *ELIF* on page 6-45
- *WHILE* and *WEND* on page 6-49.

### 6.4.1 Nesting directives

The following structures can be nested to a total depth of 256:

- *MACRO* definitions
- *WHILE*...*WEND* loops
- *IF*...*ELSE*...*ENDIF* conditional structures
- *INCLUDE* file inclusions.

The limit applies to all structures taken together, regardless of how they are nested. The limit is *not* 256 of each type of structure.

## 6.4.2 MACRO and MEND

The MACRO directive marks the start of the definition of a macro. Macro expansion terminates at the MEND directive.

### Syntax

Two directives are used to define a macro. The syntax is:

```

MACRO
{$label}  macroname{$cond} {$parameter{,$parameter}...}
          ; code
MEND

```

where:

*\$label* is a parameter that is substituted with a symbol given when the macro is invoked. The symbol is usually a label.

*macroname* is the name of the macro. It must not begin with an instruction or directive name.

*\$cond* is a special parameter designed to contain a condition code. Values other than valid condition codes are permitted.

*\$parameter* is a parameter that is substituted when the macro is invoked. A default value for a parameter can be set using this format:

*\$parameter*="default value"

Double quotes must be used if there are any spaces within, or at either end of, the default value.

### Usage

If you start any WHILE...WEND loops or IF...ENDIF conditions within a macro, they must be closed before the MEND directive is reached. You can use MEXIT to enable an early exit from a macro, for example, from within a loop.

Within the macro body, parameters such as *\$label*, *\$parameter* or *\$cond* can be used in the same way as other variables. They are given new values each time the macro is invoked. Parameters must begin with \$ to distinguish them from ordinary symbols. Any number of parameters can be used.

*\$label* is optional. It is useful if the macro defines internal labels. It is treated as a parameter to the macro. It does not necessarily represent the first instruction in the macro expansion. The macro defines the locations of any labels.

Use `|` as the argument to use the default value of a parameter. An empty string is used if the argument is omitted.

In a macro that uses several internal labels, it is useful to define each internal label as the base label with a different suffix.

Use a dot between a parameter and following text, or a following parameter, if a space is not required in the expansion. Do not use a dot between preceding text and a parameter.

You can use the `$cond` parameter for condition codes. Use the unary operator `:REVERSE_CC:` to find the inverse condition code, and `:CC_ENCODING:` to find the 4-bit encoding of the condition code.

Macros define the scope of local variables.

Macros can be nested.

## Examples

```

; macro definition
MACRO                                ; start macro definition
$label      xmac    $p1,$p2
; code
$label.loop1 ; code
; code
BGE    $label.loop1
$label.loop2 ; code
BL     $p1
BGT    $label.loop2
; code
ADR    $p2
; code
MEND                                ; end macro definition

; macro invocation
abc      xmac    subr1,de    ; invoke macro
; code    ; this is what is
abcloop1 ; code    ; is produced when
; code    ; the xmac macro is
BGE    abcloop1    ; expanded
abcloop2 ; code
BL     subr1
BGT    abcloop2
; code
ADR    de
; code

```

Using a macro to produce assembly-time diagnostics:

```

MACRO                                ; Macro definition
diagnose $param1="default"          ; This macro produces
INFO    0,"$param1"                ; assembly-time diagnostics
MEND                                ; (on second assembly pass)

; macro expansion
diagnose                            ; Prints blank line at assembly-time
diagnose "hello"                    ; Prints "hello" at assembly-time
diagnose |                          ; Prints "default" at assembly-time

```

### Conditional macro example

```

AREA    codx, CODE, READONLY

; macro definition

MACRO
Return$cond
[ {ARCHITECTURE} <> "4"
    BX$cond lr
    |
    MOV$cond pc,lr
]
MEND

; macro invocation

fun    PROC
CMP        r0,#0
MOVEQ     r0,#1
ReturnEQ
MOV        r0,#0
Return
ENDP

END

```

### See also

#### Concept:

*Using the Assembler:*

- *Use of macros* on page 5-35
- *Assembly time substitution of variables* on page 8-7.

#### Reference:

- *MEXIT* on page 6-44
- *Nesting directives* on page 6-39



- *LCLA, LCLL, and LCLS* on page 6-7.

### 6.4.3 MEXIT

The MEXIT directive is used to exit a macro definition before the end.

#### Usage

Use MEXIT when you require an exit from within the body of a macro. Any unclosed WHILE...WEND loops or IF...ENDIF conditions within the body of the macro are closed by the assembler before the macro is exited.

#### Example

```
MACRO
$abc    example abc    $param1,$param2
        ; code
        WHILE condition1
            ; code
            IF condition2
                ; code
                MEXIT
            ELSE
                ; code
            ENDIF
        WEND
        ; code
MEND
```

#### See also

##### Reference:

- *MACRO and MEND* on page 6-40.

#### 6.4.4 IF, ELSE, ENDIF, and ELIF

The IF directive introduces a condition that is used to decide whether to assemble a sequence of instructions and directives. `[` is a synonym for IF.

The ELSE directive marks the beginning of a sequence of instructions or directives that you want to be assembled if the preceding condition fails. `|` is a synonym for ELSE.

The ENDIF directive marks the end of a sequence of instructions or directives that you want to be conditionally assembled. `]` is a synonym for ENDIF.

The ELIF directive creates a structure equivalent to ELSE IF, without the requirement for nesting or repeating the condition.

##### Syntax

```
IF logical-expression           ...;code
{ELSE           ...;code}
ENDIF
```

where:

*logical-expression*

is an expression that evaluates to either {TRUE} or {FALSE}.

##### Usage

Use IF with ENDIF, and optionally with ELSE, for sequences of instructions or directives that are only to be assembled or acted on under a specified condition.

IF...ENDIF conditions can be nested.

## Using ELIF

Without using ELIF, you can construct a nested set of conditional instructions like this:

```
IF logical-expression
    instructions
ELSE
    IF logical-expression2
        instructions
    ELSE
        IF logical-expression3
            instructions
        ENDIF
    ENDIF
ENDIF
```

A nested structure like this can be nested up to 256 levels deep.

You can write the same structure more simply using ELIF:

```
IF logical-expression
    instructions
ELIF logical-expression2
    instructions
ELIF logical-expression3
    instructions
ENDIF
```

This structure only adds one to the current nesting depth, for the IF...ENDIF pair.

## Examples

Example 6-3 assembles the first set of instructions if NEWVERSION is defined, or the alternative set otherwise.

### Example 6-3 Assembly conditional on a variable being defined

---

```
IF :DEF:NEWVERSION
    ; first set of instructions or directives
ELSE
    ; alternative set of instructions or directives
ENDIF
```

---

Invoking `armasm` as follows defines `NEWVERSION`, so the first set of instructions and directives are assembled:

```
armasm --predefine "NEWVERSION SETL {TRUE}" test.s
```

Invoking `armasm` as follows leaves `NEWVERSION` undefined, so the second set of instructions and directives are assembled:

```
armasm test.s
```

Example 6-4 assembles the first set of instructions if `NEWVERSION` has the value `{TRUE}`, or the alternative set otherwise.

