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Preface

This preface introduces the Arm® Compiler armclang Reference Guide.

It contains the following:

- About this book on page 14.
About this book

The Arm Compiler armclang Reference Guide provides user information for the Arm compiler, armclang. armclang is an optimizing C and C++ compiler that compiles Standard C and Standard C++ source code into machine code for Arm architecture-based processors.

Using this book

This book is organized into the following chapters:

Chapter 1 armclang Command-line Options
This chapter summarizes the supported options used with armclang.

Chapter 2 Compiler-specific Keywords and Operators
Summarizes the compiler-specific keywords and operators that are extensions to the C and C++ Standards.

Chapter 3 Compiler-specific Function, Variable, and Type Attributes
Summarizes the compiler-specific function, variable, and type attributes that are extensions to the C and C++ Standards.

Chapter 4 Compiler-specific Intrinsics
Summarizes the Arm compiler-specific intrinsics that are extensions to the C and C++ Standards.

Chapter 5 Compiler-specific Pragmas
Summarizes the Arm compiler-specific pragmas that are extensions to the C and C++ Standards.

Chapter 6 Other Compiler-specific Features
Summarizes compiler-specific features that are extensions to the C and C++ Standards, such as predefined macros.

Chapter 7 Standard C Implementation Definition
Provides information required by the ISO C standard for conforming C implementations.

Chapter 8 Standard C++ Implementation Definition
Provides information required by the ISO C++ Standard for conforming C++ implementations.

Chapter 9 armclang Integrated Assembler Directives
Provides information on the directives you can use when writing assembly language source files in the armclang integrated assembler syntax.

Chapter 10 armclang Inline Assembler
Provides reference information on writing inline assembly.

Glossary

The Arm Glossary is a list of terms used in Arm documentation, together with definitions for those terms. The Arm Glossary does not contain terms that are industry standard unless the Arm meaning differs from the generally accepted meaning.

See the Arm Glossary for more information.

Typographic conventions

*italic*  
Introduces special terminology, denotes cross-references, and citations.

*bold*  
Highlights interface elements, such as menu names. Denotes signal names. Also used for terms in descriptive lists, where appropriate.

*monospace*  
Denotes text that you can enter at the keyboard, such as commands, file and program names, and source code.
monospace
Denotes a permitted abbreviation for a command or option. You can enter the underlined text instead of the full command or option name.

 monospace italic
Denotes arguments to monospace text where the argument is to be replaced by a specific value.

 monospace bold
Denotes language keywords when used outside example code.

<and>
Encloses replaceable terms for assembler syntax where they appear in code or code fragments. For example:

 MRC p15, 0, <Rd>, <CRn>, <CRm>, <Opcode_2>

SMALL CAPITALS
Used in body text for a few terms that have specific technical meanings, that are defined in the Arm® Glossary. For example, IMPLEMENTATION DEFINED, IMPLEMENTATION SPECIFIC, UNKNOWN, and UNPREDICTABLE.

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• An explanation with as much information as you can provide. Include symptoms and diagnostic procedures if appropriate.

Feedback on content
If you have comments on content then send an e-mail to errata@arm.com. Give:
• The title Arm Compiler armclang Reference Guide.
• The number 100067_0610_00_en.
• If applicable, the page number(s) to which your comments refer.
• A concise explanation of your comments.

Arm also welcomes general suggestions for additions and improvements.

——— Note ———
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Other information

• Arm® Developer.
• Arm® Information Center.
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• Technical Support.
• Arm® Glossary.
Chapter 1
armclang Command-line Options

This chapter summarizes the supported options used with armclang.

armclang provides many command-line options, including most Clang command-line options in addition to a number of Arm-specific options. Additional information about community feature command-line options is available in the Clang and LLVM documentation on the LLVM Compiler Infrastructure Project web site, http://llvm.org.

Note

Be aware of the following:
- Generated code might be different between two Arm Compiler releases.
- For a feature release, there might be significant code generation differences.

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- 1.2 Summary of armclang command-line options on page 1-23.
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- 1.4 -c on page 1-29.
- 1.5 -D on page 1-30.
- 1.6 -E on page 1-31.
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- 1.8 -fbare-metal-pie on page 1-33.
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- 1.10 -fcommon, -fno-common on page 1-35.
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• 1.54 -mno-neg-immediates on page 1-92.
• 1.55 -munaligned-access, -mno-unaligned-access on page 1-94.
• 1.56 -mthumb on page 1-95.
• 1.57 -nostdlib on page 1-96.
• 1.58 -nostdlibinc on page 1-97.
• 1.59 -o on page 1-98.
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• 1.61 -pedantic on page 1-101.
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1.1 Support level definitions

This describes the levels of support for various Arm Compiler 6 features.

Arm Compiler 6 is built on Clang and LLVM technology. Therefore it has more functionality than the set of product features described in the documentation. The following definitions clarify the levels of support and guarantees on functionality that are expected from these features.

Arm welcomes feedback regarding the use of all Arm Compiler 6 features, and endeavors to support users to a level that is appropriate for that feature. You can contact support at https://developer.arm.com/support.

Identification in the documentation

All features that are documented in the Arm Compiler 6 documentation are product features, except where explicitly stated. The limitations of non-product features are explicitly stated.

Product features

Product features are suitable for use in a production environment. The functionality is well-tested, and is expected to be stable across feature and update releases.

- Arm endeavors to give advance notice of significant functionality changes to product features.
- If you have a support and maintenance contract, Arm provides full support for use of all product features.
- Arm welcomes feedback on product features.
- Any issues with product features that Arm encounters or is made aware of are considered for fixing in future versions of Arm Compiler.

In addition to fully supported product features, some product features are only alpha or beta quality.

Beta product features

Beta product features are implementation complete, but have not been sufficiently tested to be regarded as suitable for use in production environments.

Beta product features are indicated with [BETA].

- Arm endeavors to document known limitations on beta product features.
- Beta product features are expected to eventually become product features in a future release of Arm Compiler 6.
- Arm encourages the use of beta product features, and welcomes feedback on them.
- Any issues with beta product features that Arm encounters or is made aware of are considered for fixing in future versions of Arm Compiler.

Alpha product features

Alpha product features are not implementation complete, and are subject to change in future releases, therefore the stability level is lower than in beta product features.

Alpha product features are indicated with [ALPHA].

- Arm endeavors to document known limitations of alpha product features.
- Arm encourages the use of alpha product features, and welcomes feedback on them.
- Any issues with alpha product features that Arm encounters or is made aware of are considered for fixing in future versions of Arm Compiler.

Community features

Arm Compiler 6 is built on LLVM technology and preserves the functionality of that technology where possible. This means that there are additional features available in Arm Compiler that are not listed in the documentation. These additional features are known as community features. For information on these community features, see the documentation for the Clang/LLVM project.
Where community features are referenced in the documentation, they are indicated with [COMMUNITY].

- Arm makes no claims about the quality level or the degree of functionality of these features, except when explicitly stated in this documentation.
- Functionality might change significantly between feature releases.
- Arm makes no guarantees that community features will remain functional across update releases, although changes are expected to be unlikely.

Some community features might become product features in the future, but Arm provides no roadmap for this. Arm is interested in understanding your use of these features, and welcomes feedback on them. Arm supports customers using these features on a best-effort basis, unless the features are unsupported. Arm accepts defect reports on these features, but does not guarantee that these issues will be fixed in future releases.

**Guidance on use of community features**

There are several factors to consider when assessing the likelihood of a community feature being functional:

- The following figure shows the structure of the Arm Compiler 6 toolchain:
Figure 1-1 Integration boundaries in Arm Compiler 6.

The dashed boxes are toolchain components, and any interaction between these components is an integration boundary. Community features that span an integration boundary might have significant limitations in functionality. The exception to this is if the interaction is codified in one of the standards supported by Arm Compiler 6. See Application Binary Interface (ABI) for the Arm® Architecture. Community features that do not span integration boundaries are more likely to work as expected.

- Features primarily used when targeting hosted environments such as Linux or BSD might have significant limitations, or might not be applicable, when targeting bare-metal environments.
- The Clang implementations of compiler features, particularly those that have been present for a long time in other toolchains, are likely to be mature. The functionality of new features, such as support
for new language features, is likely to be less mature and therefore more likely to have limited functionality.

Unsupported features

With both the product and community feature categories, specific features and use-cases are known not to function correctly, or are not intended for use with Arm Compiler 6.

Limitations of product features are stated in the documentation. Arm cannot provide an exhaustive list of unsupported features or use-cases for community features. The known limitations on community features are listed in Community features on page 1-19.

List of known unsupported features

The following is an incomplete list of unsupported features, and might change over time:

• The Clang option -stdlib=libstdc++ is not supported.
• C++ static initialization of local variables is not thread-safe when linked against the standard C++ libraries. For thread-safety, you must provide your own implementation of thread-safe functions as described in Standard C++ library implementation definition.

Note

This restriction does not apply to the [ALPHA]-supported multithreaded C++ libraries.

• Use of C11 library features is unsupported.
• Any community feature that exclusively pertains to non-Arm architectures is not supported.
• Compilation for targets that implement architectures older than Armv7 or Armv6-M is not supported.
• The long double data type is not supported for AArch64 state because of limitations in the current Arm C library.
• Complex numbers are not supported because of limitations in the current Arm C library.
1.2 Summary of armclang command-line options

This provides a summary of the armclang command-line options that Arm Compiler 6 supports.

The command-line options either affect both compilation and assembly, or only affect compilation. The command-line options that only affect compilation without affecting armclang integrated assembler are shown in the table as *Compilation only*. The command-line options that affect both compilation and assembly are shown in the table as *Compilation and assembly*.

--- Note ---
The command-line options that affect assembly are for the armclang integrated assembler, and do not apply to armasm. These options affect both inline assembly and assembly language source files.

--- Note ---
Assembly language source files are assembled using the armclang integrated assembler. C and C++ language source files, which can contain inline assembly code, are compiled using the armclang compiler. Command-line options that are shown as *Compilation only* do not affect the integrated assembler, but they can affect inline assembly code.

<table>
<thead>
<tr>
<th>Option</th>
<th>Description</th>
<th>Compilation or Assembly</th>
</tr>
</thead>
<tbody>
<tr>
<td>-C</td>
<td>Keep comments in the preprocessed output.</td>
<td>Compilation and assembly.</td>
</tr>
<tr>
<td>-c</td>
<td>Only perform the compile step, do not invoke armlink.</td>
<td>Compilation and assembly.</td>
</tr>
<tr>
<td>-D</td>
<td>Defines a preprocessor macro.</td>
<td>Compilation and assembly.</td>
</tr>
<tr>
<td>-E</td>
<td>Only perform the preprocess step, do not compile or link.</td>
<td>Compilation and assembly.</td>
</tr>
<tr>
<td>-e</td>
<td>Specifies the unique initial entry point of the image.</td>
<td>Compilation and assembly.</td>
</tr>
<tr>
<td>-fbare-metal-pie</td>
<td>Generates position-independent code.</td>
<td>Compilation only.</td>
</tr>
<tr>
<td>-fbracket-depth</td>
<td>Sets the limit for nested parentheses, brackets, and braces.</td>
<td>Compilation and assembly.</td>
</tr>
<tr>
<td>-fcommon, -fno-common</td>
<td>Generates common zero-initialized values for tentative definitions.</td>
<td>Compilation only.</td>
</tr>
<tr>
<td>-fdata-sections, -fno-data-sections</td>
<td>Enables or disables the generation of one ELF section for each variable in the source file.</td>
<td>Compilation only.</td>
</tr>
<tr>
<td>-ffast-math, -fno-fast-math</td>
<td>Enables or disables the use of aggressive floating-point optimizations.</td>
<td>Compilation only.</td>
</tr>
<tr>
<td>-ffp-mode</td>
<td>Specifies floating-point standard conformance.</td>
<td>Compilation only.</td>
</tr>
<tr>
<td>-ffunction-sections, -fno-function-sections</td>
<td>Enables or disables the generation of one ELF section for each function in the source file.</td>
<td>Compilation only.</td>
</tr>
<tr>
<td>@file</td>
<td>Reads a list of command-line options from a file.</td>
<td>Compilation and assembly.</td>
</tr>
<tr>
<td>Option</td>
<td>Description</td>
<td>Compilation or Assembly</td>
</tr>
<tr>
<td>-----------------------------</td>
<td>-----------------------------------------------------------------------------</td>
<td>-------------------------</td>
</tr>
<tr>
<td>-fldm-stm, -fno-ldm-stm</td>
<td>Enable or disable the generation of LDM and STM instructions. AArch32 only.</td>
<td>Compilation only.</td>
</tr>
<tr>
<td>-fno-inline-functions</td>
<td>Disables the automatic inlining of functions at optimization levels -O2 and -O3.</td>
<td>Compilation only.</td>
</tr>
<tr>
<td>-flto</td>
<td>Enables link time optimization, and outputs bitcode wrapped in an ELF file for link time optimization.</td>
<td>Compilation only.</td>
</tr>
<tr>
<td>-fexceptions, -fno-exceptions</td>
<td>Enables or disables the generation of code needed to support C++ exceptions.</td>
<td>Compilation only.</td>
</tr>
<tr>
<td>-fomit-frame-pointer, -fno-omit-frame-pointer</td>
<td>Enables or disables the storage of stack frame pointers during function calls.</td>
<td>Compilation only.</td>
</tr>
<tr>
<td>-fno-builtin</td>
<td>Disables special handling and optimizations of standard C library functions.</td>
<td>Compilation only.</td>
</tr>
<tr>
<td>-fropi, -fno-ropi</td>
<td>Enables or disables the generation of Read-Only Position-Independent (ROPI) code.</td>
<td>Compilation only.</td>
</tr>
<tr>
<td>-fropi-lowering, -fno-ropi-lowering</td>
<td>Enables or disables runtime static initialization when generating Read-Only Position-Independent (ROPI) code.</td>
<td>Compilation only.</td>
</tr>
<tr>
<td>-frwpi, -fno-rwpi</td>
<td>Enables or disables the generation of Read-Write Position-Independent (RWPI) code.</td>
<td>Compilation only.</td>
</tr>
<tr>
<td>-frwpi-lowering, -fno-rwpi-lowering</td>
<td>Enables or disables runtime static initialization when generating Read-Write Position-Independent (RWPI) code.</td>
<td>Compilation only.</td>
</tr>
<tr>
<td>-fshort-enums, -fno-short-enums</td>
<td>Allows or disallows the compiler to set the size of an enumeration type to the smallest data type that can hold all enumerator values.</td>
<td>Compilation only.</td>
</tr>
<tr>
<td>-fshort-wchar, -fno-short-wchar</td>
<td>Sets the size of wchar_t to 2 or 4 bytes.</td>
<td>Compilation only.</td>
</tr>
<tr>
<td>-fstrict-aliasing, -fno-strict-aliasing</td>
<td>Instructs the compiler to apply or not apply the strictest aliasing rules available.</td>
<td>Compilation only.</td>
</tr>
<tr>
<td>-fvectorize, -fno-vectorize</td>
<td>Enables or disables the generation of Advanced SIMD vector instructions directly from C or C++ code at optimization levels -O1 and higher.</td>
<td>Compilation only.</td>
</tr>
<tr>
<td>-ftrapv</td>
<td>Instructs the compiler to generate traps for signed arithmetic overflow on addition, subtraction, and multiplication operations.</td>
<td>Compilation only.</td>
</tr>
<tr>
<td>-fwrapv</td>
<td>Instructs the compiler to assume that signed arithmetic overflow of addition, subtraction, and multiplication, wraps using two's-complement representation.</td>
<td>Compilation only.</td>
</tr>
<tr>
<td>Option</td>
<td>Description</td>
<td>Compilation or Assembly</td>
</tr>
<tr>
<td>---------------</td>
<td>-----------------------------------------------------------------------------</td>
<td>-------------------------</td>
</tr>
<tr>
<td>-g, -gdwarf-2, -gdwarf-3, -gdwarf-4</td>
<td>Adds debug tables for source-level debugging.</td>
<td>Compilation and assembly.</td>
</tr>
<tr>
<td>-I</td>
<td>Adds the specified directory to the list of places that are searched to find include files.</td>
<td>Compilation and assembly.</td>
</tr>
<tr>
<td>-include</td>
<td>Includes the source code of the specified file at the beginning of the compilation.</td>
<td>Compilation only.</td>
</tr>
<tr>
<td>-L</td>
<td>Specifies a list of paths that the linker searches for user libraries.</td>
<td>Compilation only.</td>
</tr>
<tr>
<td>-l</td>
<td>Add the specified library to the list of searched libraries.</td>
<td>Compilation only.</td>
</tr>
<tr>
<td>-M, -MM</td>
<td>Produces a list of makefile dependency rules suitable for use by a make utility.</td>
<td>Compilation and assembly.</td>
</tr>
<tr>
<td>-MD, -MMD</td>
<td>Compiles or assembles source files and produces a list of makefile dependency rules suitable for use by a make utility.</td>
<td>Compilation and assembly.</td>
</tr>
<tr>
<td>-MF</td>
<td>Specifies a filename for the makefile dependency rules produced by the -M and -MD options.</td>
<td>Compilation only.</td>
</tr>
<tr>
<td>-MG</td>
<td>Prints dependency lines for header files even if the header files are missing.</td>
<td>Compilation only.</td>
</tr>
<tr>
<td>-MP</td>
<td>Emits dummy dependency rules that work around make errors that are generated if you remove header files without a corresponding update to the makefile.</td>
<td>Compilation only.</td>
</tr>
<tr>
<td>-MT</td>
<td>Changes the target of the makefile dependency rule produced by dependency generating options.</td>
<td>Compilation and assembly.</td>
</tr>
<tr>
<td>-march</td>
<td>Targets an architecture profile, generating generic code that runs on any processor of that architecture.</td>
<td>Compilation and assembly.</td>
</tr>
<tr>
<td>-marm</td>
<td>Requests that the compiler targets the A32 instruction set.</td>
<td>Compilation only.</td>
</tr>
<tr>
<td>-mcpu</td>
<td>Targets a specific processor, generating optimized code for that specific processor.</td>
<td>Compilation and assembly.</td>
</tr>
<tr>
<td>-mexecute-only</td>
<td>Generates execute-only code, and prevents the compiler from generating any data accesses to code sections.</td>
<td>Compilation only.</td>
</tr>
<tr>
<td>-mfloat-abi</td>
<td>Specifies whether to use hardware instructions or software library functions for floating-point operations, and which registers are used to pass floating-point parameters and return values.</td>
<td>Compilation only.</td>
</tr>
<tr>
<td>Option</td>
<td>Description</td>
<td>Compilation or Assembly</td>
</tr>
<tr>
<td>--------------------</td>
<td>------------------------------------------------------------------------------</td>
<td>-------------------------</td>
</tr>
<tr>
<td>-mfpu</td>
<td>Specifies the target FPU architecture, that is the floating-point hardware</td>
<td>Compilation and assembly.</td>
</tr>
<tr>
<td></td>
<td>available on the target.</td>
<td></td>
</tr>
<tr>
<td>-mimplicit-it</td>
<td>Specifies the behavior of the integrated assembler if there are conditional</td>
<td>Compilation and assembly.</td>
</tr>
<tr>
<td></td>
<td>instructions outside IT blocks.</td>
<td></td>
</tr>
<tr>
<td>-mlittle-endian</td>
<td>Generates code suitable for an Arm processor using little-endian data.</td>
<td>Compilation and assembly.</td>
</tr>
<tr>
<td>-mno-neg-immediates</td>
<td>Disables the substitution of invalid instructions with valid equivalent</td>
<td>Compilation and assembly.</td>
</tr>
<tr>
<td></td>
<td>instructions that use the logical inverse or negative of the specified</td>
<td></td>
</tr>
<tr>
<td></td>
<td>immediate value.</td>
<td></td>
</tr>
<tr>
<td>-munaligned-access,</td>
<td>Enables or disables unaligned accesses to data on Arm processors.</td>
<td>Compilation only.</td>
</tr>
<tr>
<td>-mno-unaligned-access</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-mthumb</td>
<td>Requests that the compiler targets the T32 instruction set.</td>
<td>Compilation only.</td>
</tr>
<tr>
<td>-o</td>
<td>Specifies the name of the output file.</td>
<td>Compilation and assembly.</td>
</tr>
<tr>
<td>-O</td>
<td>Specifies the level of optimization to use when compiling source files.</td>
<td>Compilation only.</td>
</tr>
<tr>
<td>-S</td>
<td>Outputs the disassembly of the machine code generated by the compiler.</td>
<td>Compilation only.</td>
</tr>
<tr>
<td>-save-temps</td>
<td>Instructs the compiler to generate intermediate assembly files from the</td>
<td>Compilation only.</td>
</tr>
<tr>
<td></td>
<td>specified C/C++ file.</td>
<td></td>
</tr>
<tr>
<td>-std</td>
<td>Specifies the language standard to compile for.</td>
<td>Compilation only.</td>
</tr>
<tr>
<td>-target</td>
<td>Generate code for the specified target triple.</td>
<td>Compilation and assembly.</td>
</tr>
<tr>
<td>-U</td>
<td>Removes any initial definition of the specified preprocessor macro.</td>
<td>Compilation only.</td>
</tr>
<tr>
<td>-u</td>
<td>Prevents the removal of a specified symbol if it is undefined.</td>
<td>Compilation and assembly.</td>
</tr>
<tr>
<td>-v</td>
<td>Displays the commands that invoke the compiler and sub-tools, such as</td>
<td>Compilation and assembly.</td>
</tr>
<tr>
<td></td>
<td>armlink, and executes those commands.</td>
<td></td>
</tr>
<tr>
<td>--version</td>
<td>Displays the same information as --vsn.</td>
<td>Compilation and assembly.</td>
</tr>
<tr>
<td>--version_number</td>
<td>Displays the version of armclang you are using.</td>
<td>Compilation and assembly.</td>
</tr>
<tr>
<td>--vsn</td>
<td>Displays the version information and the license details.</td>
<td>Compilation and assembly.</td>
</tr>
<tr>
<td>-W</td>
<td>Controls diagnostics.</td>
<td>Compilation only.</td>
</tr>
<tr>
<td>-WL</td>
<td>Specifies linker command-line options to pass to the linker when a link</td>
<td>Compilation only.</td>
</tr>
<tr>
<td></td>
<td>step is being performed after compilation.</td>
<td></td>
</tr>
<tr>
<td>-Xlinker</td>
<td>Specifies linker command-line options to pass to the linker when a link</td>
<td>Compilation only.</td>
</tr>
<tr>
<td></td>
<td>step is being performed after compilation.</td>
<td></td>
</tr>
<tr>
<td>-x</td>
<td>Specifies the language of source files.</td>
<td>Compilation and assembly.</td>
</tr>
<tr>
<td>-###</td>
<td>Displays the commands that invoke the compiler and sub-tools, such as</td>
<td>Compilation and assembly.</td>
</tr>
<tr>
<td></td>
<td>armlink, without executing those commands.</td>
<td></td>
</tr>
</tbody>
</table>
1.3 -C