### Example 6-4 Assembly conditional on a variable value

---

```
IF NEWVERSION = {TRUE}
    ; first set of instructions or directives
ELSE
    ; alternative set of instructions or directives
ENDIF
```

---

Invoking `armasm` as follows causes the first set of instructions and directives to be assembled:

```
armasm --predefine "NEWVERSION SETL {TRUE}" test.s
```

Invoking `armasm` as follows causes the second set of instructions and directives to be assembled:

```
armasm --predefine "NEWVERSION SETL {FALSE}" test.s
```

## See also

### Concept:

*Using the Assembler:*

- *Relational operators* on page 8-34.

### Reference:

- *Using ELIF* on page 6-46
- *Nesting directives* on page 6-39.

### 6.4.5 WHILE and WEND

The WHILE directive starts a sequence of instructions or directives that are to be assembled repeatedly. The sequence is terminated with a WEND directive.

#### Syntax

WHILE *logical-expression*

*code*

WEND

where:

*logical-expression*

is an expression that can evaluate to either {TRUE} or {FALSE}.

#### Usage

Use the WHILE directive, together with the WEND directive, to assemble a sequence of instructions a number of times. The number of repetitions can be zero.

You can use IF...ENDIF conditions within WHILE...WEND loops.

WHILE...WEND loops can be nested.

#### Example

```
count  SETA    1                ; you are not restricted to
      WHILE   count <= 4        ; such simple conditions
count  SETA    count+1          ; In this case,
      ; code                    ; this code will be
      ; code                    ; repeated four times
      WEND
```

#### See also

##### Concept:

*Using the Assembler:*

- *Logical expressions* on page 8-25.

##### Reference:

- *Nesting directives* on page 6-39.

## 6.5 Frame directives

This section describes the following directives:

- *FRAME ADDRESS* on page 6-52
- *FRAME POP* on page 6-54
- *FRAME PUSH* on page 6-55
- *FRAME REGISTER* on page 6-57
- *FRAME RESTORE* on page 6-58
- *FRAME RETURN ADDRESS* on page 6-59
- *FRAME SAVE* on page 6-60
- *FRAME STATE REMEMBER* on page 6-61
- *FRAME STATE RESTORE* on page 6-62
- *FRAME UNWIND ON* on page 6-63
- *FRAME UNWIND OFF* on page 6-63
- *FUNCTION* or *PROC* on page 6-65
- *ENDFUNC* or *ENDP* on page 6-66.

Correct use of these directives:

- enables the `armlink --callgraph` option to calculate stack usage of assembler functions.

The following rules are used to determine stack usage:

- If a function is not marked with `PROC` or `ENDP`, stack usage is unknown.
- If a function is marked with `PROC` or `ENDP` but with no `FRAME PUSH` or `FRAME POP`, stack usage is assumed to be zero. This means that there is no requirement to manually add `FRAME PUSH 0` or `FRAME POP 0`.
- If a function is marked with `PROC` or `ENDP` and with `FRAME PUSH n` or `FRAME POP n`, stack usage is assumed to be `n` bytes.

- helps you to avoid errors in function construction, particularly when you are modifying existing code
- enables the assembler to alert you to errors in function construction
- enables backtracing of function calls during debugging
- enables the debugger to profile assembler functions.

If you require profiling of assembler functions, but do not want frame description directives for other purposes:

- you must use the `FUNCTION` and `ENDFUNC`, or `PROC` and `ENDP`, directives



- you can omit the other FRAME directives
- you only have to use the FUNCTION and ENDFUNC directives for the functions you want to profile.

In DWARF, the canonical frame address is an address on the stack specifying where the call frame of an interrupted function is located.

### 6.5.1 FRAME ADDRESS

The `FRAME ADDRESS` directive describes how to calculate the canonical frame address for following instructions. You can only use it in functions with `FUNCTION` and `ENDFUNC` or `PROC` and `ENDP` directives.

#### Syntax

```
FRAME ADDRESS reg[,offset]
```

where:

*reg* is the register on which the canonical frame address is to be based. This is SP unless the function uses a separate frame pointer.

*offset* is the offset of the canonical frame address from *reg*. If *offset* is zero, you can omit it.

#### Usage

Use `FRAME ADDRESS` if your code alters which register the canonical frame address is based on, or if it changes the offset of the canonical frame address from the register. You must use `FRAME ADDRESS` immediately after the instruction that changes the calculation of the canonical frame address.

#### ———— Note ————

If your code uses a single instruction to save registers and alter the stack pointer, you can use `FRAME PUSH` instead of using both `FRAME ADDRESS` and `FRAME SAVE`.

If your code uses a single instruction to load registers and alter the stack pointer, you can use `FRAME POP` instead of using both `FRAME ADDRESS` and `FRAME RESTORE`.

#### Example

```
_fn    FUNCTION          ; CFA (Canonical Frame Address) is value
                                ; of SP on entry to function
PUSH    {r4,fp,ip,lr,pc}
FRAME PUSH {r4,fp,ip,lr,pc}
SUB     sp,sp,#4           ; CFA offset now changed
FRAME ADDRESS sp,24        ; - so we correct it
ADD     fp,sp,#20
FRAME ADDRESS fp,4         ; New base register
                                ; code using fp to base call-frame on, instead of SP
```

## See also

### Reference:

- *FRAME POP* on page 6-54
- *FRAME PUSH* on page 6-55.

## 6.5.2 FRAME POP

Use the FRAME POP directive to inform the assembler when the callee reloads registers. You can only use it within functions with FUNCTION and ENDFUNC or PROC and ENDP directives.

You do not have to do this after the last instruction in a function.

### Syntax

There are three alternative syntaxes for FRAME POP:

```
FRAME POP {reglist}
```

```
FRAME POP {reglist},n
```

```
FRAME POP n
```

where:

*reglist* is a list of registers restored to the values they had on entry to the function. There must be at least one register in the list.

*n* is the number of bytes that the stack pointer moves.

### Usage

FRAME POP is equivalent to a FRAME ADDRESS and a FRAME RESTORE directive. You can use it when a single instruction loads registers and alters the stack pointer.

You must use FRAME POP immediately after the instruction it refers to.

If *n* is not specified or is zero, the assembler calculates the new offset for the canonical frame address from {*reglist*}. It assumes that:

- each ARM register popped occupies four bytes on the stack
- each VFP single-precision register popped occupies four bytes on the stack, plus an extra four-byte word for each list
- each VFP double-precision register popped occupies eight bytes on the stack, plus an extra four-byte word for each list.

### See also

#### Reference:

- *FRAME ADDRESS* on page 6-52
- *FRAME RESTORE* on page 6-58.

### 6.5.3 FRAME PUSH

Use the `FRAME PUSH` directive to inform the assembler when the callee saves registers, normally at function entry. You can only use it within functions with `FUNCTION` and `ENDFUNC` or `PROC` and `ENDP` directives.

#### Syntax

There are two alternative syntaxes for `FRAME PUSH`:

```
FRAME PUSH {reglist}
```

```
FRAME PUSH {reglist},n
```

```
FRAME PUSH n
```

where:

*reglist* is a list of registers stored consecutively below the canonical frame address. There must be at least one register in the list.

*n* is the number of bytes that the stack pointer moves.

#### Usage

`FRAME PUSH` is equivalent to a `FRAME ADDRESS` and a `FRAME SAVE` directive. You can use it when a single instruction saves registers and alters the stack pointer.

You must use `FRAME PUSH` immediately after the instruction it refers to.