Keep comments in the preprocessed output.

By default, comments are stripped out. Use the -C option to keep comments in the preprocessed output.

With the -C option, all comments are passed through to the output file, except for comments in processed directives which are deleted along with the directive.

Usage

You must specify the -E option when you use the -C option.

Using the -C option does not implicitly select the -E option. If you do not specify the -E option, the compiler reports:

```
warning: argument unused during compilation: '-C' [-Wunused-command-line-argument]
```

The -C option can also be used when preprocessing assembly files, using:
- `-xassembler-with-cpp`, or a file that has an upper-case extension, with the armclang integrated assembler.
- `--cpreproc` and `--cpreproc_opts` with the legacy assembler, armasm.

Example

Here is an example program, foo.c, which contains some comments:

```c
#define HIGH 1 // Comment on same line as directive
#define LOW 0
#define LEVEL 10
// #define THIS 99
// Comment A
/* Comment B */
int Signal (int value)
{
    if (value>LEVEL) return HIGH; // Comment C
    return LOW + THIS;
}
```

Use armclang to preprocess this example code with the -C option to retain comments. The -E option executes the preprocessor step only.

```
armclang --target=aarch64-arm-none-eabi -mcpu=cortex-a53 -C -E foo.c
```

The output from the preprocessor contains:

```c
// #define THIS 99
// Comment A
/* Comment B */
int Signal (int value)
{
    if (value>LEVEL) return 1; // Comment C
    return 0 + THIS;
}
```

The preprocessor has kept the following comments:
- // #define THIS 99
- // Comment A
- /* Comment B */
- // Comment C

The #define directives HIGH and LOW have been converted into their defined values, and the comment alongside HIGH has been removed. The #define directive THIS is considered a comment because that line starts with //, and therefore has not been converted.
Related reference
1.6 -E on page 1-31
1.4 -c

Instructs the compiler to perform the compilation step, but not the link step.

Usage

Arm recommends using the -c option in projects with more than one source file.

The compiler creates one object file for each source file, with a .o file extension replacing the file extension on the input source file. For example, the following creates object files test1.o, test2.o, and test3.o:

```
armclang --target=aarch64-arm-none-eabi -mcpu=cortex-a53 -c test1.c test2.c test3.c
```

Note

If you specify multiple source files with the -c option, the -o option results in an error. For example:

```
armclang --target=aarch64-arm-none-eabi -mcpu=cortex-a53 -c test1.c test2.c -o test.o
armclang: error: cannot specify -o when generating multiple output files
```
1.5 -D

Defines a macro *name*.

**Syntax**

```
-D name[(parm-list)][=def]
```

Where:

*name*  
Is the name of the macro to be defined.

*parm-list*  
Is an optional list of comma-separated macro parameters. By appending a macro parameter list to the macro name, you can define function-style macros.

The parameter list must be enclosed in parentheses. When specifying multiple parameters, do not include spaces between commas and parameter names in the list.

_________ Note _________

Parentheses might require escaping on UNIX systems.

_________ =def _________

*def*  
Is an optional macro definition.

If *def* is omitted, the compiler defines *name* as the value 1.

To include characters recognized as tokens on the command line, enclose the macro definition in double quotes.

**Usage**

Specifying `-D name` has the same effect as placing the text `#define name` at the head of each source file.

**Example**

Specifying this option:

```
-D MAX(X,Y)="((X > Y) ? X : Y)"
```

is equivalent to defining the macro:

```
#define MAX(X, Y) ((X > Y) ? X : Y)
```

at the head of each source file.

**Related reference**

1.35 -include on page 1-64
1.67 -U on page 1-108
1.76 -x on page 1-117

**Related information**

Preprocessing assembly code
1.6 -E

Executes the preprocessor step only.

By default, output from the preprocessor is sent to the standard output stream and can be redirected to a file using standard UNIX and MS-DOS notation.

You can also use the -o option to specify a file for the preprocessed output.

By default, comments are stripped from the output. Use the -C option to keep comments in the preprocessed output.

**Examples**

Use `-E -dD` to generate interleaved macro definitions and preprocessor output:

```
armclang --target=riscv32-elf-none-eabi -mcpu=cortex-a53 -E -dD source.c > raw.c
```

Use `-E -dM` to list all the macros that are defined at the end of the translation unit, including the predefined macros:

```
armclang --target=riscv32-elf-none-eabi -mcpu=cortex-m3 -E -dM source.c
```

**Related reference**

1.3 -C on page 1-27

1.66 --target on page 1-107
1.7  -e

Specifies the unique initial entry point of the image.

If linking, armclang translates this option to --entry and passes it to armlink. If the link step is not being performed, this option is ignored.

See the Arm® Compiler toolchain Linker Reference for information about the --entry linker options.

*Related information*

armlink User Guide
1.8  -fbare-metal-pie

Generates position independent code.

This option causes the compiler to invoke armlink with the --bare_metal_pie option when performing the link step.

Note

- This option is unsupported for AArch64 state.
- Bare-metal PIE support is deprecated in this release.

Related reference

1.22  -fropi, -fno-ropi on page 1-50
1.24  -frwpi, -fno-rwpi on page 1-52

Related information

Bare-metal Position Independent Executables
--fpic armlink option
--pie armlink option
--bare_metal_pie armlink option
--ref_pre_init armlink option
1.9 -fbracket-depth=N

Sets the limit for nested parentheses, brackets, and braces to \( N \) in blocks, declarators, expressions, and struct or union declarations.

**Syntax**

- fbracket-depth=N

**Usage**

You can increase the depth limit \( N \).

**Default**

The default depth limit is 256.

**Related reference**

7.3 Translation limits on page 7-218
1.10  -fcommon, -fno-common

Generates common zero-initialized values for tentative definitions.

Tentative definitions are declarations of variables with no storage class and no initializer.

The `-fcommon` option places the tentative definitions in a common block. This common definition is not associated with any particular section or object, so multiple definitions resolve to a single symbol definition at link time.

The `-fno-common` option generates individual zero-initialized definitions for tentative definitions. These zero-initialized definitions are placed in a ZI section in the generated object. Multiple definitions of the same symbol in different files can cause a L6200E: Symbol multiply defined linker error, because the individual definitions clash with each other.

Default

The default is `-fno-common`. 
1.11  -fdata-sections, -fno-data-sections

Enables or disables the generation of one ELF section for each variable in the source file. The default is -fdata-sections.

--- Note ---

If you want to place specific data items or structures in separate sections, mark them individually with __attribute__((section("name"))).

Example

```c
volatile int a = 9;
volatile int c = 10;
volatile int d = 11;

int main(void){
  static volatile int b = 2;
  return a == b;
}
```

Compile this code with:

```
armclang --target=arm-arm-none-eabi -march=armv8-a -fdata-sections -c -O3 main.c
```

Use fromelf to see the data sections:

```
fromelf -cds main.o
```

If you compile this code with -fno-data-sections, you get:

```
Symbol table .symtab (17 symbols, 11 local)
# Symbol Name Value Bind Sec Type Vis Size
10  .L_MergedGlobals 0x00000000 Lc 10 Data De 0x8
11  main.b 0x00000004 Lc 10 Data De 0x4
12 ...
13 ...
14  a 0x00000000 Gb 10 Data De 0x4
15  c 0x00000000 Gb 10 Data Hi 0x4
16  d 0x00000000 Gb 8 Data Hi 0x4
...
```

If you compare the two Sec columns, you can see that when -fdata-sections is used, the variables are put into different sections. When -fno-data-sections is used, all the variables are put into the same section.

Related reference

1.14 -ffunction-sections, -fno-function-sections on page 1-40

3.33 __attribute__((section("name"))) variable attribute on page 3-167
1.12 -ffast-math, -fno-fast-math

-ffast-math tells the compiler to perform more aggressive floating-point optimizations.

-ffast-math results in behavior that is not fully compliant with the ISO C or C++ standard. However, numerically robust floating-point programs are expected to behave correctly. Arm recommends that you use the alias option -ffp-mode=fast instead of -ffast-math.

Using -fno-fast-math disables aggressive floating-point optimizations. It also ensures that the floating-point code that the compiler generates is compliant with the IEEE Standard for Floating-Point Arithmetic (IEEE 754). Arm recommends that you use the alias option -ffp-mode=full instead of -fno-fast-math.

Note

Arm Compiler 6 uses neither -ffast-math nor -fno-fast-math by default. For the default behavior, specify -ffp-mode=std.

These options control which floating-point library the compiler uses. For more information, see the library variants in Arm® C and C++ Libraries and Floating-Point Support User Guide.

Table 1-2 Floating-point library variants

<table>
<thead>
<tr>
<th>armclang option</th>
<th>Floating-point library variant</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Default</td>
<td>fz</td>
<td>IEEE-compliant library with fixed rounding mode and support for certain IEEE exceptions, and flushing to zero.</td>
</tr>
<tr>
<td>-ffast-math</td>
<td>fz</td>
<td>Similar to the default behavior, but also performs aggressive floating-point optimizations and therefore it is not IEEE-compliant.</td>
</tr>
<tr>
<td>-fno-fast-math</td>
<td>g</td>
<td>IEEE-compliant library with configurable rounding mode and support for all IEEE exceptions, and flushing to zero.</td>
</tr>
</tbody>
</table>

Related reference

1.13 -ffp-mode on page 1-38
1.13 -ffp-mode

-ffp-mode specifies floating-point standard conformance. This controls which floating-point optimizations the compiler can perform, and also influences library selection.

Syntax

-ffp-mode=MODEL

Where MODEL is one of the following:

std

IEEE finite values with denormals flushed to zero, round-to-nearest, and no exceptions. This is compatible with standard C and C++ and is the default option.

Normal finite values are as predicted by the IEEE standard. However:

• NaNs and infinities might not be produced in all circumstances defined by the IEEE model. When they are produced, they might not have the same sign.
• The sign of zero might not be that predicted by the IEEE model.
• Using NaNs in arithmetic operations with -ffp-mode=std causes undefined behavior.

fast

Perform more aggressive floating-point optimizations that might cause a small loss of accuracy to provide a significant performance increase. This option defines the symbol __ARM_FP_FAST.

This option results in behavior that is not fully compliant with the ISO C or C++ standard. However, numerically robust floating-point programs are expected to behave correctly.

A number of transformations might be performed, including:

• Double-precision floating-point expressions that are narrowed to single-precision are evaluated in single-precision when it is beneficial to do so. For example, float y = (float)(x + 1.0) is evaluated as float y = (float)x + 1.0f.
• Division by a floating-point constant is replaced by multiplication with its reciprocal. For example, x / 3.0 is evaluated as x * (1.0 / 3.0).
• It is not guaranteed that the value of errno is compliant with the ISO C or C++ standard after math functions have been called. This enables the compiler to inline the VFP square root instructions in place of calls to sqrt() or sqrtf().

Using a NaN with -ffp-mode=fast can produce undefined behavior.

full

All facilities, operations, and representations guaranteed by the IEEE Standard for Floating-Point Arithmetic (IEEE 754) are available in single and double-precision. Modes of operation can be selected dynamically at runtime.

These options control which floating-point library the compiler uses. For more information, see the library variants in the Arm® C and C++ Libraries and Floating-Point Support User Guide.

Note

When using the std or fast modes, the binary representation of a floating-point number that cannot be represented exactly by its type can differ depending on whether it is evaluated by the compiler at compile time or generated at run time using one of the following string to floating-point conversion functions:

• atof().
• strtod().
• strtof().
• strtold().
• A member of the scanf() family of functions using a floating-point conversion specifier.
### Table 1-3 Floating-point library variant selection

<table>
<thead>
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<th>armclang option</th>
<th>Floating-point library variant</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>-ffp-mode=std</td>
<td>fz</td>
<td>IEEE-compliant library with fixed rounding mode and support for certain IEEE exceptions, and flushing to zero.</td>
</tr>
<tr>
<td>-ffp-mode=fast</td>
<td>fz</td>
<td>Similar to the default behavior, but also performs aggressive floating-point optimizations and therefore it is not IEEE-compliant.</td>
</tr>
<tr>
<td>-ffp-mode=full</td>
<td>g</td>
<td>IEEE-compliant library with configurable rounding mode and support for all IEEE exceptions, and flushing to zero.</td>
</tr>
</tbody>
</table>

**Default**

The default is `-ffp-mode=std`. 
1.14 -ffunction-sections, -fno-function-sections

-ffunction-sections generates a separate ELF section for each function in the source file. The unused section elimination feature of the linker can then remove unused functions at link time.

The output section for each function has the same name as the function that generates the section, but with a .text. prefix. To disable this, use -fno-function-sections.

Note

If you want to place specific data items or structures in separate sections, mark them individually with __attribute__((section("name"))).

Default

-ffunction-sections is set by default.

Restrictions

-ffunction-sections reduces the potential for sharing addresses, data, and string literals between functions. Consequently, it might increase code size slightly for some functions.

Example

```c
int function1(int x)
{
    return x+1;
}

int function2(int x)
{
    return x+2;
}
```

Compiling this code with -ffunction-sections produces:

```plaintext
armclang --target=arm-arm-none-eabi -march=armv8-a -ffunction-sections -S -O3 -o- main.c
...
    .section .text.function1,"ax",%progbits
    .globl function1
    .p2align 2
    .type function1,%function
    function1: @ @function1
        .fnstart
        @ BB#0:
            add      r0, r0, #1
            bx       lr
        .Lfunc_end0:
        .size function1, .Lfunc_end0-function1
        .cantunwind
        .fnend
    .section .text.function2,"ax",%progbits
    .globl function2
    .p2align 2
    .type function2,%function
    function2: @ @function2
        .fnstart
        @ BB#0:
            add      r0, r0, #2
            bx       lr
        .Lfunc_end1:
        .size function2, .Lfunc_end1-function2
        .cantunwind
        .fnend
    ...
```

Related reference

3.17 __attribute__((section("name"))) function attribute on page 3-150
1.11 -fdata-sections, -fno-data-sections on page 1-36
Related information

Elimination of unused sections
1.15 @file

Reads a list of armclang options from a file.

**Syntax**

@file

Where *file* is the name of a file containing armclang options to include on the command line.

**Usage**

The options in the specified file are inserted in place of the @file option.

Use whitespace or new lines to separate options in the file. Enclose strings in single or double quotes to treat them as a single word.

You can specify multiple @file options on the command line to include options from multiple files. Files can contain more @file options.

If any @file option specifies a non-existent file or circular dependency, armclang exits with an error.

**Note**

To use Windows-style file paths on the command-line, you must escape the backslashes. For example:

```
-I"..\my libs\"
```

**Example**

Consider a file options.txt with the following content:

```
-I"../my libs/"
--target=aarch64-arm-none-eabi -mcpu=cortex-a57
```

Compile a source file main.c with the following command line:

```
armclang @options.txt main.c
```

This command is equivalent to the following:

```
armclang -I"../my libs/" --target=aarch64-arm-none-eabi -mcpu=cortex-a57 main.c
```
-fldm-stm, -fno-ldm-stm

Enable or disable the generation of LDM and STM instructions. AArch32 only.

**Usage**

The `--fno-ldm-stm` option can reduce interrupt latency on systems that:

- Do not have a cache or a write buffer.
- Use zero-wait-state, 32-bit memory.

--- **Note** ---

Using `--fno-ldm-stm` might slightly increase code size and decrease performance.

---

**Restrictions**

Existing LDM and STM instructions (for example, in assembly code you are assembling with armclang) are not removed.

**Default**

The default is `-fldm-stm`. That is, by default armclang can generate LDM and STM instructions.
1.17 **-fno-builtin**

Disables special handling and optimizations of standard C library functions, for example for `printf()`, `strlen()`, and `malloc()`.

When compiling without `-fno-builtin`, the compiler can replace calls to certain standard C library functions with inline code or with calls to other library functions. Subsequently, your re-implementations of the standard C library functions might not be used, and might be removed by the linker.

**Default**

`-fno-builtin` is disabled by default.

**Example**

This example shows the result of compiling the following program with and without `-fno-builtin`:

```c
#include "stdio.h"

void foo( void )
{
    printf("Hello\n");
}
```

1. Compile without `-fno-builtin`:

   ```bash
   armclang -c -O2 -g --target=arm-arm-none-eabi -mcpu=cortex-a9 -mfpu=none -nostdlib foo.c -o foo.o
   ```

2. Run the following `fromelf` command to show the disassembled output:

   ```bash
   fromelf --disassemble foo.o -o foo.s
   ```

   ```
   |foo| PROC
   |ADR|     r0,[L3.8]|
   |B |  puts |
   |L3.8| DCD 0x6c6c6548
   |    | DCD 0x0000006f
   |    | ENDP ...
   ```

   **Note**

   The compiler has replaced the `printf()` function with the `puts()` function.

3. Compile with `-fno-builtin`:

   ```bash
   armclang -c -O2 -g --target=arm-arm-none-eabi -mcpu=cortex-a9 -mfpu=none -nostdlib -fno-builtin foo.c -o foo.o
   ```

4. Run the following `fromelf` command to show the disassembled output:

   ```bash
   fromelf --disassemble foo.o -o foo.s
   ```

   ```
   |foo| PROC
   |ADR|     r0,[L3.8]|
   |B |  printf |
   |L3.8| DCD 0x6c6c6548
   |    | DCD 0x0000006f
   |    | ENDP ...
   ```

   **Note**

   The compiler has not replaced the `printf()` function with the `puts()` function when using the `-fno-builtin` option.

**Related reference**

1.57 `-nostdlib` on page 1-96
1.58 -nostdlibinc on page 1-97
1.18 -fno-inline-functions

Disabling the inlining of functions can help to improve the debug experience.

The compiler attempts to automatically inline functions at optimization levels -O2 and -O3. When these levels are used with -fno-inline-functions, automatic inlining is disabled.

When optimization levels -O0 and -O1 are used with -fno-inline-functions, no automatic inlining is attempted, and only functions that are tagged with __attribute__((always_inline)) are inlined.

Related concepts
6.3 Inline functions on page 6-205

Related reference
1.60 -O on page 1-99
1.19  

-flto, -fno-lto

Enables or disables link time optimization. -flto outputs bitcode wrapped in an ELF file for link time optimization.

The primary use for files containing bitcode is for link time optimization. See *Optimizing across modules with link time optimization* in the *Software Development Guide* for more information about link time optimization.

**Usage**

The compiler creates one file for each source file, with a .o file extension replacing the file extension on the input source file.

The -flto option passes the --lto option to armlink to enable link time optimization, unless the -c option is specified.

-flto is automatically enabled when you specify the armclang -Omax option.

------ Note ------

Object files produced with -flto contain bitcode, which cannot be disassembled into meaningful disassembly using the -S option or the fromelf tool.

------ Caution ------

Object files generated using the -flto option are not suitable for creating static libraries, or ROPI or RWPI images.

------ Caution ------

Link Time Optimization performs aggressive optimizations. Sometimes this can result in large chunks of code being removed.

------ Note ------

Link Time Optimization does not honor the armclang -mexecute-only option. If you use the armclang -flto or -Omax options, then the compiler cannot generate execute-only code and produces a warning.

**Default**

The default is -fno-lto, except when you specify the optimization level -Omax.

**Related reference**

1.4 -c on page 1-29

**Related information**

Optimizing across modules with link time optimization

Restrictions with link time optimization

--lto armlink option
1.20  -fexceptions, -fno-exceptions

Enables or disables the generation of code needed to support C++ exceptions.

Default

The default is -fexceptions for C++ sources. The default is -fno-exceptions for C sources.

Usage

Compiling with -fno-exceptions disables exceptions support and uses the variant of C++ libraries without exceptions. Use of try, catch, or throw results in an error message.

Linking objects that have been compiled with -fno-exceptions automatically selects the libraries without exceptions. You can use the linker option --no_exceptions to diagnose whether the objects being linked contain exceptions.

Note

If an exception propagates into a function that has been compiled without exceptions support, then the program terminates.

Related information

Standard C++ library implementation definition
1.21 -fomit-frame-pointer, -fno-omit-frame-pointer

-fomit-frame-pointer omits the storing of stack frame pointers during function calls.

The -fomit-frame-pointer option instructs the compiler to not store stack frame pointers if the function does not need it. You can use this option to reduce the code image size.

The -fno-omit-frame-pointer option instructs the compiler to store the stack frame pointer in a register. In AArch32, the frame pointer is stored in register R11 for A32 code or register R7 for T32 code. In AArch64, the frame pointer is stored in register X29. The register that is used as a frame pointer is not available for use as a general-purpose register. It is available as a general-purpose register if you compile with -fomit-frame-pointer.

Frame pointer limitations for stack unwinding
Frame pointers enable the compiler to insert code to remove the automatic variables from the stack when C++ exceptions are thrown. This is called stack unwinding. However, there are limitations on how the frame pointers are used:

- By default, there are no guarantees on the use of the frame pointers.
- There are no guarantees about the use of frame pointers in the C or C++ libraries.
- If you specify -fno-omit-frame-pointer, then any function which uses space on the stack creates a frame record, and changes the frame pointer to point to it. There is a short time period at the beginning and end of a function where the frame pointer points to the frame record in the caller's frame.
- If you specify -fno-omit-frame-pointer, then the frame pointer always points to the lowest address of a valid frame record. A frame record consists of two words:
  — the value of the frame pointer at function entry in the lower-addressed word.
  — the value of the link register at function entry in the higher-addressed word.
- A function that does not use any stack space does not need to create a frame record, and leaves the frame pointer pointing to the caller's frame.
- In AArch32 state, there is currently no reliable way to unwind mixed A32 and T32 code using frame pointers.
- The behavior of frame pointers in AArch32 state is not part of the ABI and therefore might change in the future. The behavior of frame pointers in AArch64 state is part of the ABI and is therefore unlikely to change.

Default
The default is -fomit-frame-pointer.
1.22  -fropi, -fno-ropi

Enables or disables the generation of Read-Only Position-Independent (ROPI) code.

**Usage**
When generating ROPI code, the compiler:
• Addresses read-only code and data PC-relative.
• Sets the Position Independent (PI) attribute on read-only output sections.

------ Note ------
• This option is independent from -frwpi, meaning that these two options can be used individually or together.
• When using -fropi, -fropi-lowering is automatically enabled.

**Default**
The default is -fno-ropi.

**Restrictions**
The following restrictions apply:
• This option is not supported in AArch64 state.
• This option cannot be used with C++ code.
• This option is not compatible with -fpic, -fpie, or -fbare-metal-pie options.

**Related reference**
1.24 -frwpi, -fno-rwpi on page 1-52
1.25 -frwpi-lowering, -fno-rwpi-lowering on page 1-53
1.23 -fropi-lowering, -fno-ropi-lowering on page 1-51
1.23  -fropi-lowering, -fno-ropi-lowering

Enables or disables runtime static initialization when generating Read-Only Position-Independent (ROPI) code.

If you compile with -fropi-lowering, then the static initialization is done at runtime. It is done by the same mechanism that is used to call the constructors of static C++ objects that must run before main(). This enables these static initializations to work with ROPI code.

Default

The default is -fno-ropi-lowering. If -fropi is used, then the default is -fropi-lowering. If -frwpi is used without -fropi, then the default is -fropi-lowering.
1.24 -frwpi, -fno-rwpi

Enables or disables the generation of Read-Write Position-Independent (RWPI) code.

Usage
When generating RWPI code, the compiler:
• Addresses the writable data using offsets from the static base register sb. This means that:
  — The base address of the RW data region can be fixed at runtime.
  — Data can have multiple instances.
  — Data can be, but does not have to be, position-independent.
• Sets the PI attribute on read/write output sections.

Note
• This option is independent from -fropi, meaning that these two options can be used individually or together.
• When using -frwpi, -frwpi-lowering and -fropi-lowering are automatically enabled.

Restrictions
The following restrictions apply:
• This option is not supported in AArch64 state.
• This option is not compatible with -fpic, -fpie, or -fbare-metal-pie options.

Default
The default is -fno-rwpi.

Related reference
1.22 -fropi, -fno-ropi on page 1-50
1.23 -fropi-lowering, -fno-ropi-lowering on page 1-51
1.25 -frwpi-lowering, -fno-rwpi-lowering on page 1-53
1.25 -frwpi-lowering, -fno-rwpi-lowering

Enables or disables runtime static initialization when generating Read-Write Position-Independent (RWPI) code.

If you compile with -frwpi-lowering, then the static initialization is done at runtime by the C++ constructor mechanism for both C and C++ code. This enables these static initializations to work with RWPI code.

Default

The default is -fno-rwpi-lowering. If -frwpi is used, then the default is -frwpi-lowering.
-fshort-enums, -fno-short-enums

Allows the compiler to set the size of an enumeration type to the smallest data type that can hold all enumerator values.

The -fshort-enums option can improve memory usage, but might reduce performance because narrow memory accesses can be less efficient than full register-width accesses.

--- Note ---
All linked objects, including libraries, must make the same choice. It is not possible to link an object file compiled with -fshort-enums, with another object file that is compiled without -fshort-enums.

--- Note ---
The -fshort-enums option is not supported for AArch64. The Procedure Call Standard for the Arm® 64-bit Architecture states that the size of enumeration types must be at least 32 bits.

Default

The default is -fno-short-enums. That is, the size of an enumeration type is at least 32 bits regardless of the size of the enumerator values.

Example

This example shows the size of four different enumeration types: 8-bit, 16-bit, 32-bit, and 64-bit integers.

```c
#include <stdio.h>

// Largest value is 8-bit integer
enum int8Enum {int8Val1 =0x01, int8Val2 =0x02, int8Val3 =0xf1 };

// Largest value is 16-bit integer
enum int16Enum {int16Val1=0x01, int16Val2=0x02, int16Val3=0xFFF1 };

// Largest value is 32-bit integer
enum int32Enum {int32Val1=0x01, int32Val2=0x02, int32Val3=0xFFFFFFFFF1 };

// Largest value is 64-bit integer
enum int64Enum {int64Val1=0x01, int64Val2=0x02, int64Val3=0xFFFFFFFFFFFFFFF1 };

int main(void)
{
    printf("size of int8Enum is %zd\n", sizeof (enum int8Enum));
    printf("size of int16Enum is %zd\n", sizeof (enum int16Enum));
    printf("size of int32Enum is %zd\n", sizeof (enum int32Enum));
    printf("size of int64Enum is %zd\n", sizeof (enum int64Enum));
}
```

When compiled without the -fshort-enums option, all enumeration types are 32 bits (4 bytes) except for int64Enum which requires 64 bits (8 bytes):

```
armclang --target=arm-arm-none-eabi -march=armv8-a enum_test.cpp
```

<table>
<thead>
<tr>
<th>Type</th>
<th>Size (Bytes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>int8Enum</td>
<td>4</td>
</tr>
<tr>
<td>int16Enum</td>
<td>4</td>
</tr>
<tr>
<td>int32Enum</td>
<td>4</td>
</tr>
<tr>
<td>int64Enum</td>
<td>8</td>
</tr>
</tbody>
</table>

When compiled with the -fshort-enums option, each enumeration type has the smallest size possible to hold the largest enumerator value:

```
armclang -fshort-enums --target=arm-arm-none-eabi -march=armv8-a enum_test.cpp
```

<table>
<thead>
<tr>
<th>Type</th>
<th>Size (Bytes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>int8Enum</td>
<td>1</td>
</tr>
<tr>
<td>int16Enum</td>
<td>2</td>
</tr>
<tr>
<td>int32Enum</td>
<td>4</td>
</tr>
<tr>
<td>int64Enum</td>
<td>8</td>
</tr>
</tbody>
</table>
——— Note ———

ISO C restricts enumerator values to the range of int. By default armclang does not issue warnings about enumerator values that are too large, but with -Wpedantic a warning is displayed.

Related information

Procedure Call Standard for the Arm 64-bit Architecture (AArch64)
1.27 -fshort-wchar, -fno-short-wchar

-fshort-wchar sets the size of wchar_t to 2 bytes. -fno-short-wchar sets the size of wchar_t to 4 bytes.

The -fshort-wchar option can improve memory usage, but might reduce performance because narrow memory accesses can be less efficient than full register-width accesses.

Note

All linked objects must use the same wchar_t size, including libraries. It is not possible to link an object file compiled with -fshort-wchar, with another object file that is compiled without -fshort-wchar.

Default

The default is -fno-short-wchar.

Example

This example shows the size of the wchar_t type:

```c
#include <stdio.h>
#include <wchar.h>

int main(void)
{
    printf("size of wchar_t is %zd\n", sizeof (wchar_t));
    return 0;
}
```

When compiled without the -fshort-wchar option, the size of wchar_t is 4 bytes:

```
armclang --target=aarch64-arm-none-eabi -mcpu=cortex-a53 wchar_test.c
size of wchar_t is 4
```

When compiled with the -fshort-wchar option, the size of wchar_t is 2 bytes:

```
armclang -fshort-wchar --target=aarch64-arm-none-eabi -mcpu=cortex-a53 wchar_test.c
size of wchar_t is 2
```
1.28 -fstrict-aliasing, -fno-strict-aliasing

Instructs the compiler to apply the strictest aliasing rules available.

Usage

-fstrict-aliasing is implicitly enabled at -O1 or higher. It is disabled at -O0, or when no optimization level is specified.

When optimizing at -O1 or higher, this option can be disabled with -fno-strict-aliasing.

Note

Specifying -fstrict-aliasing on the command-line has no effect, since it is either implicitly enabled, or automatically disabled, depending on the optimization level that is used.

Examples

In the following example, -fstrict-aliasing is enabled:

armclang --target=aarch64-arm-none-eabi -O2 -c hello.c

In the following example, -fstrict-aliasing is disabled:

armclang --target=aarch64-arm-none-eabi -O2 -fno-strict-aliasing -c hello.c

In the following example, -fstrict-aliasing is disabled:

armclang --target=aarch64-arm-none-eabi -c hello.c
1.29  

-ftrapv

Instructs the compiler to generate traps for signed arithmetic overflow on addition, subtraction, and multiplication operations.