If *n* is not specified or is zero, the assembler calculates the new offset for the canonical frame address from {*reglist*}. It assumes that:

- each ARM register pushed occupies four bytes on the stack
- each VFP single-precision register pushed occupies four bytes on the stack, plus an extra four-byte word for each list
- each VFP double-precision register popped occupies eight bytes on the stack, plus an extra four-byte word for each list.

**Example**

```

p  PROC ; Canonical frame address is SP + 0
   EXPORT p
   PUSH {r4-r6,lr}
      ; SP has moved relative to the canonical frame address,
      ; and registers R4, R5, R6 and LR are now on the stack
   FRAME PUSH {r4-r6,lr}
      ; Equivalent to:
      ; FRAME ADDRESS    sp,16      ; 16 bytes in {R4-R6,LR}
      ; FRAME SAVE      {r4-r6,lr},-16

```

**See also****Reference:**

- *FRAME ADDRESS* on page 6-52
- *FRAME SAVE* on page 6-60.

### 6.5.4 FRAME REGISTER

Use the `FRAME REGISTER` directive to maintain a record of the locations of function arguments held in registers. You can only use it within functions with `FUNCTION` and `ENDFUNC` or `PROC` and `ENDP` directives.

#### Syntax

```
FRAME REGISTER reg1, reg2
```

where:

*reg1* is the register that held the argument on entry to the function.

*reg2* is the register in which the value is preserved.

#### Usage

Use the `FRAME REGISTER` directive when you use a register to preserve an argument that was held in a different register on entry to a function.

### 6.5.5 FRAME RESTORE

Use the `FRAME RESTORE` directive to inform the assembler that the contents of specified registers have been restored to the values they had on entry to the function. You can only use it within functions with `FUNCTION` and `ENDFUNC` or `PROC` and `ENDP` directives.

#### Syntax

```
FRAME RESTORE {reglist}
```

where:

*reglist* is a list of registers whose contents have been restored. There must be at least one register in the list.

#### Usage

Use `FRAME RESTORE` immediately after the callee reloads registers from the stack. You do not have to do this after the last instruction in a function.

*reglist* can contain integer registers or floating-point registers, but not both.

#### ———— Note ————

If your code uses a single instruction to load registers and alter the stack pointer, you can use `FRAME POP` instead of using both `FRAME RESTORE` and `FRAME ADDRESS`.

#### See also

#### Reference:

- *FRAME POP* on page 6-54.



## 6.5.6 FRAME RETURN ADDRESS

The FRAME RETURN ADDRESS directive provides for functions that use a register other than LR for their return address. You can only use it within functions with FUNCTION and ENDFUNC or PROC and ENDP directives.

---

### Note

---

Any function that uses a register other than LR for its return address is not AAPCS compliant. Such a function must not be exported.

---

### Syntax

FRAME RETURN ADDRESS *reg*

where:

*reg* is the register used for the return address.

### Usage

Use the FRAME RETURN ADDRESS directive in any function that does not use LR for its return address. Otherwise, a debugger cannot backtrace through the function.

Use FRAME RETURN ADDRESS immediately after the FUNCTION or PROC directive that introduces the function.

## 6.5.7 FRAME SAVE

The `FRAME SAVE` directive describes the location of saved register contents relative to the canonical frame address. You can only use it within functions with `FUNCTION` and `ENDFUNC` or `PROC` and `ENDP` directives.

### Syntax

`FRAME SAVE {reglist}, offset`

where:

*reglist* is a list of registers stored consecutively starting at *offset* from the canonical frame address. There must be at least one register in the list.

### Usage

Use `FRAME SAVE` immediately after the callee stores registers onto the stack.

*reglist* can include registers which are not required for backtracing. The assembler determines which registers it requires to record in the DWARF call frame information.

#### ———— Note ————

If your code uses a single instruction to save registers and alter the stack pointer, you can use `FRAME PUSH` instead of using both `FRAME SAVE` and `FRAME ADDRESS`.

### See also

#### Reference:

- *FRAME PUSH* on page 6-55.

## 6.5.8 FRAME STATE REMEMBER

The `FRAME STATE REMEMBER` directive saves the current information on how to calculate the canonical frame address and locations of saved register values. You can only use it within functions with `FUNCTION` and `ENDFUNC` or `PROC` and `ENDP` directives.

### Syntax

```
FRAME STATE REMEMBER
```

### Usage

During an inline exit sequence the information about calculation of canonical frame address and locations of saved register values can change. After the exit sequence another branch can continue using the same information as before. Use `FRAME STATE REMEMBER` to preserve this information, and `FRAME STATE RESTORE` to restore it.

These directives can be nested. Each `FRAME STATE RESTORE` directive must have a corresponding `FRAME STATE REMEMBER` directive.

### Example

```

; function code
FRAME STATE REMEMBER
    ; save frame state before in-line exit sequence
POP    {r4-r6,pc}
    ; do not have to FRAME POP here, as control has
    ; transferred out of the function
FRAME STATE RESTORE
    ; end of exit sequence, so restore state
exitB  ; code for exitB
POP    {r4-r6,pc}
ENDP

```

### See also

#### Reference:

- *FRAME STATE RESTORE* on page 6-62
- *FUNCTION or PROC* on page 6-65.

## 6.5.9 FRAME STATE RESTORE

The `FRAME STATE RESTORE` directive restores information about how to calculate the canonical frame address and locations of saved register values. You can only use it within functions with `FUNCTION` and `ENDFUNC` or `PROC` and `ENDP` directives.

### Syntax

`FRAME STATE RESTORE`

### See also

#### Reference:

- *FRAME STATE REMEMBER* on page 6-61
- *FUNCTION* or *PROC* on page 6-65.

### 6.5.10 FRAME UNWIND ON

The `FRAME UNWIND ON` directive instructs the assembler to produce *unwind* tables for this and subsequent functions.

#### Syntax

`FRAME UNWIND ON`

#### Usage

You can use this directive outside functions. In this case, the assembler produces *unwind* tables for all following functions until it reaches a `FRAME UNWIND OFF` directive.

#### Note

A `FRAME UNWIND` directive is not sufficient to turn on exception table generation. Furthermore a `FRAME UNWIND` directive, without other `FRAME` directives, is not sufficient information for the assembler to generate the *unwind* information.

#### See also

#### Reference:

- `--exceptions` on page 2-15
- `--exceptions_unwind` on page 2-15.

### 6.5.11 FRAME UNWIND OFF

The `FRAME UNWIND OFF` directive instructs the assembler to produce *nounwind* tables for this and subsequent functions.

#### Syntax

`FRAME UNWIND OFF`

#### Usage

You can use this directive outside functions. In this case, the assembler produces *nounwind* tables for all following functions until it reaches a `FRAME UNWIND ON` directive.

## See also

### Reference:

- `--exceptions` on page 2-15
- `--exceptions_unwind` on page 2-15.

## 6.5.12 FUNCTION or PROC

The FUNCTION directive marks the start of a function. PROC is a synonym for FUNCTION.

### Syntax

```
label FUNCTION [{reglist1} [, {reglist2}]]
```

where:

*reglist1* is an optional list of callee saved ARM registers. If *reglist1* is not present, and your debugger checks register usage, it will assume that the AAPCS is in use.

*reglist2* is an optional list of callee saved VFP registers.

### Usage

Use FUNCTION to mark the start of functions. The assembler uses FUNCTION to identify the start of a function when producing DWARF call frame information for ELF.

FUNCTION sets the canonical frame address to be R13 (SP), and the frame state stack to be empty.

Each FUNCTION directive must have a matching ENDFUNC directive. You must not nest FUNCTION and ENDFUNC pairs, and they must not contain PROC or ENDP directives.

You can use the optional *reglist* parameters to inform the debugger about an alternative procedure call standard, if you are using your own. Not all debuggers support this feature. See your debugger documentation for details.

#### ————— Note —————

FUNCTION does not automatically cause alignment to a word boundary (or halfword boundary for Thumb). Use ALIGN if necessary to ensure alignment, otherwise the call frame might not point to the start of the function.

**Examples**

```

        ALIGN      ; ensures alignment
dadd    FUNCTION   ; without the ALIGN directive, this might not be word-aligned
        EXPORT    dadd
        PUSH      {r4-r6,lr}    ; this line automatically word-aligned
        FRAME PUSH {r4-r6,lr}
        ; subroutine body
        POP       {r4-r6,pc}
        ENDFUNC
func6    PROC {r4-r8,r12},{D1-D3} ; non-AAPCS-conforming function
        ...
        ENDP

```

**See also****Reference:**

- *FRAME ADDRESS* on page 6-52
- *FRAME STATE RESTORE* on page 6-62
- *ALIGN* on page 6-78.

**6.5.13 ENDFUNC or ENDP**

The ENDFUNC directive marks the end of an AAPCS-conforming function. ENDP is a synonym for ENDFUNC.

**See also****Reference:**

- *FUNCTION or PROC* on page 6-65.



## 6.6 Reporting directives

This section describes the following directives:

- *ASSERT*  
generates an error message if an assertion is false during assembly.
- *INFO* on page 6-69  
generates diagnostic information during assembly.
- *OPT* on page 6-71  
sets listing options.
- *TTL and SUBT* on page 6-73  
insert titles and subtitles in listings.

### 6.6.1 ASSERT

The *ASSERT* directive generates an error message during the second pass of the assembly if a given assertion is false.

#### Syntax

*ASSERT logical-expression*

where:

*logical-expression*

is an assertion that can evaluate to either {TRUE} or {FALSE}.

#### Usage

Use *ASSERT* to ensure that any necessary condition is met during assembly.

If the assertion is false an error message is generated and assembly fails.

#### Example

```

ASSERT label1 <= label2    ; Tests if the address
                           ; represented by label1
                           ; is <= the address
                           ; represented by label2.
```

**See also**

**Reference:**

- *INFO* on page 6-69.

## 6.6.2 INFO

The INFO directive supports diagnostic generation on either pass of the assembly.

! is very similar to INFO, but has less detailed reporting.

### Syntax

INFO *numeric-expression*, *string-expression*{, *severity*}

where:

*numeric-expression*

is a numeric expression that is evaluated during assembly. If the expression evaluates to zero:

- no action is taken during pass one
- *string-expression* is printed as a warning during pass two if *severity* is 1
- *string-expression* is printed as a message during pass two if *severity* is 0 or not specified.

If the expression does not evaluate to zero:

- *string-expression* is printed as an error message and the assembly fails irrespective of whether *severity* is specified or not (non-zero values for *severity* are reserved in this case).

*string-expression*

is an expression that evaluates to a string.

*severity*

is an optional number that controls the severity of the message. Its value can be either 0 or 1. All other values are reserved.

### Usage

INFO provides a flexible means of creating custom error messages.

### Examples

```
INFO    0, "Version 1.0"
IF endofdata <= label1
    INFO    4, "Data overrun at label1"
ENDIF
```

## See also

### Concept:

*Using the Assembler:*

- *Numeric expressions* on page 8-20
- *String expressions* on page 8-18.

### Reference:

- *ASSERT* on page 6-67.

### 6.6.3 OPT

The OPT directive sets listing options from within the source code.

#### Syntax

OPT *n*

where:

*n* is the OPT directive setting. Table 6-2 lists valid settings.

**Table 6-2 OPT directive settings**

OPT <i>n</i>	Effect
1	Turns on normal listing.
2	Turns off normal listing.
4	Page throw. Issues an immediate form feed and starts a new page.
8	Resets the line number counter to zero.
16	Turns on listing for SET, GBL and LCL directives.
32	Turns off listing for SET, GBL and LCL directives.
64	Turns on listing of macro expansions.
128	Turns off listing of macro expansions.
256	Turns on listing of macro invocations.
512	Turns off listing of macro invocations.
1024	Turns on the first pass listing.
2048	Turns off the first pass listing.
4096	Turns on listing of conditional directives.
8192	Turns off listing of conditional directives.
16384	Turns on listing of MEND directives.
32768	Turns off listing of MEND directives.

## Usage

Specify the `--list=` assembler option to turn on listing.

By default the `--list=` option produces a normal listing that includes variable declarations, macro expansions, call-conditioned directives, and `MEND` directives. The listing is produced on the second pass only. Use the `OPT` directive to modify the default listing options from within your code.

You can use `OPT` to format code listings. For example, you can specify a new page before functions and sections.

## Example

```

        AREA    Example, CODE, READONLY
start   ; code
        ; code
        BL      func1
        ; code
        OPT 4           ; places a page break before func1
func1   ; code

```

## See also

### Reference:

- `--list=file` on page 2-21.

### 6.6.4 TTL and SUBT

The TTL directive inserts a title at the start of each page of a listing file. The title is printed on each page until a new TTL directive is issued.

The SUBT directive places a subtitle on the pages of a listing file. The subtitle is printed on each page until a new SUBT directive is issued.

#### Syntax

TTL *title*

SUBT *subtitle*

where:

*title* is the title.

*subtitle* is the subtitle.

#### Usage

Use the TTL directive to place a title at the top of the pages of a listing file. If you want the title to appear on the first page, the TTL directive must be on the first line of the source file.

Use additional TTL directives to change the title. Each new TTL directive takes effect from the top of the next page.

Use SUBT to place a subtitle at the top of the pages of a listing file. Subtitles appear in the line below the titles. If you want the subtitle to appear on the first page, the SUBT directive must be on the first line of the source file.

Use additional SUBT directives to change subtitles. Each new SUBT directive takes effect from the top of the next page.

#### Examples

TTL	First Title	; places a title on the first ; and subsequent pages of a ; listing file.
SUBT	First Subtitle	; places a subtitle on the ; second and subsequent pages ; of a listing file.

## 6.7 Instruction set and syntax selection directives

This section describes the following directives:

- *ARM, THUMB, THUMBX, CODE16 and CODE32* on page 6-75.



### 6.7.1 ARM, THUMB, THUMBX, CODE16 and CODE32

The ARM directive and the CODE32 directive are synonyms. They instruct the assembler to interpret subsequent instructions as ARM instructions, using either the UAL or the pre-UAL ARM assembler language syntax.

The THUMB directive instructs the assembler to interpret subsequent instructions as Thumb instructions, using the UAL syntax.

The THUMBX directive instructs the assembler to interpret subsequent instructions as Thumb-2EE instructions, using the UAL syntax.

The CODE16 directive instructs the assembler to interpret subsequent instructions as Thumb instructions, using the pre-UAL assembly language syntax.