Usage
The compiler inserts code that checks for overflow and traps the overflow with an undefined instruction. An undefined instruction handler must be provided for the overflow to get caught at run-time.

Note
When both -fwrapv and -ftrapv are used in a single command, the furthest-right option overrides the other.

For example, here -ftrapv overrides -fwrapv:

armclang --target=aarch64-arm-none-eabi -fwrapv -c -ftrapv hello.c
### 1.30 -fvectorize, -fno-vectorize

Enables or disables the generation of Advanced SIMD vector instructions directly from C or C++ code at optimization levels -01 and higher.

**Default**

The default depends on the optimization level in use.

- At optimization level -00 (the default optimization level), armclang never performs automatic vectorization. The -fvectorize and -fno-vectorize options are ignored.
- At optimization level -01, the default is -fno-vectorize. Use -fvectorize to enable automatic vectorization. When using -fvectorize with -01, vectorization might be inhibited in the absence of other optimizations which might be present at -02 or higher.
- At optimization level -02 and above, the default is -fvectorize. Use -fno-vectorize to disable automatic vectorization.

Using -fno-vectorize does not necessarily prevent the compiler from emitting Advanced SIMD instructions. The compiler or linker might still introduce Advanced SIMD instructions, such as when linking libraries that contain these instructions.

**Examples**

This example enables automatic vectorization with optimization level -01:

```
armclang --target=arm-arm-none-eabi -march=armv8-a -fvectorize -01 -c file.c
```

To prevent the compiler from emitting Advanced SIMD instructions for AArch64 targets, specify +nosimd using -march or -mcpu. For example:

```
armclang --target=aarch64-arm-none-eabi -march=armv8-a+nosimd -02 file.c -c -S -o file.s
```

To prevent the compiler from emitting Advanced SIMD instructions for AArch32 targets, set the option -mfpu to the correct value that does not include Advanced SIMD, for example fp-armv8:

```
armclang --target=aarch32-arm-none-eabi -march=armv8-a -mfpu=fp-armv8 -02 file.c -c -S -o file.s
```

**Related reference**

1.4 -c on page 1-29  
1.60 -O on page 1-99
1.31  

**-fvisibility**

Sets the default visibility of ELF symbols to the specified option.

**Syntax**

```
-fvisibility=visibility_type
```

Where `visibility_type` is one of the following:

**default**

Default visibility corresponds to external linkage.

**hidden**

The symbol is not placed into the dynamic symbol table, so no other executable or shared library can directly reference it. Indirect references are possible using function pointers.

```
extern declarations are visible, and all other symbols are hidden.
```

**protected**

The symbol is placed into the dynamic symbol table, but references within the defining module bind to the local symbol. That is, another module cannot override the symbol.

```
Note
You can override this option in code with the __attribute__((visibility("visibility_type"))) attribute.
```

**Default**

The default type is `-fvisibility=hidden`.

**Related reference**

- 3.21 __attribute__((visibility("visibility_type"))) function attribute on page 3-155
- 3.36 __attribute__((visibility("visibility_type"))) variable attribute on page 3-170
1.32 -fwrapv

Instructs the compiler to assume that signed arithmetic overflow of addition, subtraction, and multiplication, wraps using two's-complement representation.

Note

When both -fwrapv and -ftrapv are used in a single command, the furthest-right option overrides the other.

For example, here -fwrapv overrides -ftrapv:

```
armclang --target=aarch64-arm-none-eabi -ftrapv -c -fwrapv hello.c
```

-g, -gdwarf-2, -gdwarf-3, -gdwarf-4

Adds debug tables for source-level debugging.

**Syntax**

- **-g**
- **-gdwarf-version**

Where:

**version**

is the DWARF format to produce. Valid values are 2, 3, and 4.

The **-g** option is a synonym for **-gdwarf-4**.

**Usage**

The compiler produces debug information that is compatible with the specified DWARF standard.

Use a compatible debugger to load, run, and debug images. For example, Arm DS-5 Debugger is compatible with DWARF 4. Compile with the **-g** or **-gdwarf-4** options to debug with Arm DS-5 Debugger.

Legacy and third-party tools might not support DWARF 4 debug information. In this case you can specify the level of DWARF conformance required using the **-gdwarf-2** or **-gdwarf-3** options.

Because the DWARF 4 specification supports language features that are not available in earlier versions of DWARF, the **-gdwarf-2** and **-gdwarf-3** options should only be used for backwards compatibility.

**Default**

By default, armclang does not produce debug information. When using **-g**, the default level is DWARF 4.

**Examples**

If you specify multiple options, the last option specified takes precedence. For example:

- **-gdwarf-3 -gdwarf-2** produces DWARF 2 debug, because **-gdwarf-2** overrides **-gdwarf-3**.
- **-g -gdwarf-2** produces DWARF 2 debug, because **-gdwarf-2** overrides the default DWARF level implied by **-g**.
- **-gdwarf-2 -g** produces DWARF 4 debug, because **-g** (a synonym for **-gdwarf-4**) overrides **-gdwarf-2**.
1.34 -I

Adds the specified directory to the list of places that are searched to find include files.
If you specify more than one directory, the directories are searched in the same order as the -I options specifying them.

Syntax

-Idir

Where:

dir

is a directory to search for included files.

Use multiple -I options to specify multiple search directories.
1.35  **-include**

Includes the source code of the specified file at the beginning of the compilation.

**Syntax**

```
#include filename
```

Where `filename` is the name of the file whose source code is to be included.

--- **Note** ---

Any `-D`, `-I`, and `-U` options on the command line are always processed before `-include filename`.

--- **Related reference** ---

1.5 `.-D` on page 1-30  
1.34 `.-I` on page 1-63  
1.67 `.-U` on page 1-108
1.36 -L

Specifies a list of paths that the linker searches for user libraries.

**Syntax**

-L dir[,dir, ...]

Where:

dir[,dir, ...]

is a comma-separated list of directories to be searched for user libraries.

At least one directory must be specified.

When specifying multiple directories, do not include spaces between commas and directory names in the list.

armclang translates this option to --userlibpath and passes it to armlink.

See the Arm® Compiler armlink User Guide for information about the --userlibpath linker option.

——— Note ————

The -L option has no effect when used with the -c option, that is when not linking.

**Related information**

armlink User Guide
1.37 -l

Add the specified library to the list of searched libraries.

Syntax
-l name

Where name is the name of the library.

armclang translates this option to -l library and passes it to armlink.

See the Arm® Compiler toolchain Linker Reference for information about the -l library linker option.

Note
The -l option has no effect when used with the -c option, that is when not linking.

Related information
armlink User Guide
1.38  

**-M, -MM**

Produces a list of makefile dependency rules suitable for use by a make utility.

`armclang` executes only the preprocessor step of the compilation or assembly. By default, output is on the standard output stream.

If you specify multiple source files, a single dependency file is created.

- **-M** lists both system header files and user header files.
- **-MM** lists only user header files.

——— Note ———
The **-MT** option lets you override the target name in the dependency rules.

——— Note ———
To compile or assemble the source files and produce makefile dependency rules, use the **-MD** or **-MMD** option instead of the **-M** or **-MM** option respectively.

**Example**

You can redirect output to a file using standard UNIX and MS-DOS notation, the **-o** option, or the **-MF** option. For example:

```
armclang --target=arm-arm-none-eabi -march=armv8-a -M source.c > deps.mk
armclang --target=arm-arm-none-eabi -march=armv8-a -M source.c -o deps.mk
armclang --target=arm-arm-none-eabi -march=armv8-a -M source.c -MF deps.mk
```

**Related reference**

1.39 **-MD, -MMD** on page 1-68
1.40 **-MF** on page 1-69
1.43 **-MT** on page 1-72
1.59 **-o** on page 1-98
1.39 -MD, -MMD

Compiles or assembles source files and produces a list of makefile dependency rules suitable for use by a make utility.

armclang creates a makefile dependency file for each source file, using a .d suffix. Unlike -M and -MM, that cause compilation or assembly to stop after the preprocessing stage, -MD and -MMD allow for compilation or assembly to continue.

- MD lists both system header files and user header files.
- MMD lists only user header files.

Example

The following example creates makefile dependency lists test1.d and test2.d and compiles the source files to an image with the default name, a.out:

```
armclang --target=arm-arm-none-eabi -march=armv8-a -MD test1.c test2.c
```

Related reference

1.38 -M, -MM on page 1-67
1.40 -MF on page 1-69
1.43 -MT on page 1-72
1.40 -MF

Specifies a filename for the makefile dependency rules produced by the -M and -MD options.

**Syntax**

`-MF filename`

Where:

*filename*

Specifies the filename for the makefile dependency rules.

--- **Note** ---

The -MF option only has an effect when used in conjunction with one of the -M, -MM, -MD, or -MMD options.

---

The -MF option overrides the default behavior of sending dependency generation output to the standard output stream, and sends output to the specified filename instead.

`armclang -MD` sends output to a file with the same name as the source file by default, but with a .d suffix. The -MF option sends output to the specified filename instead. Only use a single source file with `armclang -MD -MF`.

**Examples**

This example sends makefile dependency rules to standard output, without compiling the source:

```
armclang --target=aarch64-arm-none-eabi -mcpu=cortex-a53 -M source.c
```

This example saves makefile dependency rules to `deps.mk`, without compiling the source:

```
armclang --target=aarch64-arm-none-eabi -mcpu=cortex-a53 -M source.c -MF deps.mk
```

This example compiles the source and saves makefile dependency rules to `source.d` (using the default file naming rules):

```
armclang --target=aarch64-arm-none-eabi -mcpu=cortex-a53 -MD source.c
```

This example compiles the source and saves makefile dependency rules to `deps.mk`:

```
armclang --target=aarch64-arm-none-eabi -mcpu=cortex-a53 -MD source.c -MF deps.mk
```

**Related reference**

1.38 -M, -MM on page 1-67
1.39 -MD, -MMD on page 1-68
1.43 -MT on page 1-72
1.41 -MG

Prints dependency lines for header files even if the header files are missing.
Warning and error messages on missing header files are suppressed, and compilation continues.

Note

The -MG option only has an effect when used with one of the following options: -M or -MM.

Example

source.c contains a reference to a missing header file header.h:

```
#include <stdio.h>
#include "header.h"
int main(void){
    puts("Hello world\n");
    return 0;
}
```

This first example is compiled without the -MG option, and results in an error:

```
armclang --target=aarch64-arm-none-eabi -mcpu=cortex-a53 -M source.c
source.c:2:10: fatal error: 'header.h' file not found
#include "header.h"
```

1 error generated.

This second example is compiled with the -MG option, and the error is suppressed:

```
armclang --target=aarch64-arm-none-eabi -mcpu=cortex-a53 -M -MG source.c
source.o: source.c \
/include/stdio.h \
header.h
```
1.42 -MP

Emits dummy dependency rules.

These rules work around make errors that are generated if you remove header files without a corresponding update to the makefile.

Note

The -MP option only has an effect when used in conjunction with the -M, -MD, -MM, or -MMD options.

Examples

This example sends dependency rules to standard output, without compiling the source.

source.c includes a header file:

```c
#include <stdio.h>

int main(void){
    puts("Hello world\n");
    return 0;
}
```

This first example is compiled without the -MP option, and results in a dependency rule for source.o:

```
armclang --target=aarch64-arm-none-eabi -mcpu=cortex-a53 -M source.c
source.o: source.c \
/include/stdio.h
```

This second example is compiled with the -MP option, and results in a dependency rule for source.o and a dummy rule for the header file:

```
armclang --target=aarch64-arm-none-eabi -mcpu=cortex-a53 -M -MP source.c
source.o: source.c \
/include/stdio.h
/include/stdio.h:
```
1.43 -MT

Changes the target of the makefile dependency rule produced by dependency generating options.

Note

The -MT option only has an effect when used in conjunction with either the -M, -MM, -MD, or -MMD options.

By default, armclang -M creates makefile dependencies rules based on the source filename:

```
armclang --target=aarch64-arm-none-eabi -mcpu=cortex-a53 -M test.c
  test.o: test.c header.h
```

The -MT option renames the target of the makefile dependency rule:

```
armclang --target=aarch64-arm-none-eabi -mcpu=cortex-a53 -M test.c -MT foo
  foo: test.c header.h
```

The compiler executes only the preprocessor step of the compilation. By default, output is on the standard output stream.

If you specify multiple source files, the -MT option renames the target of all dependency rules:

```
armclang --target=aarch64-arm-none-eabi -mcpu=cortex-a53 -M test1.c test2.c -MT foo
  foo: test1.c header.h
  foo: test2.c header.h
```

Specifying multiple -MT options creates multiple targets for each rule:

```
armclang --target=aarch64-arm-none-eabi -mcpu=cortex-a53 -M test1.c test2.c -MT foo -MT bar
  foo bar: test1.c header.h
  foo bar: test2.c header.h
```

Related reference

1.38 -M, -MM on page 1-67
1.39 -MD, -MMD on page 1-68
1.40 -MF on page 1-69
1.44 -march

Targets an architecture profile, generating generic code that runs on any processor of that architecture.

Syntax

To specify a target architecture, use:

```
-march=name
-march=name+[no]feature+...
```

(for architectures with optional extensions)

Where:

- **name**
  
  Specifies the architecture.

To view a list of all the supported architectures, use:

```
-march=list
```

The following are valid -march values:

- **armv8-a**
  
  Armv8 application architecture profile. Valid with both --target=aarch64-arm-none-eabi and --target=arm-arm-none-eabi.

- **armv8.1-a**
  
  Armv8.1 application architecture profile. Valid with both --target=aarch64-arm-none-eabi and --target=arm-arm-none-eabi.

- **armv8.2-a**
  
  Armv8.2 application architecture profile. Valid with both --target=aarch64-arm-none-eabi and --target=arm-arm-none-eabi.

- **armv8.3-a**
  
  Armv8.3 application architecture profile. Valid with both --target=aarch64-arm-none-eabi and --target=arm-arm-none-eabi.

- **armv8.4-a**
  
  Armv8.4 application architecture profile. Valid with both --target=aarch64-arm-none-eabi and --target=arm-arm-none-eabi.

- **armv8-r**
  
  Armv8 real-time architecture profile. Only valid with --target=arm-arm-none-eabi.

- **armv8-m.base**
  
  Armv8 microcontroller architecture profile without the Main Extension. Derived from the Armv6-M architecture. Only valid with --target=arm-arm-none-eabi.

- **armv8-m.main**
  
  Armv8 microcontroller architecture profile with the Main Extension. Derived from the Armv7-M architecture. Only valid with --target=arm-arm-none-eabi.

- **armv7-a**
  
  Armv7 application architecture profile. Only valid with --target=arm-arm-none-eabi.

- **armv7-r**
  
  Armv7 real-time architecture profile. Only valid with --target=arm-arm-none-eabi.

- **armv7-m**
  
  Armv7 microcontroller architecture profile. Only valid with --target=arm-arm-none-eabi.
armv7e-m
Armv7 microcontroller architecture profile with DSP extension. Only valid with --target=arm-arm-none-eabi.

armv6-m
Armv6 microcontroller architecture profile. Only valid with --target=arm-arm-none-eabi.
**feature**

Is an optional architecture feature that might be enabled or disabled by default depending on the architecture or processor.

--- **Note** ---

In general, if an architecture supports the optional feature, then this optional feature is enabled by default. To determine whether the optional feature is enabled, use `fromelf --decode_build_attributes`.

+feature enables the feature if it is disabled by default. +feature has no effect if the feature is already enabled by default.

+nofeature disables the feature if it is enabled by default. +nofeature has no effect if the feature is already disabled by default.

Use +feature or +nofeature to explicitly enable or disable an optional architecture feature.

For targets in AArch64 state, you can specify one or more of the following features if the architecture supports it:

- `aes` - Cryptographic extension. See *Cryptographic extensions on page 1-84* for more information.
- `crc` - CRC extension.
- `crypto` - Cryptographic extension. See *Cryptographic extensions on page 1-84* for more information.
- `dotprod` - Enables the SDOT and UDOT instructions. Supported in the Armv8.2 and later Application profile architectures, and is optional in Armv8.2 and Armv8.3.
- `fp` - Floating-point extension. See *Floating-point extensions on page 1-84* for more information.
- `fp16` - Armv8.2-A half-precision floating-point extension. See *Floating-point extensions on page 1-84* for more information.
- `profile` - Armv8.2-A statistical profiling extension.
- `ras` - Reliability, Availability, and Serviceability extension.
- `rcpc` - Release Consistent Processor Consistent extension. This extension applies to Armv8.2 and later Application profile architectures.
- `sha2` - Cryptographic extension. See *Cryptographic extensions on page 1-84* for more information.
- `sha3` - Cryptographic extension. See *Cryptographic extensions on page 1-84* for more information.
- `simd` - Advanced SIMD extension.
- `sm4` - Cryptographic extension. See *Cryptographic extensions on page 1-84* for more information.

For targets in AArch32 state, you can specify one or more of the following features if the architecture supports it:

- `crc` - CRC extension for architectures Armv8 and above.
- `dotprod` - Enables the VSDOT and VUDOT instructions. Supported in Armv8.2 and later Application profile architectures, and is optional in Armv8.2 and Armv8.3.
- `dsp` - DSP extension for the Armv8-M.mainline architecture.
- `fp16` - Armv8.2-A half-precision floating-point extension. See *Floating-point extensions on page 1-84* for more information.
- `ras` - Reliability, Availability, and Serviceability extension.
Note

For targets in AArch32 state, you can use -mfp to specify the support for floating-point, Advanced SIMD, and cryptographic extensions.