If necessary, these directives also insert up to three bytes of padding to align to the next word boundary for ARM, or up to one byte of padding to align to the next halfword boundary for Thumb or Thumb-2EE.

#### Syntax

ARM  
THUMB  
THUMBX  
CODE16  
CODE32

#### Usage

In files that contain code using different instruction sets:

- ARM must precede any ARM code. CODE32 is a synonym for ARM.
- THUMB must precede Thumb code written in UAL syntax.
- THUMBX must precede Thumb-2EE code written in UAL syntax.
- CODE16 must precede Thumb code written in pre-UAL syntax.

These directives do not assemble to any instructions. They also do not change the state. They only instruct the assembler to assemble ARM, Thumb, or Thumb-2EE instructions as appropriate, and insert padding if necessary.

## Example

This example shows how ARM and THUMB can be used to switch state and assemble both ARM and Thumb instructions in a single area.

```

        AREA ToThumb, CODE, READONLY    ; Name this block of code
        ENTRY                            ; Mark first instruction to execute
        ARM                              ; Subsequent instructions are ARM
start
        ADR    r0, into_thumb + 1        ; Processor starts in ARM state
        BX     r0                        ; Inline switch to Thumb state
        THUMB                               ; Subsequent instructions are Thumb
into_thumb
        MOVS   r0, #10                    ; New-style Thumb instructions

```

## 6.8 Miscellaneous directives

This section describes the following directives:

- *ALIGN* on page 6-78
- *AREA* on page 6-81
- *ATTR* on page 6-85
- *END* on page 6-87
- *ENTRY* on page 6-87
- *EQU* on page 6-89
- *EXPORT* or *GLOBAL* on page 6-91
- *EXPORTAS* on page 6-93
- *GET* or *INCLUDE* on page 6-94
- *IMPORT* and *EXTERN* on page 6-95
- *INCBIN* on page 6-98
- *KEEP* on page 6-99
- *NOFP* on page 6-100
- *REQUIRE* on page 6-100
- *REQUIRE8* and *PRESERVE8* on page 6-101
- *ROUT* on page 6-102.

### 6.8.1 ALIGN

The ALIGN directive aligns the current location to a specified boundary by padding with zeros or NOP instructions.

#### Syntax

```
ALIGN {expr{,offset{,pad{,padsizesize}}}}
```

where:

<i>expr</i>	is a numeric expression evaluating to any power of 2 from $2^0$ to $2^{31}$
<i>offset</i>	can be any numeric expression
<i>pad</i>	can be any numeric expression
<i>padsizesize</i>	can be 1, 2 or 4.

#### Operation

The current location is aligned to the next address of the form:

$$offset + n * expr$$

*n* is 0 or any positive integer {0, 1, 2, 3, ...}. The assembler selects a value for *n* to find an alignment in the section that satisfies  $offset + n * expr$ .

If *expr* is not specified, ALIGN sets the current location to the next word (four byte) boundary. The unused space between the previous and the new current location are filled with:

- copies of *pad*, if *pad* is specified
- NOP instructions, if all the following conditions are satisfied:
  - *pad* is not specified
  - the ALIGN directive follows ARM or Thumb instructions
  - the current section has the CODEALIGN attribute set on the AREA directive
- zeros otherwise.

*pad* is treated as a byte, halfword, or word, according to the value of *padsizesize*. If *padsizesize* is not specified, *pad* defaults to bytes in data sections, halfwords in Thumb code, or words in ARM code.

## Usage

Use ALIGN to ensure that your data and code is aligned to appropriate boundaries. This is typically required in the following circumstances:

- The ADR Thumb pseudo-instruction can only load addresses that are word aligned, but a label within Thumb code might not be word aligned. Use ALIGN 4 to ensure four-byte alignment of an address within Thumb code.
- Use ALIGN to take advantage of caches on some ARM processors. For example, the ARM940T has a cache with 16-byte lines. Use ALIGN 16 to align function entries on 16-byte boundaries and maximize the efficiency of the cache.
- LDRD and STRD doubleword data transfers must be eight-byte aligned. Use ALIGN 8 before memory allocation directives such as DCQ if the data is to be accessed using LDRD or STRD.
- A label on a line by itself can be arbitrarily aligned. Following ARM code is word-aligned (Thumb code is halfword aligned). The label therefore does not address the code correctly. Use ALIGN 4 (or ALIGN 2 for Thumb) before the label.

Alignment is relative to the start of the ELF section where the routine is located. The section must be aligned to the same, or coarser, boundaries. The ALIGN attribute on the AREA directive is specified differently.

## Examples

```

        AREA    cacheable, CODE, ALIGN=3
rout1   ; code           ; aligned on 8-byte boundary
        ; code
        MOV     pc,lr      ; aligned only on 4-byte boundary
        ALIGN   8          ; now aligned on 8-byte boundary
rout2   ; code

```

```

        AREA    OffsetExample, CODE
        DCB     1          ; This example places the two
        ALIGN   4,3        ; bytes in the first and fourth
        DCB     1          ; bytes of the same word.

```

```

AREA OffsetExample, CODE
DCB 1      ; In this example, n cannot be 0 because it clashes with
DCB 1      ; the 3rd DCB. The assembler sets n to 1.
DCB 1
ALIGN 4,2  ; The next instruction is word aligned and offset by 2.
DCB 2

```

```

start AREA Example, CODE, READONLY
      LDR r6,=label1
      ; code
      MOV pc,lr
label1 DCB 1      ; PC now misaligned
      ALIGN      ; ensures that subroutine1 addresses
subroutine1 ; the following instruction.
      MOV r5,#0x5

```

## See also

### Reference:

- *Data definition directives* on page 6-18
- *AREA* on page 6-81
- *Examples* on page 6-79.

## 6.8.2 AREA

The AREA directive instructs the assembler to assemble a new code or data section. Sections are independent, named, indivisible chunks of code or data that are manipulated by the linker.

### Syntax

AREA *sectionname*{, *attr*}{, *attr*}...

where:

*sectionname* is the name to give to the section.

You can choose any name for your sections. However, names starting with a non-alphabetic character must be enclosed in bars or a missing section name error is generated. For example, `|1_DataArea|`.

Certain names are conventional. For example, `|.text|` is used for code sections produced by the C compiler, or for code sections otherwise associated with the C library.

*attr* are one or more comma-delimited section attributes. Valid attributes are:

ALIGN=*expression*

By default, ELF sections are aligned on a four-byte boundary. *expression* can have any integer value from 0 to 31. The section is aligned on a  $2^{\text{expression}}$ -byte boundary. For example, if *expression* is 10, the section is aligned on a 1KB boundary.

*This is not the same as the way that the ALIGN directive is specified.*

#### ————— **Note** —————

Do not use ALIGN=0 or ALIGN=1 for ARM code sections.  
Do not use ALIGN=0 for Thumb code sections.

ASSOC=*section*

*section* specifies an associated ELF section.  
*sectionname* must be included in any link that includes *section*

CODE Contains machine instructions. READONLY is the default.

**CODEALIGN**

Causes the assembler to insert NOP instructions when the ALIGN directive is used after ARM or Thumb instructions within the section, unless the ALIGN directive specifies a different padding.

**COMDEF**

Is a common section definition. This ELF section can contain code or data. It must be identical to any other section of the same name in other source files.

Identical ELF sections with the same name are overlaid in the same section of memory by the linker. If any are different, the linker generates a warning and does not overlay the sections.

**COMGROUP=*symbol\_name***

Is a common group section. All sections within a common group are common. When the object is linked, other object files may have a GROUP with signature *symbol\_name*. Only one group is kept in the final image.

**COMMON**

Is a common data section. You must not define any code or data in it. It is initialized to zeros by the linker. All common sections with the same name are overlaid in the same section of memory by the linker. They do not all have to be the same size. The linker allocates as much space as is required by the largest common section of each name.

**DATA**

Contains data, not instructions. READWRITE is the default.

**FINI\_ARRAY**

Sets the ELF type of the current area to SHT\_FINI\_ARRAY.

**GROUP=*symbol\_name***

Is the signature for the group and must be defined by the source file, or a file included by the source-file. All AREAS with the same *symbol\_name* signature are placed in the same group. Sections within a group are kept or discovered together.

**INIT\_ARRAY**

Sets the ELF type of the current area to SHT\_INIT\_ARRAY.



**LINKORDER=section**

Specifies a relative location for the current section in the image. It ensures that the order of all the sections with the LINKORDER attribute, with respect to each other, is the same as the order of the corresponding named *sections* in the image.

**MERGE=*n*** Indicates that the linker can merge the current section with other sections with the MERGE=*n* attribute. *n* is the size of the elements in the section, for example *n* is 1 for characters. You must not assume that the section will be merged because the attribute does not force the linker to merge the sections.

**NOALLOC** Indicates that no memory on the target system is allocated to this area.

**NOINIT** Indicates that the data section is uninitialized, or initialized to zero. It contains only space reservation directives SPACE or DCB, DCD, DCDU, DCQ, DCQU, DCW, or DCWU with initialized values of zero. You can decide at link time whether an area is uninitialized or zero initialized.

**PREINIT\_ARRAY**

Sets the ELF type of the current area to SHT\_PREINIT\_ARRAY.

**READONLY** Indicates that this section should not be written to. This is the default for Code areas.

**READWRITE** Indicates that this section can be read from and written to. This is the default for Data areas.

**SECFLAGS=*n***

Adds one or more ELF flags, denoted by *n*, to the current section.

**SECTYPE=*n***

Sets the ELF type of the current section to *n*.

**STRINGS** Adds the SHF\_STRINGS flag to the current section. To use the STRINGS attribute, you must also use the MERGE=1 attribute. The contents of the section must be strings that are nul-terminated using the DCB directive.

## Usage

Use the AREA directive to subdivide your source file into ELF sections. You can use the same name in more than one AREA directive. All areas with the same name are placed in the same ELF section. Only the attributes of the first AREA directive of a particular name are applied.

You should normally use separate ELF sections for code and data. Large programs can usually be conveniently divided into several code sections. Large independent data sets are also usually best placed in separate sections.

The scope of local labels is defined by AREA directives, optionally subdivided by ROUT directives.

There must be at least one AREA directive for an assembly.

## Example

The following example defines a read-only code section named Example.

```
AREA    Example, CODE, READONLY    ; An example code section.  
; code
```

## See also

### Concept:

*Using the Assembler:*

- *ELF sections and the AREA directive* on page 4-5.

### Concept:

*Using the Linker:*

- *Chapter 4 Image structure and generation.*

### Reference:

- *ALIGN* on page 6-78.

### 6.8.3 ATTR

The ATTR set directives set values for the ABI build attributes.

The ATTR scope directives specify the scope for which the set value applies to.

#### Syntax

ATTR FILESCOPE

ATTR SCOPE *name*

ATTR *settype* *tagid*, *value*

where:

*name* is a section name or symbol name.

*settype* can be any of:

- SETVALUE
- SETSTRING
- SETCOMPATIBLEWITHVALUE
- SETCOMPATIBLEWITHSTRING

*tagid* is an attribute tag name (or its numerical value) defined in the ABI for the ARM Architecture.

*value* depends on *settype*:

- is a 32-bit integer value when *settype* is SETVALUE or SETCOMPATIBLEWITHVALUE
- is a nul-terminated string when *settype* is SETSTRING or SETCOMPATIBLEWITHSTRING

#### Usage

The ATTR set directives following the ATTR FILESCOPE directive apply to the entire object file. The ATTR set directives following the ATTR SCOPE *name* directive apply only to the named section or symbol.

For tags that expect an integer, you must use SETVALUE or SETCOMPATIBLEWITHVALUE. For tags that expect a string, you must use SETSTRING or SETCOMPATIBLEWITHSTRING.

Use SETCOMPATIBLEWITHVALUE and SETCOMPATIBLEWITHSTRING to set tag values which the object file is also compatible with.

## Examples

```
ATTR SETSTRING Tag_CPU_raw_name, "Cortex-A8"
ATTR SETVALUE  Tag_VFP_arch, 3      ; VFPv3 instructions were permitted.
ATTR SETVALUE  10, 3                ; 10 is the numerical value of
                                     ; Tag_VFP_arch.
```

## See also

## Reference

- *Addenda to, and Errata in, the ABI for the ARM Architecture*,  
<http://infocenter.arm.com/help/topic/com.arm.doc.ih0045-/index.html>.

## 6.8.4 END

The END directive informs the assembler that it has reached the end of a source file.

### Syntax

END

### Usage

Every assembly language source file must end with END on a line by itself.

If the source file has been included in a parent file by a GET directive, the assembler returns to the parent file and continues assembly at the first line following the GET directive.

If END is reached in the top-level source file during the first pass without any errors, the second pass begins.

If END is reached in the top-level source file during the second pass, the assembler finishes the assembly and writes the appropriate output.

### See also

#### Reference:

- *GET or INCLUDE* on page 6-94.

## 6.8.5 ENTRY

The ENTRY directive declares an entry point to a program.

### Syntax

ENTRY

### Usage

You must specify at least one ENTRY point for a program. If no ENTRY exists, a warning is generated at link time.

You must not use more than one ENTRY directive in a single source file. Not every source file has to have an ENTRY directive. If more than one ENTRY exists in a single source file, an error message is generated at assembly time.

## Example

```
AREA    ARMex, CODE, READONLY
ENTRY   ; Entry point for the application
```

## 6.8.6 EQU

The EQU directive gives a symbolic name to a numeric constant, a register-relative value or a PC-relative value. \* is a synonym for EQU.

### Syntax

*name* EQU *expr*{, *type*}

where:

*name* is the symbolic name to assign to the value.

*expr* is a register-relative address, a PC-relative address, an absolute address, or a 32-bit integer constant.

*type* is optional. *type* can be any one of:

- ARM
- THUMB
- CODE32
- CODE16
- DATA

You can use *type* only if *expr* is an absolute address. If *name* is exported, the *name* entry in the symbol table in the object file will be marked as ARM, THUMB, CODE32, CODE16, or DATA, according to *type*. This can be used by the linker.

### Usage

Use EQU to define constants. This is similar to the use of **#define** to define a constant in C.

### Examples

```
abc EQU 2           ; assigns the value 2 to the symbol abc.
xyz EQU label+8     ; assigns the address (label+8) to the
                    ; symbol xyz.
fiq EQU 0x1C, CODE32 ; assigns the absolute address 0x1C to
                    ; the symbol fiq, and marks it as code
```

### See also

#### Reference:

- *KEEP* on page 6-99

- *EXPORT or GLOBAL* on page 6-91.