Note

There are no software floating-point libraries for targets in AArch64 state. At link time armlink links against AArch64 library code that can use floating-point and SIMD instructions and registers. This still applies if you compile the source with -march=<name>+noff+nosimd to prevent the compiler from using floating-point and SIMD instructions and registers.

To prevent the use of any floating-point instruction or register, either re-implement the library functions or create your own library that does not use floating-point instructions or registers.

Default

For targets in AArch64 state (--target=aarch64-arm-none-eabi), unless you target a particular processor using -mcpu, the compiler defaults to -march=armv8-a, generating generic code for Armv8-A in AArch64 state.

For targets in AArch32 state (--target=arm-arm-none-eabi), there is no default. You must specify either -march (to target an architecture) or -mcpu (to target a processor).

Related reference
1.48 -mcpu on page 1-81
1.45 -marm on page 1-77
1.56 -mthumb on page 1-95
1.66 --target on page 1-107
6.4 Half-precision floating-point data types on page 6-206
6.6 Half-precision floating-point intrinsics on page 6-209
1.45  -marm

Requests that the compiler targets the A32 instruction set.

Most Armv7-A (and earlier) processors support two instruction sets. These are the A32 instruction set (formerly ARM), and the T32 instruction set (formerly Thumb). Armv8-A processors in AArch32 state continue to support these two instruction sets, but with additional instructions. The Armv8-A architecture additionally introduces the A64 instruction set, used in AArch64 state. Different architectures support different instruction sets:

- Armv8-A processors in AArch64 state execute A64 instructions.
- Armv8-A processors in AArch32 state, in addition to Armv7 and earlier A- and R-profile processors execute A32 and T32 instructions.
- M-profile processors execute T32 instructions.

Note

This option is only valid for targets that support the A32 instruction set. For example, the -marm option is not valid for targets in AArch64 state. The compiler ignores the -marm option and generates a warning when compiling for a target in AArch64 state.

Default

The default for all targets that support A32 instructions is -marm.

Related reference

1.56 -mthumb on page 1-95
1.66 --target on page 1-107
1.48 -mcpu on page 1-81

Related information

Specifying a target architecture, processor, and instruction set
1.46 -mbig-endian

Generates code suitable for an Arm processor using byte-invariant big-endian (BE-8) data.

Default

The default is -mlittle-endian.

Related reference

1.53 -mlittle-endian on page 1-91
1.47 **-mcmse**

Enables the generation of code for the Secure state of the Armv8-M Security Extension. This option is required when creating a Secure image.

--- Note ---

The Armv8-M Security Extension is not supported when building Read-Only Position-Independent (ROPI) and Read-Write Position-Independent (RWPI) images.

--- Usage ---

Specifying `-mcmse` targets the Secure state of the Armv8-M Security Extension. When compiling with `-mcmse`, the following are available:

- The Test Target, `TT`, instruction.
- `TT` instruction intrinsics.
- Non-secure function pointer intrinsics.
- `__attribute__((cmse_nonsecure_call))` and `__attribute__((cmse_nonsecure_entry))` function attributes.

--- Note ---

- The value of the `__ARM_FEATURE_CMSE` predefined macro indicates what Armv8-M Security Extension features are supported.
- Compile Secure code with the maximum capabilities for the target. For example, if you compile with no FPU then the Secure functions do not clear floating-point registers when returning from functions declared as `__attribute__((cmse_nonsecure_entry))`. Therefore, the functions could potentially leak sensitive data.
- Structs with undefined bits caused by padding and half-precision floating-point members are currently unsupported as arguments and return values for Secure functions. Using such structs might leak sensitive information. Structs that are large enough to be passed by reference are also unsupported and produce an error.
- The following cases are not supported when compiling with `-mcmse` and produce an error:
  - Variadic entry functions.
  - Entry functions with arguments that do not fit in registers, because there are either many arguments or the arguments have large values.
  - Non-secure function calls with arguments that do not fit in registers, because there are either many arguments or the arguments have large values.

--- Example ---

This example shows how to create a Secure image using an input import library, `oldimportlib.o`, and a scatter file, `secure.scat`:

```
armclang --target=arm-arm-none-eabi --march=armv8m.main --mcmse secure.c -o secure.o
armlink secure.o -o secure.axf --import-cmse-lib-out importlib.o --import-cmse-lib-in
oldimportlib.o --scatter secure.scat
```

`armlink` also generates the Secure code import library, `importlib.o` that is required for a Non-secure image to call the Secure image.

**Related reference**

1.44 `-march` on page 1-73
1.51 `-mfpu` on page 1-88
1.66 `--target` on page 1-107
3.3 `__attribute__((cmse_nonsecure_call))` function attribute on page 3-136
3.4 `__attribute__((cmse_nonsecure_entry))` function attribute on page 3-137
6.2 Predefined macros on page 6-200
6.8 TT instruction intrinsics on page 6-211
6.9 Non-secure function pointer intrinsics on page 6-214

Related information
Building Secure and Non-secure Images Using the Armv8-M Security Extension
TT, TTT, TTA, TTAT instruction
--fpu linker option
--import_cmse_lib_in linker option
--import_cmse_lib_out linker option
--scatter linker option
1.48  **-mcpu**

Enables code generation for a specific Arm processor.

**Syntax**

To specify a target processor, use:

- `-mcpu=name`

- `-mcpu=name[+[no]feature+...]` (for architectures with optional extensions)

Where:

`name`

Specifies the processor.

To view a list of all supported processors for your target, use:

- `-mcpu=list`
feature

Is an optional architecture feature that might be enabled or disabled by default depending on the architecture or processor.

Note

In general, if an architecture supports the optional feature, then this optional feature is enabled by default. To determine whether the optional feature is enabled, use `fromelf --decode_build_attributes`.

+feature enables the feature if it is disabled by default. +feature has no effect if the feature is already enabled by default.

+nofeature disables the feature if it is enabled by default. +nofeature has no effect if the feature is already disabled by default.

Use +feature or +nofeature to explicitly enable or disable an optional architecture feature.

For targets in AArch64 state, you can specify one or more of the following features if the architecture supports it:

- aes - Cryptographic extension. See Cryptographic extensions on page 1-84 for more information.
- crc - CRC extension.
- crypto - Cryptographic extension. See Cryptographic extensions on page 1-84 for more information.
- dotprod - Enables the SDOT and UDOT instructions. Supported in the Armv8.2 and later Application profile architectures, and is optional in Armv8.2 and Armv8.3.
- fp - Floating-point extension. See Floating-point extensions on page 1-84 for more information.
- fp16 - Armv8.2-A half-precision floating-point extension. See Floating-point extensions on page 1-84 for more information.
- profile - Armv8.2-A statistical profiling extension.
- ras - Reliability, Availability, and Serviceability extension.
- rcpc - Release Consistent Processor Consistent extension. This extension applies to Armv8.2 and later Application profile architectures.
- sha2 - Cryptographic extension. See Cryptographic extensions on page 1-84 for more information.
- sha3 - Cryptographic extension. See Cryptographic extensions on page 1-84 for more information.
- simd - Advanced SIMD extension.
- sm4 - Cryptographic extension. See Cryptographic extensions on page 1-84 for more information.

For targets in AArch32 state, you can specify one or more of the following features if the architecture supports it:

- crc - CRC extension for architectures Armv8 and above.
- dotprod - Enables the VSDOT and VUDOT instructions. Supported in Armv8.2 and later Application profile architectures, and is optional in Armv8.2 and Armv8.3.
- dsp - DSP extension for the Armv8-M.mainline architecture.
- fp16 - Armv8.2-A half-precision floating-point extension. See Floating-point extensions on page 1-84 for more information.
- ras - Reliability, Availability, and Serviceability extension.
For targets in AArch32 state, you can use -mfpu to specify the support for floating-point, Advanced SIMD, and cryptographic extensions.

To write code that generates instructions for these extensions, use the intrinsics described in the Arm® C Language Extensions.

Usage

You can use -mcpu option to enable and disable specific architecture features.

To disable a feature, prefix with no, for example cortex-a57+nocrypto.

To enable or disable multiple features, chain multiple feature modifiers. For example, to enable CRC instructions and disable all other extensions:

```bash
armclang --target=aarch64-arm-none-eabi -mcpu=cortex-a57+nocrypto+nofp+nosimd+crc
```

If you specify conflicting feature modifiers with -mcpu, the rightmost feature is used. For example, the following command enables the floating-point extension:

```bash
armclang --target=aarch64-arm-none-eabi -mcpu=cortex-a57+nofp+fp
```

You can prevent the use of floating-point instructions or floating-point registers for targets in AArch64 state with the -mcpu=name+nofp+nosimd option. Subsequent use of floating-point data types in this mode is unsupported.

There are no software floating-point libraries for targets in AArch64 state. When linking for targets in AArch64 state, armlink uses AArch64 libraries that contain floating-point and Advanced SIMD instructions and registers. This applies even if you compile the source with -mcpu=<name>+nofp+nosimd to prevent the compiler from using floating-point and Advanced SIMD instructions and registers. Therefore, there is no guarantee that the linked image for targets in AArch64 state is entirely free of floating-point and Advanced SIMD instructions and registers.

You can prevent the use of floating-point and Advanced SIMD instructions and registers in images that are linked for targets in AArch64 state. To do this, re-implement the library functions or create your own library that does not use floating-point and Advanced SIMD instructions and registers.

Default

For targets in AArch64 state (--target=aarch64-arm-none-eabi), the compiler generates generic code for the Armv8-A architecture in AArch64 state by default.

For targets in AArch32 state (--target=arm-arm-none-eabi), there is no default. You must specify either -march (to target an architecture) or -mcpu (to target a processor).

To see the default floating-point configuration for your processor:

1. Compile with -mcpu=name -S to generate the assembler file.
2. Open the assembler file and check that the value for the .fpu directive corresponds to one of the -mfpu options. No .fpu directive implies -mfpu=none.
**Cryptographic extensions**

The following table shows which algorithms the cryptographic features include for AArch64 state in the different versions of the Armv8-A architecture:

<table>
<thead>
<tr>
<th>Feature</th>
<th>Armv8.0-A</th>
<th>Armv8.1-A</th>
<th>Armv8.2-A</th>
<th>Armv8.3-A</th>
<th>Armv8.4-A</th>
</tr>
</thead>
<tbody>
<tr>
<td>+crypto</td>
<td>SHA1, SHA256, AES</td>
<td>SHA1, SHA256, AES</td>
<td>SHA1, SHA256, AES</td>
<td>SHA1, SHA256, AES</td>
<td>SHA1, SHA256, AES</td>
</tr>
<tr>
<td>+aes</td>
<td>AES</td>
<td>AES</td>
<td>AES</td>
<td>AES</td>
<td>AES</td>
</tr>
<tr>
<td>+sha2</td>
<td>SHA1, SHA256</td>
<td>SHA1, SHA256</td>
<td>SHA1, SHA256</td>
<td>SHA1, SHA256</td>
<td>SHA1, SHA256</td>
</tr>
<tr>
<td>+sha3</td>
<td>-</td>
<td>-</td>
<td>SHA1, SHA256, SHA512, SHA3</td>
<td>SHA1, SHA256, SHA512, SHA3</td>
<td>SHA1, SHA256, SHA512, SHA3</td>
</tr>
<tr>
<td>+sm4</td>
<td>-</td>
<td>-</td>
<td>SM3, SM4</td>
<td>SM3, SM4</td>
<td>SM3, SM4</td>
</tr>
</tbody>
</table>

---

**Note**

- SHA512, SHA3, SM3, and SM4 are only available in AArch64 state in Armv8.4-A.
- Armv8.0-A refers to the generic Armv8-A architecture without any incremental architecture extensions. On the armclang command-line, use `-march=armv8-a` to compile for Armv8.0-A.

For AArch32 state in Armv8-A and Armv8-R, if you specify an `-mfpu` option that includes the cryptographic extension, then the cryptographic extension supports the AES, SHA1, and SHA256 algorithms.

**Floating-point extensions**

The following table shows the floating-point instructions that are available when you use the floating-point features:

<table>
<thead>
<tr>
<th>Feature</th>
<th>Armv8.0-A</th>
<th>Armv8.1-A</th>
<th>Armv8.2-A</th>
<th>Armv8.3-A</th>
<th>Armv8.4-A</th>
</tr>
</thead>
<tbody>
<tr>
<td>+fp</td>
<td>FP</td>
<td>FP</td>
<td>FP</td>
<td>FP</td>
<td>FP</td>
</tr>
<tr>
<td>+fp16</td>
<td>-</td>
<td>-</td>
<td>FP, FP16</td>
<td>FP, FP16</td>
<td>FP, FP16</td>
</tr>
</tbody>
</table>

FP refers to the single-precision and double-precision arithmetic operations.

FP16 refers to the Armv8.2-A half-precision floating-point arithmetic operations.

---

**Note**

Armv8.0-A refers to the generic Armv8-A architecture without any incremental architecture extensions. On the armclang command-line, use `-march=armv8-a` to compile for Armv8.0-A.

**Examples**

To list the processors that target the AArch64 state:

```
armclang --target=aarch64-arm-none-eabi -mcpu=list
```

To target the AArch64 state of a Cortex®-A57 processor:

```
armclang --target=aarch64-arm-none-eabi -mcpu=cortex-a57 test.c
```
To target the AArch32 state of a Cortex-A53 processor, generating A32 instructions:

```
armclang --target=arm-arm-none-eabi -mcpu=cortex-a53 -marm test.c
```

To target the AArch32 state of a Cortex-A53 processor, generating T32 instructions:

```
armclang --target=arm-arm-none-eabi -mcpu=cortex-a53 -mthumb test.c
```

**Related reference**

1.45 -marm on page 1-77  
1.56 -mthumb on page 1-95  
1.66 --target on page 1-107  
1.51 -mfpu on page 1-88  
6.4 Half-precision floating-point data types on page 6-206  
6.6 Half-precision floating-point intrinsics on page 6-209

**Related information**

Specifying a target architecture, processor, and instruction set  
Preventing the use of floating-point instructions and registers
1.49 -mexecute-only

Generates execute-only code, and prevents the compiler from generating any data accesses to code sections.

To keep code and data in separate sections, the compiler disables literal pools and branch tables when using the -mexecute-only option.

Restrictions

Execute-only code must be T32 code.

Execute-only code is only supported for:

- Processors that support the Armv8-M architecture, with or without the Main Extension.
- Processors that support the Armv7-M architecture, such as the Cortex-M3.

If your application calls library functions, the library objects included in the image are not execute-only compliant. You must ensure these objects are not assigned to an execute-only memory region.

--- Note ---

Arm does not provide libraries that are built without literal pools. The libraries still use literal pools, even when you use the -mexecute-only option.

--- Note ---

Link Time Optimization does not honor the armclang -mexecute-only option. If you use the armclang -flto or -Omax options, then the compiler cannot generate execute-only code and produces a warning.

Related information

Building applications for execute-only memory
1.50 **-mfloat-abi**

Specifies whether to use hardware instructions or software library functions for floating-point operations, and which registers are used to pass floating-point parameters and return values.

**Syntax**

-mfloat-abi=value

Where value is one of:

- **soft**
  
  Software library functions for floating-point operations and software floating-point linkage.

- **softfp**
  
  Hardware floating-point instructions and software floating-point linkage.

- **hard**
  
  Hardware floating-point instructions and hardware floating-point linkage.

--- **Note** ---

The -mfloat-abi option is not valid with AArch64 targets. AArch64 targets use hardware floating-point instructions and hardware floating-point linkage. However, you can prevent the use of floating-point instructions or floating-point registers for AArch64 targets with the -mcpu=name+nofp+nosimd option. Subsequent use of floating-point data types in this mode is unsupported.

--- **Note** ---

In AArch32 state, if you specify -mfloat-abi=soft, then specifying the -mfpu option does not have an effect.

---

**Default**

The default for --target=arm-arm-none-eabi is softfp.

**Related reference**

1.51 -mfpu on page 1-88
1.51 -mfpu

Specifies the target FPU architecture, that is the floating-point hardware available on the target.

**Syntax**

To view a list of all the supported FPU architectures, use:

```
-mfpu=list
```

---

**Note**

-mfpu=list is rejected when targeting AArch64 state.

---

Alternatively, to specify a target FPU architecture, use:

```
-mfpu=name
```

Where `name` is one of the following:

- **none**
  
  Prevents the compiler from using hardware-based floating-point functions. If the compiler encounters floating-point types in the source code, it will use software-based floating-point library functions. This is similar to the `-mfloat-abi=soft` option.

- **vfpv3**
  
  Enable the Armv7 VFPv3 floating-point extension. Disable the Advanced SIMD extension.

- **vfpv3-d16**
  
  Enable the Armv7 VFPv3-D16 floating-point extension. Disable the Advanced SIMD extension.

- **vfpv3-fp16**
  
  Enable the Armv7 VFPv3 floating-point extension, including the optional half-precision extensions. Disable the Advanced SIMD extension.

- **vfpv3-d16-fp16**
  
  Enable the Armv7 VFPv3-D16 floating-point extension, including the optional half-precision extensions. Disable the Advanced SIMD extension.

- **vfpv3xd**
  
  Enable the Armv7 VFPv3XD floating-point extension. Disable the Advanced SIMD extension.

- **vfpv3xd-fp16**
  
  Enable the Armv7 VFPv3XD floating-point extension, including the optional half-precision extensions. Disable the Advanced SIMD extension.

- **neon**
  
  Enable the Armv7 VFPv3 floating-point extension and the Advanced SIMD extension.

- **neon-fp16**
  
  Enable the Armv7 VFPv3 floating-point extension, including the optional half-precision extensions, and the Advanced SIMD extension.