## 6.8.7 EXPORT or GLOBAL

The EXPORT directive declares a symbol that can be used by the linker to resolve symbol references in separate object and library files. GLOBAL is a synonym for EXPORT.

### Syntax

```
EXPORT {[WEAK]}
```

```
EXPORT symbol {[SIZE=n]}
```

```
EXPORT symbol {[type{,set}]}
```

```
EXPORT symbol [attr{,type{,set}},{,SIZE=n}]
```

```
EXPORT symbol [WEAK{,attr}{,type{,set}},{,SIZE=n}]
```

where:

<i>symbol</i>	is the symbol name to export. The symbol name is case-sensitive. If <i>symbol</i> is omitted, all symbols are exported.
WEAK	<i>symbol</i> is only imported into other sources if no other source exports an alternative <i>symbol</i> . If [WEAK] is used without <i>symbol</i> , all exported symbols are weak.
<i>attr</i>	can be any one of: <ul style="list-style-type: none"> <li>DYNAMIC sets the ELF symbol visibility to STV_DEFAULT.</li> <li>PROTECTED sets the ELF symbol visibility to STV_PROTECTED.</li> <li>HIDDEN sets the ELF symbol visibility to STV_HIDDEN.</li> <li>INTERNAL sets the ELF symbol visibility to STV_INTERNAL.</li> </ul>
<i>type</i>	specifies the symbol type: <ul style="list-style-type: none"> <li>DATA <i>symbol</i> is treated as data when the source is assembled and linked.</li> <li>CODE <i>symbol</i> is treated as code when the source is assembled and linked.</li> <li>ELFTYPE=<i>n</i> <i>symbol</i> is treated as a particular ELF symbol, as specified by the value of <i>n</i>, where <i>n</i> can be any number from 0 to 15.</li> </ul> If unspecified, the assembler determines the most appropriate <i>type</i> . Usually the assembler determines the correct type so there is no need to specify the <i>type</i> .
<i>set</i>	specifies the instruction set: <ul style="list-style-type: none"> <li>ARM <i>symbol</i> is treated as an ARM symbol.</li> </ul>

THUMB *symbol* is treated as a Thumb symbol.

If unspecified, the assembler determines the most appropriate set.

- n* specifies the size and can be any 32-bit value. If the SIZE attribute is not specified, the assembler calculates the size:
- For PROC and FUNCTION symbols, the size is set to the size of the code until its ENDP or ENDFUNC.
  - For other symbols, the size is the size of instruction or data on the same source line. If there is no instruction or data, the size is zero.

## Usage

Use EXPORT to give code in other files access to symbols in the current file.

Use the [WEAK] attribute to inform the linker that a different instance of *symbol* takes precedence over this one, if a different one is available from another source. You can use the [WEAK] attribute with any of the symbol visibility attributes.

## Example

```

AREA    Example, CODE, READONLY
EXPORT  DoAdd          ; Export the function name
                        ; to be used by external
                        ; modules.
DoAdd   ADD     r0, r0, r1

```

Symbol visibility can be overridden for duplicate exports. In the following example, the last EXPORT takes precedence for both binding and visibility:

```

EXPORT  SymA[WEAK]      ; Export as weak-hidden
EXPORT  SymA[DYNAMIC]   ; SymA becomes non-weak dynamic.

```

The following examples show the use of the SIZE attribute:

```

EXPORT symA [SIZE=4]
EXPORT symA [DATA, SIZE=4]

```

## See also

### Reference:

- *IMPORT and EXTERN* on page 6-95.
- *ELF for the ARM Architecture ABI*,  
<http://infocenter/help/topic/com.arm.doc.ih0044-/index.html>.

## 6.8.8 EXPORTAS

The EXPORTAS directive enables you to export a symbol to the object file, corresponding to a different symbol in the source file.

### Syntax

```
EXPORTAS symbol1, symbol2
```

where:

*symbol1* is the symbol name in the source file. *symbol1* must have been defined already. It can be any symbol, including an area name, a label, or a constant.

*symbol2* is the symbol name you want to appear in the object file.

The symbol names are case-sensitive.

### Usage

Use EXPORTAS to change a symbol in the object file without having to change every instance in the source file.

### Examples

```
AREA data1, DATA      ; starts a new area data1
AREA data2, DATA      ; starts a new area data2
EXPORTAS data2, data1  ; the section symbol referred to as data2 will
                        ; appear in the object file string table as data1.
one EQU 2
EXPORTAS one, two
EXPORT one              ; the symbol 'two' will appear in the object
                        ; file's symbol table with the value 2.
```

### See also

#### Reference:

- *EXPORT* or *GLOBAL* on page 6-91.

### 6.8.9 GET or INCLUDE

The GET directive includes a file within the file being assembled. The included file is assembled at the location of the GET directive. INCLUDE is a synonym for GET.

#### Syntax

GET *filename*

where:

*filename* is the name of the file to be included in the assembly. The assembler accepts pathnames in either UNIX or MS-DOS format.

#### Usage

GET is useful for including macro definitions, EQUs, and storage maps in an assembly. When assembly of the included file is complete, assembly continues at the line following the GET directive.

By default the assembler searches the current place for included files. The current place is the directory where the calling file is located. Use the -i assembler command-line option to add directories to the search path. File names and directory names containing spaces must not be enclosed in double quotes ( " " ).

The included file can contain additional GET directives to include other files.

If the included file is in a different directory from the current place, this becomes the current place until the end of the included file. The previous current place is then restored.

GET cannot be used to include object files.

#### Examples

```
AREA    Example, CODE, READONLY
GET     file1.s           ; includes file1 if it exists
                        ; in the current place.
GET     c:\project\file2.s ; includes file2
GET     c:\Program files\file3.s ; space is permitted
```

#### See also

##### Reference:

- *INCBIN* on page 6-98
- *Nesting directives* on page 6-39.

## 6.8.10 IMPORT and EXTERN

These directives provide the assembler with a name that is not defined in the current assembly.

### Syntax

*directive symbol* {[SIZE=*n*]}

*directive symbol* {[*type*]}

*directive symbol* [*attr*{,*type*}{},SIZE=*n*]

*directive symbol* [WEAK{,*attr*}{},*type*}{},SIZE=*n*]

where:

*directive* can be either:

IMPORT imports the symbol unconditionally.

EXTERN imports the symbol only if it is referred to in the current assembly.

*symbol* is a symbol name defined in a separately assembled source file, object file, or library. The symbol name is case-sensitive.

WEAK prevents the linker generating an error message if the symbol is not defined elsewhere. It also prevents the linker searching libraries that are not already included.

*attr* can be any one of:

DYNAMIC sets the ELF symbol visibility to STV\_DEFAULT.

PROTECTED sets the ELF symbol visibility to STV\_PROTECTED.

HIDDEN sets the ELF symbol visibility to STV\_HIDDEN.

INTERNAL sets the ELF symbol visibility to STV\_INTERNAL.

*type* specifies the symbol type:

DATA *symbol* is treated as data when the source is assembled and linked.

CODE *symbol* is treated as code when the source is assembled and linked.

ELFTYPE=*n* *symbol* is treated as a particular ELF symbol, as specified by the value of *n*, where *n* can be any number from 0 to 15.