- **vfpv4**
  
  Enable the Armv7 VFPv4 floating-point extension. Disable the Advanced SIMD extension.

- **vfpv4-d16**
  
  Enable the Armv7 VFPv4-D16 floating-point extension. Disable the Advanced SIMD extension.

- **neon-vfpv4**
  
  Enable the Armv7 VFPv4 floating-point extension and the Advanced SIMD extension.

- **fpv4-sp-d16**
  
  Enable the Armv7 FPv4-SP-D16 floating-point extension.
fpv5-d16
Enable the Armv7 FPv5-D16 floating-point extension.

fpv5-sp-d16
Enable the Armv7 FPv5-SP-D16 floating-point extension.

fp-armv8
Enable the Armv8 floating-point extension. Disable the cryptographic extension and the Advanced SIMD extension.

neon-fp-armv8
Enable the Armv8 floating-point extension and the Advanced SIMD extensions. Disable the cryptographic extension.

crypto-neon-fp-armv8
Enable the Armv8 floating-point extension, the cryptographic extension, and the Advanced SIMD extension.

The **-mfpu** option overrides the default FPU option implied by the target architecture.

---
**Note**
---

- The **-mfpu** option is ignored with AArch64 targets, for example aarch64-arm-none-eabi. Use the **-mcpu** option to override the default FPU for aarch64-arm-none-eabi targets. For example, to prevent the use of floating-point instructions or floating-point registers for the aarch64-arm-none-eabi target use the **-mcpu=\text{name}+nofp+nosimd** option. Subsequent use of floating-point data types in this mode is unsupported.
- In Armv7, the Advanced SIMD extension was called the Arm NEON™ Advanced SIMD extension.

---
**Note**
---

There are no software floating-point libraries for targets in AArch64 state. When linking for targets in AArch64 state, armblink uses AArch64 libraries that contain floating-point and Advanced SIMD instructions and registers. This applies even if you compile the source with **-mcpu=\text{name}+nofp+nosimd** to prevent the compiler from using floating-point and Advanced SIMD instructions and registers. Therefore, there is no guarantee that the linked image for targets in AArch64 state is entirely free of floating-point and Advanced SIMD instructions and registers.

You can prevent the use of floating-point and Advanced SIMD instructions and registers in images that are linked for targets in AArch64 state. To do this, re-implement the library functions or create your own library that does not use floating-point and Advanced SIMD instructions and registers.

---
**Note**
---

In AArch32 state, if you specify **-mfloat-abi=soft**, then specifying the **-mfpu** option does not have an effect.

---
**Default**
---

The default FPU option depends on the target processor.

**Related reference**

 1.48 **-mcpu** on page 1-81
 1.50 **-mfloat-abi** on page 1-87
 1.66 **--target** on page 1-107

**Related information**

Specifying a target architecture, processor, and instruction set
Preventing the use of floating-point instructions and registers
1.52  -mimplicit-it

Specifies the behavior of the integrated assembler if there are conditional instructions outside IT blocks.

- mimplicit-it=name

Where name is one of the following:

never

In A32 code, the integrated assembler gives a warning when there is a conditional instruction without an enclosing IT block. In T32 code, the integrated assembler gives an error, when there is a conditional instruction without an enclosing IT block.

always

In A32 code, the integrated assembler accepts all conditional instructions without giving an error or warning. In T32 code, the integrated assembler outputs an implicit IT block when there is a conditional instruction without an enclosing IT block. The integrated assembler does not give an error or warning about this.

arm

This is the default. In A32 code, the integrated assembler accepts all conditional instructions without giving an error or warning. In T32 code, the integrated assembler gives an error, when there is a conditional instruction without an enclosing IT block.

thumb

In A32 code, the integrated assembler gives a warning when there is a conditional instruction without an enclosing IT block. In T32 code, the integrated assembler outputs an implicit IT block when there is a conditional instruction without an enclosing IT block. The integrated assembler does not give an error or warning about this in T32 code.

——— Note ————

This option has no effect for targets in AArch64 state because the A64 instruction set does not include the IT instruction. The integrated assembler gives a warning if you use the -mimplicit-it option with A64 code.

——— Default ————

The default is -mimplicit-it=arm.

Related information

IT
1.53  -mlittle-endian

Generates code suitable for an Arm processor using little-endian data.

Default

The default is -mlittle-endian.

Related reference

1.46 -mbig-endian on page 1-78
1.54 -mno-neg-immediates

Disables the substitution of invalid instructions with valid equivalent instructions that use the logical inverse or negative of the specified immediate value.

Syntax

-mno-neg-immediates

Usage

If an instruction does not have an encoding for the specified value of the immediate operand, but the logical inverse or negative of the immediate operand is available, then armclang produces a valid equivalent instruction and inverts or negates the specified immediate value. This applies to both assembly language source files and to inline assembly code in C and C++ language source files.

For example, armclang substitutes the instruction `sub r0, r0, #0xFFFFFF01` with the equivalent instruction `add r0, r0, #0xFFF`. You can disable this substitution using the option `-mno-neg-immediates`. In this case, armclang generates the error `instruction requires: NegativeImmediates`, if it encounters an invalid instruction that can be substituted using the logical inverse or negative of the immediate value.

When you do not use the option `-mno-neg-immediates`, armclang is able to substitute instructions but does not produce a diagnostic message when a substitution has occurred. When you are comparing disassembly listings with source code, be aware that some instructions might have been substituted.

Default

By default, armclang substitutes invalid instructions with an alternative instruction if the substitution is a valid equivalent instruction that produces the same result by using the logical inverse or negative of the specified immediate value.

Example

Copy the following code to a file called `neg.s`.

```assembly
.arm
sub r0, r0, #0xFFFFFF01
.thumb
subw r0, r1, #0xFFFFFF01
```

Assemble the file `neg.s` without the `-mno-neg-immediates` option to produce the output `neg.o`.

```
armclang --target=arm-arm-none-eabi -march=armv7-a -c neg.s -o neg.o
```

Use `fromelf` to see the disassembly from `neg.o`.

```
fromelf --cpu=7-A --text -c neg.o
```

Note that the disassembly from `neg.o` contains substituted instructions `ADD` and `ADDW`:

```
** Section #2 '.text' (SHT_PROGBITS) [SHF_ALLOC + SHF_EXEINSTR]
Size : 8 bytes (alignment 4)
Address: 0x00000000

$a.0
0x00000000: e28000ff .... ADD r0,r0,#0xff
$t.1
0x00000004: f20100ff .... ADDW r0,r1,#0xff
```

Assemble the file `neg.s` with the `-mno-neg-immediates` option to produce the output `neg.o`.

```
armclang --target=arm-arm-none-eabi -march=armv7-a -c -mno-neg-immediates neg.s -o neg.o
```
Note that armclang generates the error `instruction requires: NegativeImmediates` when assembling this example with the `-mno-neg-immediates` option.

```
  neg.s:2:2: error: instruction requires: NegativeImmediates
    sub r0,#0xFFFFFFFF01
   ^
  neg.s:4:2: error: instruction requires: NegativeImmediates
    subw r0,r1,#0xFFFFFFFF01
   ^
```
**1.55 -munaligned-access, -mno-unaligned-access**

Enables or disables unaligned accesses to data on Arm processors.

The compiler defines the `__ARM_FEATURE_UNALIGNED` macro when `-munaligned-access` is enabled.

The libraries include special versions of certain library functions designed to exploit unaligned accesses. When unaligned access support is enabled, using `-munaligned-access`, the compilation tools use these library functions to take advantage of unaligned accesses. When unaligned access support is disabled, using `-mno-unaligned-access`, these special versions are not used.

**Default**

`-munaligned-access` is the default for architectures that support unaligned accesses to data. This applies to all architectures supported by Arm Compiler 6, except Armv6-M, and Armv8-M without the Main Extension.

**Usage**

`-munaligned-access`

Use this option on processors that support unaligned accesses to data, to speed up accesses to packed structures.

--- **Note** ---

Compiling with this option generates an error for the following architectures:

- Armv6-M.
- Armv8-M without the Main Extension.

---

`-mno-unaligned-access`

If unaligned access is disabled, any unaligned data that is wider than 8-bit is accessed one byte at a time. For example, fields wider than 8-bit, in packed data structures, are always accessed one byte at a time even if they are aligned.

**Related reference**

6.2 Predefined macros on page 6-200

**Related information**

*Arm C Language Extensions 2.0*
1.56  -mthumb

Requests that the compiler targets the T32 instruction set.

Most Armv7-A (and earlier) processors support two instruction sets. These are the A32 instruction set (formerly ARM), and the T32 instruction set (formerly Thumb). Armv8-A processors in AArch32 state continue to support these two instruction sets, but with additional instructions. The Armv8-A architecture additionally introduces the A64 instruction set, used in AArch64 state.

Different architectures support different instruction sets:

- Armv8-A processors in AArch64 state execute A64 instructions.
- Armv8-A processors in AArch32 state, in addition to Armv7 and earlier A- and R- profile processors execute A32 and T32 instructions.
- M-profile processors execute T32 instructions.

Note

- The -mthumb option is not valid for targets in AArch64 state, for example --target=aarch64-arm-none-eabi. The compiler ignores the -mthumb option and generates a warning when compiling for a target in AArch64 state.
- The -mthumb option is recognized when using armclang as a compiler, but not when using it as an assembler. To request armclang to assemble using the T32 instruction set for your assembly source files, you must use the .thumb or .code 16 directive in the assembly files.

Default

The default for all targets that support A32 instructions is -marm.

Example

armclang -c --target=arm-arm-none-eabi -march=armv8-a -mthumb test.c

Related reference

1.45 -marm on page 1-77
1.66 --target on page 1-107
1.48 -mcpu on page 1-81

Related information

Specifying a target architecture, processor, and instruction set
Assembling armasm and GNU syntax assembly code
1.57  -nostdlib

Tells the compiler to not use the Arm standard C and C++ libraries.

If you use the -nostdlib option, armclang does not collude with the Arm standard library and only emits calls to functions that the C Standard or the AEABI defines. The output from armclang works with any ISO C library that is compliant with AEABI.

The -nostdlib armclang option, passes the --no_scanlib linker option to armlink. Therefore you must specify the location of the libraries you want to use as input objects to armlink, or with the --userlibpath armlink option.

———  Note  ———

If you want to use your own libraries instead of the Arm standard libraries or if you want to re-implement the standard library functions, then you must use the -nostdlib armclang option. Your libraries must be compliant with the ISO C library and with the AEABI specification.

———  Default  ———

-nostdlib is disabled by default.

Example

```c
#include "math.h"

double foo(double d)
{
    return sqrt(d + 1.0);
}

int main(int argc, char *argv[])
{
    return foo(argc);
}
```

Compiling this code with -nostdlib generates a call to sqrt, which is AEABI compliant.

```
armclang --target=arm-arm-none-eabi -mcpu=Cortex-A9 -O0 -S -o- file.c -mfloat-abi=hard -nostdlib
```

Compiling this code without -nostdlib generates a call to __hardfp_sqrt (from the Arm standard library), which the C Standard and the AEABI do not define.

```
armclang --target=arm-arm-none-eabi -mcpu=Cortex-A9 -O0 -S -o- file.c -mfloat-abi=hard
```

Related reference

1.58 -nostdlibinc on page 1-97

Related information

Run-time ABI for the Arm Architecture

C Library ABI for the Arm Architecture
1.58 -nostdlibinc

Tells the compiler to exclude the Arm standard C and C++ library header files.

If you want to disable the use of the Arm standard library, then use the -nostdlibinc and -nostdlib armclang options.

Default

-nostdlibinc is disabled by default.

Example

```c
#include "math.h"

double foo(double d)
{
    return sqrt(d + 1.0);
}

int main(int argc, char *argv[])
{
    return foo(argc);
}
```

Compiling this code without -nostdlibinc generates a call to __hardfp_sqrt, from the Arm standard library.

```bash
armclang --target=arm-arm-none-eabi -mcpu=Cortex-A9 -O0 -S -o- file.c -mfloat-abi=hard
```

Compiling this code with -nostdlibinc and -nostdlib generates an error because the compiler cannot include the standard library header file math.h.

```bash
armclang --target=arm-arm-none-eabi -mcpu=Cortex-A9 -O0 -S -o- file.c -mfloat-abi=hard -nostdlibinc -nostdlib
```

Related reference

1.57 -nostdlib on page 1-96
-o

Specifies the name of the output file.

The option `-o filename` specifies the name of the output file produced by the compiler.

The option `-o-` redirects output to the standard output stream when used with the `-c` or `-S` options.

**Default**

If you do not specify a `-o` option, the compiler names the output file according to the conventions described by the following table.

**Table 1-6 Compiling without the -o option**

<table>
<thead>
<tr>
<th>Compiler option</th>
<th>Action</th>
<th>Usage notes</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>-c</code></td>
<td>Produces an object file whose name defaults to <code>filename.o</code> in the current directory. <code>filename</code> is the name of the source file stripped of any leading directory names.</td>
<td>-</td>
</tr>
<tr>
<td><code>-S</code></td>
<td>Produces an assembly file whose name defaults to <code>filename.s</code> in the current directory. <code>filename</code> is the name of the source file stripped of any leading directory names.</td>
<td>-</td>
</tr>
<tr>
<td><code>-E</code></td>
<td>Writes output from the preprocessor to the standard output stream</td>
<td>-</td>
</tr>
<tr>
<td>(No option)</td>
<td>Produces temporary object files, then automatically calls the linker to produce an executable image with the default name of <code>a.out</code></td>
<td>None of <code>-o</code>, <code>-c</code>, <code>-E</code> or <code>-S</code> is specified on the command line</td>
</tr>
</tbody>
</table>
1.60 -O

Specifies the level of optimization to use when compiling source files.

**Syntax**

-`O`*level*

Where *level* is one of the following:

0

Minimum optimization for the performance of the compiled binary. Turns off most optimizations. When debugging is enabled, this option generates code that directly corresponds to the source code. Therefore, this optimization might result in a significantly larger image. This optimization is the default optimization level.

1

Restricted optimization. When debugging is enabled, this option selects a good compromise between image size, performance, and quality of debug view.

2

High optimization. When debugging is enabled, the debug view might be less satisfactory because the mapping of object code to source code is not always clear. The compiler might perform optimizations that the debug information cannot describe.

3

Very high optimization. When debugging is enabled, this option typically gives a poor debug view. Arm recommends debugging at lower optimization levels.

**fast**

Enables all the optimizations from level 3 including those optimizations that are performed with the `-ffp-mode=fast` armclang option. This level also performs other aggressive optimizations that might violate strict compliance with language standards.
Max

Maximum optimization. Specifically targets performance optimization. Enables all the optimizations from level fast, together with other aggressive optimizations.

--------- Caution ---------

This option is not guaranteed to be fully standards-compliant for all code cases.

--------- Caution ---------

-Omax automatically enables the armclang -flto option and the generated object files are not suitable for creating static libraries. When -flto is enabled, you cannot build ROPI or RWPI images.

--------- Note ---------

When using -Omax:

• Code-size, build-time, and the debug view can each be adversely affected.
• Arm cannot guarantee that the best performance optimization is achieved in all code cases.
• It is not possible to output meaningful disassembly when the -flto option is enabled. The reason is because the -flto option is turned on by default at -Omax, and that option generates files containing bitcode.
• If you are trying to compile at -Omax and have separate compile and link steps, then also include -Omax on your armlink command line.

--------- Note ---------

Link Time Optimization does not honor the armclang -mexecute-only option. If you use the armclang -flto or -Omax options, then the compiler cannot generate execute-only code and produces a warning.

s

Performs optimizations to reduce code size, balancing code size against code speed.

z

Performs optimizations to minimize image size.

Default

If you do not specify -Olevel, the compiler assumes -O0. For the best debug view, Arm recommends -O1 rather than -O0 for the best trade-off between image size, performance, and debug.

Related reference

1.19 -flto, -fno-lto on page 1-47
1.22 -fropi, -fno-ropi on page 1-50
1.24 -frwpi, -fno-rwpi on page 1-52

Related information

Restrictions with link time optimization
1.61 -pedantic

Generate warnings if code violates strict ISO C and ISO C++.

If you use the -pedantic option, the compiler generates warnings if your code uses any language feature that conflicts with strict ISO C or ISO C++.

Default

-pedantic is disabled by default.

Example

```c
void foo(void)
{
    long long i; /* okay in nonstrict C90 */
}
```

Compiling this code with -pedantic generates a warning.

```
armclang --target=arm-arm-none-eabi -march=armv8-a file.c -c -std=c90 -pedantic
```

Note

The -pedantic option is stricter than the -Wpedantic option.
1.62 -pedantic-errors

Generate errors if code violates strict ISO C and ISO C++.

If you use the -pedantic-errors option, the compiler does not use any language feature that conflicts with strict ISO C or ISO C++. The compiler generates an error if your code violates strict ISO language standard.

Default

-pedantic-errors is disabled by default.

Example

```c
void foo(void)
{
  long long i; /* okay in nonstrict C90 */
}
```

Compiling this code with -pedantic-errors generates an error:

```
armclang --target=arm-arm-none-eabi -march=armv8-a file.c -c -std=c90 -pedantic-errors
```
1.63  -S

Outputs the disassembly of the machine code generated by the compiler.

Object modules are not generated. The name of the assembly output file defaults to `filename.s` in the current directory, where `filename` is the name of the source file stripped of any leading directory names. The default filename can be overridden with the `-o` option.

Note

It is not possible to output meaningful disassembly when the `-flto` option is enabled, which is turned on by default at `-Omax`, because this generates files containing bitcode.