If unspecified, the linker determines the most appropriate type.

- n* specifies the size and can be any 32-bit value. If the SIZE attribute is not specified, the assembler calculates the size:
- For PROC and FUNCTION symbols, the size is set to the size of the code until its ENDP or ENDFUNC.
  - For other symbols, the size is the size of instruction or data on the same source line. If there is no instruction or data, the size is zero.

## Usage

The name is resolved at link time to a symbol defined in a separate object file. The symbol is treated as a program address. If [WEAK] is not specified, the linker generates an error if no corresponding symbol is found at link time.

If [WEAK] is specified and no corresponding symbol is found at link time:

- If the reference is the destination of a B or BL instruction, the value of the symbol is taken as the address of the following instruction. This makes the B or BL instruction effectively a NOP.
- Otherwise, the value of the symbol is taken as zero.

## Example

The example tests to see if the C++ library has been linked, and branches conditionally on the result.

```

AREA    Example, CODE, READONLY
EXTERN  __CPP_INITIALIZE[WEAK] ; If C++ library linked, gets the address of
                                ; __CPP_INITIALIZE function.
LDR     r0,=__CPP_INITIALIZE    ; If not linked, address is zeroed.
CMP     r0,#0                  ; Test if zero.
BEQ     nopplusplus            ; Branch on the result.
```

The following examples show the use of the SIZE attribute:

```

EXTERN symA [SIZE=4]
EXTERN symA [DATA, SIZE=4]
```

## See also

## Reference

- *ELF for the ARM Architecture*,  
<http://infocenter.arm.com/help/topic/com.arm.doc.ih0044-/index.html>.

- *EXPORT or GLOBAL* on page 6-91.

### 6.8.11 INCBIN

The INCBIN directive includes a file within the file being assembled. The file is included as it is, without being assembled.

#### Syntax

INCBIN *filename*

where:

*filename* is the name of the file to be included in the assembly. The assembler accepts pathnames in either UNIX or MS-DOS format.

#### Usage

You can use INCBIN to include executable files, literals, or any arbitrary data. The contents of the file are added to the current ELF section, byte for byte, without being interpreted in any way. Assembly continues at the line following the INCBIN directive.

By default, the assembler searches the current place for included files. The current place is the directory where the calling file is located. Use the `-i` assembler command-line option to add directories to the search path. File names and directory names containing spaces must not be enclosed in double quotes ( " " ).

#### Example

```
AREA    Example, CODE, READONLY
INCBIN  file1.dat                ; includes file1 if it
                                   ; exists in the
                                   ; current place.
INCBIN  c:\project\file2.txt     ; includes file2
```



## 6.8.12 KEEP

The KEEP directive instructs the assembler to retain local symbols in the symbol table in the object file.

### Syntax

```
KEEP {symbol}
```

where:

*symbol* is the name of the local symbol to keep. If *symbol* is not specified, all local symbols are kept except register-relative symbols.

### Usage

By default, the only symbols that the assembler describes in its output object file are:

- exported symbols
- symbols that are relocated against.

Use KEEP to preserve local symbols that can be used to help debugging. Kept symbols appear in the ARM debuggers and in linker map files.

KEEP cannot preserve register-relative symbols.

### Example

```
label  ADC    r2,r3,r4
        KEEP  label      ; makes label available to debuggers
        ADD    r2,r2,r5
```

### See also

#### Reference:

- *MAP* on page 6-21.

### 6.8.13 NOFP

The NOFP directive ensures that there are no floating-point instructions in an assembly language source file.

#### Syntax

NOFP

#### Usage

Use NOFP to ensure that no floating-point instructions are used in situations where there is no support for floating-point instructions either in software or in target hardware.

If a floating-point instruction occurs after the NOFP directive, an Unknown opcode error is generated and the assembly fails.

If a NOFP directive occurs after a floating-point instruction, the assembler generates the error:

Too late to ban floating point instructions  
and the assembly fails.

### 6.8.14 REQUIRE

The REQUIRE directive specifies a dependency between sections.

#### Syntax

REQUIRE *label*

where:

*label* is the name of the required label.

#### Usage

Use REQUIRE to ensure that a related section is included, even if it is not directly called. If the section containing the REQUIRE directive is included in a link, the linker also includes the section containing the definition of the specified label.

### 6.8.15 REQUIRE8 and PRESERVE8

The REQUIRE8 directive specifies that the current file requires eight-byte alignment of the stack. It sets the REQ8 build attribute to inform the linker.

The PRESERVE8 directive specifies that the current file preserves eight-byte alignment of the stack. It sets the PRES8 build attribute to inform the linker.

The linker checks that any code that requires eight-byte alignment of the stack is only called, directly or indirectly, by code that preserves eight-byte alignment of the stack.

#### Syntax

```
REQUIRE8 {bool}
```

```
PRESERVE8 {bool}
```

where:

*bool* is an optional Boolean constant, either {TRUE} or {FALSE}.

#### Usage

Where required, if your code preserves eight-byte alignment of the stack, use PRESERVE8 to set the PRES8 build attribute on your file. If your code does not preserve eight-byte alignment of the stack, use PRESERVE8 {FALSE} to ensure that the PRES8 build attribute is not set. If there are multiple REQUIRE8 or PRESERVE8 directives in a file, the assembler uses the value of the last directive.

#### Note

If you omit both PRESERVE8 and PRESERVE8 {FALSE}, the assembler decides whether to set the PRES8 build attribute or not, by examining instructions that modify the SP. ARM recommends that you specify PRESERVE8 explicitly.

You can enable a warning with:

```
armasm --diag_warning 1546
```

This gives you warnings like:

```
"test.s", line 37: Warning: A1546W: Stack pointer update potentially
                        breaks 8 byte stack alignment
    37 00000044          STMFD    sp!,{r2,r3,lr}
```

## Examples

```

REQUIRE8
REQUIRE8 {TRUE}      ; equivalent to REQUIRE8
REQUIRE8 {FALSE}     ; equivalent to absence of REQUIRE8
PRESERVE8 {TRUE}      ; equivalent to PRESERVE8
PRESERVE8 {FALSE}     ; NOT exactly equivalent to absence of PRESERVE8

```

## See also

### Reference:

- *Assembler command line options* on page 2-3.

## 6.8.16 ROUT

The ROUT directive marks the boundaries of the scope of local labels.

### Syntax

```
{name} ROUT
```

where:

*name* is the name to be assigned to the scope.

### Usage

Use the ROUT directive to limit the scope of local labels. This makes it easier for you to avoid referring to a wrong label by accident. The scope of local labels is the whole area if there are no ROUT directives in it.

Use the *name* option to ensure that each reference is to the correct local label. If the name of a label or a reference to a label does not match the preceding ROUT directive, the assembler generates an error message and the assembly fails.

### Example

```

routineA    ; code
ROUT       ; ROUT is not necessarily a routine
; code
3routineA   ; code      ; this label is checked
; code
BEQ %4routineA ; this reference is checked
; code
BGE %3      ; refers to 3 above, but not checked
; code

```

```
4routineA    ; code          ; this label is checked  
              ; code  
otherstuff ROUT      ; start of next scope
```

**See also****Concept:**

*Using the Assembler:*

- *Local labels* on page 8-15.

**Reference:**

- *AREA* on page 6-81.