Related reference

1.59 -o on page 1-98
1.60 -O on page 1-99
1.19 -flto, -fno-lto on page 1-47
1.64 -save-temps

Instructs the compiler to generate intermediate assembly files from the specified C/C++ file.

It is similar to disassembling object code that has been compiled from C/C++.

Example

```
armclang --target=aarch64-arm-none-eabi -save-temps -c hello.c
```

Executing this command outputs the following files, that are listed in the order they are created:

- `hello.i` (or `hello.ii` for C++): the C or C++ file after pre-processing.
- `hello.bc`: the llvm-ir bitcode file.
- `hello.s`: the assembly file.
- `hello.o`: the output object file.

_____ Note _____

- Specifying `-c` means that the compilation process stops after the compilation step, and does not do any linking.
- Specifying `-S` means that the compilation process stops after the disassembly step, and does not create an object file.

_____ Related reference _____

1.4 -c on page 1-29
1.63 -S on page 1-103
1.65 -std

Specifies the language standard to compile for.

Note

This topic includes descriptions of [BETA] and [COMMUNITY] features. See Support level definitions on page 1-19.

Syntax

-std=name

Where:

name

Specifies the language mode. Valid values include:

- **c90**
  C as defined by the 1990 C standard.

- **gnu90**
  C as defined by the 1990 C standard, with additional GNU extensions.

- **c99**
  C as defined by the 1999 C standard.

- **gnu99**
  C as defined by the 1999 C standard, with additional GNU extensions.

- **c11 [COMMUNITY]**
  C as defined by the 2011 C standard.

- **gnu11 [COMMUNITY]**
  C as defined by the 2011 C standard, with additional GNU extensions.

- **c++98**
  C++ as defined by the 1998 C++ standard.

- **gnu++98**
  C++ as defined by the 1998 C++ standard, with additional GNU extensions.

- **c++03**
  C++ as defined by the 2003 C++ standard.

- **gnu++03**
  C++ as defined by the 2003 C++ standard, with additional GNU extensions.

- **c++11**
  C++ as defined by the 2011 C++ standard.

- **gnu++11**
  C++ as defined by the 2011 C++ standard, with additional GNU extensions.

- **c++14 [BETA]**
  C++ as defined by the 2014 C++ standard.

- **gnu++14 [BETA]**
  C++ as defined by the 2014 C++ standard, with additional GNU extensions.

- **c++17 [COMMUNITY]**
  C++ as defined by the 2017 C++ standard.

- **gnu++17 [COMMUNITY]**
  C++ as defined by the 2017 C++ standard, with additional GNU extensions.

For C++ code, the default is gnu++14. Arm recommends compiling with -std=c++11 to restrict Arm Compiler to using only C++11 language and library features, which are fully supported. For more information about C++ support, see C++ Status on the Clang web site.
For C code, the default is gnu11. For more information about C support, see Language Compatibility on the Clang web site.

--- Note ---
Use of C11 library features is unsupported.

Related reference
1.76 -x on page 1-117

Related information
Language Compatibility
C++ Status
Language Support Levels
1.66  --target

Generate code for the specified target triple.

**Syntax**

```
--target=triple
```

Where:

```
triple
```

has the form `architecture-vendor-OS-abi`.

Supported target triples are as follows:

**aarch64-arm-none-eabi**

Generates A64 instructions for AArch64 state. Implies `-march=armv8-a` unless `-mcpu` or `-march` is specified.

**arm-arm-none-eabi**

Generates A32/T32 instructions for AArch32 state. Must be used in conjunction with `-march` (to target an architecture) or `-mcpu` (to target a processor).

--- **Note** ---

- The target triples are case-sensitive.
- The `--target` option is an armclang option. For all of the other tools, such as armasm and armlink, use the `--cpu` and `--fpu` options to specify target processors and architectures.

**Default**

The `--target` option is mandatory and has no default. You must always specify a target triple.

**Related reference**

1.45 `-marm` on page 1-77
1.56 `-mthumb` on page 1-95
1.48 `-mcpu` on page 1-81
1.51 `-mfpu` on page 1-88

**Related information**

Specifying a target architecture, processor, and instruction set

armasm User Guide

armlink User Guide
1.67 -U

Removes any initial definition of the specified macro.

Syntax

-U name

Where:

name

is the name of the macro to be undefined.

The macro name can be either:

- A predefined macro.
- A macro specified using the -D option.

——— Note ———

Not all compiler predefined macros can be undefined.

Usage

Specifying -U name has the same effect as placing the text #undef name at the head of each source file.

Restrictions

The compiler defines and undefines macros in the following order:

1. Compiler predefined macros.
2. Macros defined explicitly, using -Dname.
3. Macros explicitly undefined, using -Uname.

Related reference

1.5 -D on page 1-30
6.2 Predefined macros on page 6-200
1.35 -include on page 1-64
1.68 -u

Prevents the removal of a specified symbol if it is undefined.

**Syntax**

```
-u symbol
```

Where `symbol` is the symbol to keep.

`armclang` translates this option to `--undefined` and passes it to `armlink`.

See the *Arm® Compiler armlink User Guide* for information about the `--undefined` linker option.

**Related information**

*armlink User Guide*
1.69 **-v**

Displays the commands that invoke the compiler and sub-tools, such as `armlink`, and executes those commands.

**Usage**

The `-v` compiler option produces diagnostic output showing exactly how the compiler and linker are invoked, displaying the options for each tool. The `-v` compiler option also displays version information.

With the `-v` option, `armclang` displays this diagnostic output and executes the commands.

--- **Note** ---

To display the diagnostic output without executing the commands, use the `-###` option.

---

**Related reference**

1.77 `-###` on page 1-118
1.70 --version

Displays the same information as --vsn.

Related reference
1.72 --vsn on page 1-113
1.71 --version_number

Displays the version of armclang you are using.

Usage
The compiler displays the version number in the format Mmmuuxx, where:
• M is the major version number, 6.
• mm is the minor version number.
• uu is the update number.
• xx is reserved for Arm internal use. You can ignore this for the purposes of checking whether the current release is a specific version or within a range of versions.

Related reference
6.2 Predefined macros on page 6-200
1.72 --vsn on page 1-113
1.72 --vsn

Displays the version information and the license details.

Note

--vsn is intended to report the version information for manual inspection. The Component line indicates the release of Arm Compiler you are using. If you need to access the version in other tools or scripts, for example in build scripts, use the output from --version_number.

Example

Example output:

> armclang --vsn
Product: ARM Compiler N.n.p
Component: ARM Compiler N.n.p
Tool: armclang [tool_id]
Target: target_name

Related reference

1.70 --version on page 1-111
1.71 --version_number on page 1-112
1.73  **-W**

Controls diagnostics.

**Syntax**

```plaintext
-Wname
```

Where common values for `name` include:

- **-Wc11-extensions**
  
  Warns about any use of C11-specific features.

- **-Werror**
  
  Turn warnings into errors.

- **-Werror=foo**
  
  Turn warning foo into an error.

- **-Wno-error=foo**
  
  Leave warning foo as a warning even if `-Werror` is specified.

- **-Wfoo**
  
  Enable warning foo.

- **-Wno-foo**
  
  Suppress warning foo.

- **-Weverything**
  
  Enable all warnings.

- **-Wpedantic**
  
  Generate warnings if code violates strict ISO C and ISO C++.

See *Controlling Errors and Warnings* in the *Clang Compiler User's Manual* for full details about controlling diagnostics with `armclang`.

**Related information**

*Options for controlling diagnostics with armclang*
1.74 -Wl

Specifies linker command-line options to pass to the linker when a link step is being performed after compilation.

See the Arm® Compiler armlink User Guide for information about available linker options.

**Syntax**

-`Wl,opt,[opt[,...]]`

Where:

`opt`

is a linker command-line option to pass to the linker.

You can specify a comma-separated list of options or `option=argument` pairs.

**Restrictions**

The linker generates an error if `-Wl` passes unsupported options.

**Examples**

The following examples show the different syntax usages. They are equivalent because `armlink` treats the single option `--list=diag.txt` and the two options `--list diag.txt` equivalently:

```
armclang --target=aarch64-arm-none-eabi -mcpu=cortex-a53 hello.c -Wl,--split,--list,diag.txt
armclang --target=aarch64-arm-none-eabi -mcpu=cortex-a53 hello.c -Wl,--split,--list=diag.txt
```

**Related reference**

1.75 -Xlinker on page 1-116

**Related information**

Arm Compiler Linker Command-line Options
1.75 -Xlinker

Specifies linker command-line options to pass to the linker when a link step is being performed after compilation.

See the Arm Compiler armlink User Guide for information about available linker options.

**Syntax**

-Xlinker opt

Where:

opt

is a linker command-line option to pass to the linker.

If you want to pass multiple options, use multiple -Xlinker options.

**Restrictions**

The linker generates an error if -Xlinker passes unsupported options.

**Examples**

This example passes the option --split to the linker:

```
armclang --target=aarch64-arm-none-eabi -mcpu=cortex-a53 hello.c -Xlinker --split
```

This example passes the options --list diag.txt to the linker:

```
armclang --target=aarch64-arm-none-eabi -mcpu=cortex-a53 hello.c -Xlinker --list -Xlinker diag.txt
```

**Related reference**

1.74 -Wl on page 1-115

**Related information**

Arm Compiler Linker Command-line Options
1.76  **-x**

Specifies the language of source files.

**Syntax**

- `x Language`

Where:

*Language*

Specifies the language of subsequent source files, one of the following:

- **c**  
  C code.
- **c++**  
  C++ code.
- **assembler-with-cpp**  
  Assembly code containing C directives that require the C preprocessor.
- **assembler**  
  Assembly code that does not require the C preprocessor.

**Usage**

- `x` overrides the default language standard for the subsequent input files that follow it on the command-line. For example:

```
armclang inputfile1.s -xc inputfile2.s inputfile3.s
```

In this example, `armclang` treats the input files as follows:

- `inputfile1.s` appears before the `-xc` option, so `armclang` treats it as assembly code because of the `.s` suffix.
- `inputfile2.s` and `inputfile3.s` appear after the `-xc` option, so `armclang` treats them as C code.

****Note****

Use `-std` to set the default language standard.

**Default**

By default the compiler determines the source file language from the filename suffix, as follows:

- `.cpp`, `.cxx`, `.c++`, `.cc`, and `.CC` indicate C++, equivalent to `-x c++`
- `.c` indicates C, equivalent to `-x c`
- `.s` (lower-case) indicates assembly code that does not require preprocessing, equivalent to `-x assembler`
- `.S` (upper-case) indicates assembly code that requires preprocessing, equivalent to `-x assembler-with-cpp`

**Related reference**

1.5 `-D` on page 1-30  
1.65 `-std` on page 1-105

**Related information**

*Preprocessing assembly code*
1.77 -###

Displays the commands that invoke the compiler and sub-tools, such as armlink, without executing those commands.

**Usage**

The -### compiler option produces diagnostic output showing exactly how the compiler and linker are invoked, displaying the options for each tool. The -### compiler option also displays version information.

With the -### option, armclang only displays this diagnostic output. armclang does not compile source files or invoke armlink.

----- Note -----

To display the diagnostic output and execute the commands, use the -v option.

**Related reference**

1.69 -v on page 1-110
Chapter 2
Compiler-specific Keywords and Operators

Summarizes the compiler-specific keywords and operators that are extensions to the C and C++ Standards.

It contains the following sections:
• 2.1 Compiler-specific keywords and operators on page 2-120.
• 2.2 __alignof__ on page 2-121.
• 2.3 __asm on page 2-123.
• 2.4 __declspec attributes on page 2-125.
• 2.5 __declspec(noinline) on page 2-126.
• 2.6 __declspec(noreturn) on page 2-127.
• 2.7 __declspec(nothrow) on page 2-128.
• 2.8 __inline on page 2-129.
• 2.9 __unaligned on page 2-130.
2.1 Compiler-specific keywords and operators

The Arm compiler armclang provides keywords that are extensions to the C and C++ Standards.

Standard C and Standard C++ keywords that do not have behavior or restrictions specific to the Arm compiler are not documented.

Keyword extensions that the Arm compiler supports:
• __alignof__
• __asm
• __declspec
• __inline

Related reference
2.2 __alignof__ on page 2-121
2.3 __asm on page 2-123
2.4 __declspec attributes on page 2-125
2.8 __inline on page 2-129
2.2 __alignof__

The __alignof__ keyword enables you to inquire about the alignment of a type or variable.

--- Note ---

This keyword is a GNU compiler extension that the Arm compiler supports.

**Syntax**

- `__alignof__(type)`
- `__alignof__(expr)`

Where:

- `type` is a type
- `expr` is an lvalue.

**Return value**

- `__alignof__(type)` returns the alignment requirement for the type, or 1 if there is no alignment requirement.
- `__alignof__(expr)` returns the alignment requirement for the type of the lvalue `expr`, or 1 if there is no alignment requirement.

**Example**

The following example displays the alignment requirements for a variety of data types, first directly from the data type, then from an lvalue of the corresponding data type:

```c
#include <stdio.h>

int main(void)
{
  int var_i;
  char var_c;
  double var_d;
  float var_f;
  long var_l;
  long long var_ll;

  printf("Alignment requirement from data type:\n");
  printf("  int : %d
", __alignof__(int));
  printf("  char : %d
", __alignof__(char));
  printf("  double : %d
", __alignof__(double));
  printf("  float : %d
", __alignof__(float));
  printf("  long : %d
", __alignof__(long));
  printf("  long long : %d
", __alignof__(long long));
  printf("\n");
  printf("Alignment requirement from data type of lvalue:\n");
  printf("  int : %d
", __alignof__(var_i));
  printf("  char : %d
", __alignof__(var_c));
  printf("  double : %d
", __alignof__(var_d));
  printf("  float : %d
", __alignof__(var_f));
  printf("  long : %d
", __alignof__(var_l));
  printf("  long long : %d
", __alignof__(var_ll));
}
```

Compiling with the following command produces the following output:

```
armclang --target=arm-arm-none-eabi -march=armv8-a alignof_test.c -o alignof.axf
```

```
Alignment requirement from data type:
int : 4
char : 1
```
<table>
<thead>
<tr>
<th>Data Type</th>
<th>Alignment Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>double</td>
<td>8</td>
</tr>
<tr>
<td>float</td>
<td>4</td>
</tr>
<tr>
<td>long</td>
<td>4</td>
</tr>
<tr>
<td>long long</td>
<td>8</td>
</tr>
</tbody>
</table>

Alignment requirement from data type of lvalue:
- int       : 4
- char      : 1
- double    : 8
- float     : 4
- long      : 4
- long long : 8
### 2.3 __asm

This keyword passes information to the armclang assembler.

The precise action of this keyword depends on its usage.

#### Usage

**Inline assembly**

The `__asm` keyword can incorporate inline GCC syntax assembly code into a function. For example:

```c
#include <stdio.h>

int add(int i, int j)
{
    int res = 0;
    __asm {
        "ADD %[result], %[input_i], %[input_j]"
        : [result] "r" (res)
        : [input_i] "r" (i), [input_j] "r" (j)
    };
    return res;
}

int main(void)
{
    int a = 1;
    int b = 2;
    int c = 0;
    c = add(a,b);
    printf("Result of %d + %d = %d\n", a, b, c);
}
```

The general form of an `__asm` inline assembly statement is:

```c
__asm(code [: output_operand_list [: input_operand_list [: clobbered_register_list]]]);
```

- **code** is the assembly code. In our example, this is "ADD %[result], %[input_i], %input_j".
- **output_operand_list** is an optional list of output operands, separated by commas. Each operand consists of a symbolic name in square brackets, a constraint string, and a C expression in parentheses. In our example, there is a single output operand: [result] "r" (res).
- **input_operand_list** is an optional list of input operands, separated by commas. Input operands use the same syntax as output operands. In our example there are two input operands: [input_i] "r" (i), [input_j] "r" (j).
- **clobbered_register_list** is an optional list of clobbered registers. In our example, this is omitted.

**Embedded assembly**

For embedded assembly, you cannot use the `__asm` keyword on the function declaration. Use the `__attribute__((naked))` function attribute on the function declaration. For more information, see `__attribute__((naked))` on page 3-143. For example:

```c
__attribute__((naked)) void foo (int i);
```

Naked functions with the `__attribute__((naked))` function attribute only support assembler instructions in the basic format:

```c
__asm(code);
```
Assembly labels

The `__asm` keyword can specify an assembly label for a C symbol. For example:

```c
int count __asm__("count_v1"); // export count_v1, not count
```

**Related reference**

3.10 `__attribute__((naked))` function attribute on page 3-143
2.4 __declspec attributes

The __declspec keyword enables you to specify special attributes of objects and functions. The __declspec keyword must prefix the declaration specification. For example:

```c
__declspec(noreturn) void overflow(void);
```

The available __declspec attributes are as follows:

- __declspec(noinline)
- __declspec(noreturn)
- __declspec(throw)

__declspec attributes are storage class modifiers. They do not affect the type of a function or variable.

Related reference

2.5 __declspec(noinline) on page 2-126
2.6 __declspec(noreturn) on page 2-127
2.7 __declspec(throw) on page 2-128
3.11 __attribute__((noinline)) function attribute on page 3-144
3.13 __attribute__((noreturn)) function attribute on page 3-146
3.14 __attribute__((nothrow)) function attribute on page 3-147
### 2.5 __declspec(noinline)

The __declspec(noinline) attribute suppresses the inlining of a function at the call points of the function.

__declspec(noinline) can also be applied to constant data, to prevent the compiler from using the value for optimization purposes, without affecting its placement in the object. This is a feature that can be used for patchable constants, that is, data that is later patched to a different value. It is an error to try to use such constants in a context where a constant value is required. For example, an array dimension.

__________ Note __________

This __declspec attribute has the function attribute equivalent __attribute__((noinline)).

---

**Example**

```c
/* Prevent y being used for optimization */
__declspec(noinline) const int y = 5;

/* Suppress inlining of foo() wherever foo() is called */
__declspec(noinline) int foo(void);
```

**Related reference**

3.11 __attribute__((noinline)) function attribute on page 3-144
2.6 __declspec(noreturn)

The __declspec(noreturn) attribute asserts that a function never returns.

Note

This __declspec attribute has the function attribute equivalent __attribute__((noreturn)).

Usage

Use this attribute to reduce the cost of calling a function that never returns, such as exit(). If a noreturn function returns to its caller, the behavior is undefined.

Restrictions

The return address is not preserved when calling the noreturn function. This limits the ability of a debugger to display the call stack.

Example

```c
__declspec(noreturn) void overflow(void); // never return on overflow
int negate(int x)
{  
    if (x == 0x80000000) overflow();
    return -x;
}
```

Related reference

3.13 __attribute__((noreturn)) function attribute on page 3-146
### 2.7 __declspec(nothrow)

The __declspec(nothrow) attribute asserts that a call to a function never results in a C++ exception being propagated from the callee into the caller.

The Arm library headers automatically add this qualifier to declarations of C functions that, according to the ISO C Standard, can never throw an exception. However, there are some restrictions on the unwinding tables produced for the C library functions that might throw an exception in a C++ context, for example, bsearch and qsort.

_______ Note _______
This __declspec attribute has the function attribute equivalent __attribute__((nothrow)).

Usage

If the compiler knows that a function can never throw an exception, it might be able to generate smaller exception-handling tables for callers of that function.

Restrictions

If a call to a function results in a C++ exception being propagated from the callee into the caller, the behavior is undefined.

This modifier is ignored when not compiling with exceptions enabled.

Example

```c
struct S
{
    ~S();
} __declspec(nothrow) extern void f(void);
void g(void)
{
    S s;
    f();
}
```

Related reference

3.14 __attribute__((nothrow)) function attribute on page 3-147

Related information

Standard C++ library implementation definition
2.8 __inline

The __inline keyword suggests to the compiler that it compiles a C or C++ function inline, if it is sensible to do so.

__inline can be used in C90 code, and serves as an alternative to the C99 inline keyword.

Both __inline and __inline__ are supported in armclang.

Example

```c
static __inline int f(int x){
    return x*5+1;
}

int g(int x, int y){
    return f(x) + f(y);
}
```

Related concepts

6.3 Inline functions on page 6-205
2.9 __unaligned

The __unaligned keyword is a type qualifier that tells the compiler to treat the pointer or variable as an unaligned pointer or variable.

Members of packed structures might be unaligned. Use the __unaligned keyword on pointers that you use for accessing packed structures or members of packed structures.

Example

```c
typedef struct __attribute__((packed)) S{
    char c;
    int x;
} S;

int f1_load(__unaligned S *s)
{
    return s->x;
}
```

The compiler generates an error if you assign an unaligned pointer to a regular pointer without type casting.

Example

```c
struct __attribute__((packed)) S { char c; int x; };
void foo(__unaligned S *s2)
{
    int *p = &s2->x;             // compiler error because &s2->x is an unaligned pointer
    but p is a regular pointer.
    __unaligned int *q = &s2->x; // No error because q and &s2->x are both unaligned
    pointers.
}
```
Chapter 3
Compiler-specific Function, Variable, and Type Attributes

Summarizes the compiler-specific function, variable, and type attributes that are extensions to the C and C++ Standards.

It contains the following sections:

• 3.1 Function attributes on page 3-133.
• 3.2 __attribute__((always_inline)) function attribute on page 3-135.
• 3.3 __attribute__((cmse_nonsecure_call)) function attribute on page 3-136.
• 3.4 __attribute__((cmse_nonsecure_entry)) function attribute on page 3-137.
• 3.5 __attribute__((const)) function attribute on page 3-138.
• 3.6 __attribute__((constructor[priority])) function attribute on page 3-139.
• 3.7 __attribute__((format_arg(string-index))) function attribute on page 3-140.
• 3.8 __attribute__((interrupt("type"))) function attribute on page 3-141.
• 3.9 __attribute__((malloc)) function attribute on page 3-142.
• 3.10 __attribute__((naked)) function attribute on page 3-143.
• 3.11 __attribute__((noinline)) function attribute on page 3-144.
• 3.12 __attribute__((nonnull)) function attribute on page 3-145.
• 3.13 __attribute__((noretturn)) function attribute on page 3-146.
• 3.14 __attribute__((nothrow)) function attribute on page 3-147.
• 3.15 __attribute__((pcs("calling_convention"))) function attribute on page 3-148.
• 3.16 __attribute__((pure)) function attribute on page 3-149.
• 3.17 __attribute__((section("name"))) function attribute on page 3-150.
• 3.18 __attribute__((unused)) function attribute on page 3-151.
• 3.19 __attribute__((used)) function attribute on page 3-152.
• 3.20 __attribute__((value_in_regs)) function attribute on page 3-153.
• 3.21 __attribute__((visibility("visibility_type"))) function attribute on page 3-155.
• 3.22 __attribute__((weak)) function attribute on page 3-156.
• 3.23 __attribute__((weakref("target"))) function attribute on page 3-157.
• 3.24 Type attributes on page 3-158.
• 3.25 __attribute__((aligned)) type attribute on page 3-159.
• 3.26 __attribute__((packed)) type attribute on page 3-160.
• 3.27 __attribute__((transparent_union)) type attribute on page 3-161.
• 3.28 Variable attributes on page 3-162.
• 3.29 __attribute__((alias)) variable attribute on page 3-163.
• 3.30 __attribute__((aligned)) variable attribute on page 3-164.
• 3.31 __attribute__((deprecated)) variable attribute on page 3-165.
• 3.32 __attribute__((packed)) variable attribute on page 3-166.
• 3.33 __attribute__((section("name"))) variable attribute on page 3-167.
• 3.34 __attribute__((unused)) variable attribute on page 3-168.
• 3.35 __attribute__((used)) variable attribute on page 3-169.
• 3.36 __attribute__((visibility("visibility_type"))) variable attribute on page 3-170.
• 3.37 __attribute__((weak)) variable attribute on page 3-171.
• 3.38 __attribute__((weakref("target"))) variable attribute on page 3-172.
3.1 Function attributes

The __attribute__ keyword enables you to specify special attributes of variables, structure fields, functions, and types.

The keyword format is either of the following:

__attribute__((attr1, attr2, ...))
__attribute__((attr1, attr2, ...))

For example:

```c
int my_function(int b) __attribute__((const));
static int my_variable __attribute__((__unused));
```

The following table summarizes the available function attributes.

<table>
<thead>
<tr>
<th>Function attribute</th>
<th>Non-attribute equivalent</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>attribute</strong>((alias))</td>
<td>-</td>
</tr>
<tr>
<td><strong>attribute</strong>((always_inline))</td>
<td>-</td>
</tr>
<tr>
<td><strong>attribute</strong>((cmse_nonsecure_call))</td>
<td>-</td>
</tr>
<tr>
<td><strong>attribute</strong>((cmse_nonsecure_entry))</td>
<td>-</td>
</tr>
<tr>
<td><strong>attribute</strong>((const))</td>
<td>-</td>
</tr>
<tr>
<td><strong>attribute</strong>((constructor[(priority)]))</td>
<td>-</td>
</tr>
<tr>
<td><strong>attribute</strong>((deprecated))</td>
<td>-</td>
</tr>
<tr>
<td><strong>attribute</strong>((destructor[(priority)]))</td>
<td>-</td>
</tr>
<tr>
<td><strong>attribute</strong>((format_arg(string-index)))</td>
<td>-</td>
</tr>
<tr>
<td><strong>attribute</strong>((interrupt(&quot;type&quot;)))</td>
<td>-</td>
</tr>
<tr>
<td><strong>attribute</strong>((malloc))</td>
<td>-</td>
</tr>
<tr>
<td><strong>attribute</strong>((naked))</td>
<td>-</td>
</tr>
<tr>
<td><strong>attribute</strong>((nonnull))</td>
<td>__declspecnonnull(noinline)</td>
</tr>
<tr>
<td><strong>attribute</strong>((nomerge))</td>
<td>-</td>
</tr>
<tr>
<td><strong>attribute</strong>((nonnull))</td>
<td>-</td>
</tr>
<tr>
<td><strong>attribute</strong>((noreturn))</td>
<td>__declspecnoretturn(noreturn)</td>
</tr>
<tr>
<td><strong>attribute</strong>((nothrow))</td>
<td>-</td>
</tr>
<tr>
<td><strong>attribute</strong>((notailcall))</td>
<td>__declspecnothrow(nothrow)</td>
</tr>
<tr>
<td><strong>attribute</strong>((pcs(&quot;calling_convention&quot;)))</td>
<td>-</td>
</tr>
<tr>
<td><strong>attribute</strong>((pure))</td>
<td>-</td>
</tr>
<tr>
<td><strong>attribute</strong>((section(&quot;name&quot;)))</td>
<td>-</td>
</tr>
<tr>
<td><strong>attribute</strong>((unused))</td>
<td>-</td>
</tr>
<tr>
<td><strong>attribute</strong>((used))</td>
<td>-</td>
</tr>
<tr>
<td><strong>attribute</strong>((value_in_regs))</td>
<td>-</td>
</tr>
<tr>
<td><strong>attribute</strong>((visibility(&quot;visibility_type&quot;)))</td>
<td>-</td>
</tr>
</tbody>
</table>
Table 3-1  Function attributes that the compiler supports, and their equivalents (continued)

<table>
<thead>
<tr>
<th>Function attribute</th>
<th>Non-attribute equivalent</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>attribute</strong>((weak))</td>
<td>-</td>
</tr>
<tr>
<td><strong>attribute</strong>((weakref(&quot;target&quot;)))</td>
<td>-</td>
</tr>
</tbody>
</table>

Usage

You can set these function attributes in the declaration, the definition, or both. For example:

```c
void AddGlobals(void) __attribute__((always_inline));
__attribute__((always_inline)) void AddGlobals(void) {...}
```

When function attributes conflict, the compiler uses the safer or stronger one. For example, __attribute__((used)) is safer than __attribute__((unused)), and __attribute__((noinline)) is safer than __attribute__((always_inline)).

Related reference

3.2 __attribute__((always_inline)) function attribute on page 3-135
3.5 __attribute__((const)) function attribute on page 3-138
3.6 __attribute__((constructor[priority])) function attribute on page 3-139
3.7 __attribute__((format_arg(string-index))) function attribute on page 3-140
3.9 __attribute__((malloc)) function attribute on page 3-142
3.12 __attribute__((nonnull)) function attribute on page 3-145
3.10 __attribute__((naked)) function attribute on page 3-143
3.15 __attribute__((pcs("calling_convention"))) function attribute on page 3-148
3.11 __attribute__((noinline)) function attribute on page 3-144
3.14 __attribute__((nothrow)) function attribute on page 3-147
3.17 __attribute__((section("name"))) function attribute on page 3-150
3.16 __attribute__((pure)) function attribute on page 3-149
3.13 __attribute__((noreturn)) function attribute on page 3-146
3.18 __attribute__((unused)) function attribute on page 3-151
3.19 __attribute__((used)) function attribute on page 3-152
3.21 __attribute__((visibility("visibility_type"))) function attribute on page 3-155
3.22 __attribute__((weak)) function attribute on page 3-156
3.23 __attribute__((weakref("target"))) function attribute on page 3-157
2.2 __alignof__ on page 2-121
2.3 __asm on page 2-123
2.4 __declspec attributes on page 2-125
3.2 __attribute__((always_inline)) function attribute

This function attribute indicates that a function must be inlined.

The compiler attempts to inline the function, regardless of the characteristics of the function.

In some circumstances, the compiler might choose to ignore __attribute__((always_inline)), and not inline the function. For example:

- A recursive function is never inlined into itself.
- Functions that use alloca() might not be inlined.

Example

```c
static int max(int x, int y) __attribute__((always_inline));
static int max(int x, int y)
{
    return x > y ? x : y; // always inline if possible
}
```

--- Note ---

__attribute__((always_inline)) does not affect the linkage characteristics of the function in the same way that the inline function-specifier does. When using __attribute__((always_inline)), if you want the declaration and linkage of the function to be governed by the rules of the inline function-specifier of the source language, then you must also use the keyword inline or __inline__ (for C90). For example:

```c
inline int max(int x, int y) __attribute__((always_inline));
inline int max(int x, int y)
{
    return x > y ? x : y; // always inline if possible
}
```
3.3 __attribute__((cmse_nonsecure_call)) function attribute

Declares a non-secure function type

A call to a function that switches state from Secure to Non-secure is called a non-secure function call. A non-secure function call can only happen through function pointers. This is a consequence of separating secure and non-secure code into separate executable files.

A non-secure function type must only be used as a base type of a pointer.

Example

```c
#include <arm_cmse.h>
typedef void __attribute__((cmse_nonsecure_call)) nsfunc(void);

void default_callback(void) { … }

// fp can point to a secure function or a non-secure function
nsfunc *fp = (nsfunc *) default_callback; // secure function pointer

void __attribute__((cmse_nonsecure_entry)) entry(nsfunc *callback) {
    fp = cmse_nsfptr_create(callback); // non-secure function pointer
}

void call_callback(void) {
    if (cmse_is_nsfptr(fp)){
        fp();           // non-secure function call
    } else {
        ((void (*)(void)) fp)();           // normal function call
    }
}
```

Related reference

3.4 __attribute__((cmse_nonsecure_entry)) function attribute on page 3-137
6.9 Non-secure function pointer intrinsics on page 6-214

Related information

Building Secure and Non-secure Images Using the Armv8-M Security Extension
3.4 __attribute__((cmse_nonsecure_entry)) function attribute

Declarations an entry function that can be called from Non-secure state or Secure state.

Syntax

C linkage:
void __attribute__((cmse_nonsecure_entry)) entry_func(int val)

C++ linkage:
extern "C" void __attribute__((cmse_nonsecure_entry)) entry_func(int val)

Note

Compile Secure code with the maximum capabilities for the target. For example, if you compile with no FPU then the Secure functions do not clear floating-point registers when returning from functions declared as __attribute__((cmse_nonsecure_entry)). Therefore, the functions could potentially leak sensitive data.

Example

```
#include <arm_cmse.h>
void __attribute__((cmse_nonsecure_entry)) entry_func(int val) {
    int state = cmse_nonsecure_caller();
    if (state)
        // called from non-secure
        // do non-secure work
        ...
    else
        // called from within secure
        // do secure work
        ...
}
```

Related reference
3.3 __attribute__((cmse_nonsecure_call)) function attribute on page 3-136
6.9 Non-secure function pointer intrinsics on page 6-214

Related information
Building Secure and Non-secure Images Using the Armv8-M Security Extension
3.5 __attribute__((const)) function attribute

The const function attribute specifies that a function examines only its arguments, and has no effect except for the return value. That is, the function does not read or modify any global memory.

If a function is known to operate only on its arguments then it can be subject to common sub-expression elimination and loop optimizations.

This attribute is stricter than __attribute__((pure)) because functions are not permitted to read global memory.

Example

```c
#include <stdio.h>

// __attribute__((const)) functions do not read or modify any global memory
int my_double(int b) __attribute__((const));

int my_double(int b) {
    return b*2;
}

int main(void) {
    int i;
    int result;
    for (i = 0; i < 10; i++) {
        result = my_double(i);
        printf(" %d ; result = %d \n", i, result);
    }
}
```
3.6 __attribute__((constructor[(priority)])) function attribute

This attribute causes the function it is associated with to be called automatically before `main()` is entered.

**Syntax**

```
__attribute__((constructor[(priority)]))
```

Where `priority` is an optional integer value denoting the priority. A constructor with a low integer value runs before a constructor with a high integer value. A constructor with a priority runs before a constructor without a priority.

Priority values up to and including 100 are reserved for internal use. If you use these values, the compiler gives a warning.

**Usage**

You can use this attribute for start-up or initialization code.

**Example**

In the following example, the constructor functions are called before execution enters `main()`, in the order specified:

```c
#include <stdio.h>
void my_constructor1(void) __attribute__((constructor));
void my_constructor2(void) __attribute__((constructor(102)));
void my_constructor3(void) __attribute__((constructor(103)));
void my_constructor1(void) /* This is the 3rd constructor */
{                        /* function to be called */
   printf("Called my_constructor1()\n");
}
void my_constructor2(void) /* This is the 1st constructor */
{                        /* function to be called */
   printf("Called my_constructor2()\n");
}
void my_constructor3(void) /* This is the 2nd constructor */
{                        /* function to be called */
   printf("Called my_constructor3()\n");
}
int main(void)
{
   printf("Called main()\n");
}
```

This example produces the following output:

```
Called my_constructor2()
Called my_constructor3()
Called my_constructor1()
Called main()
```
This attribute specifies that a function takes a format string as an argument. Format strings can contain typed placeholders that are intended to be passed to printf-style functions such as printf(), scanf(), strftime(), or strfmon().

This attribute causes the compiler to perform placeholder type checking on the specified argument when the output of the function is used in calls to a printf-style function.

Syntax

```c
__attribute__((format_arg(string-index)))
```

Where `string-index` specifies the argument that is the format string argument (starting from one).

Example

The following example declares two functions, `myFormatText1()` and `myFormatText2()`, that provide format strings to printf().

The first function, `myFormatText1()`, does not specify the `format_arg` attribute. The compiler does not check the types of the printf arguments for consistency with the format string.

The second function, `myFormatText2()`, specifies the `format_arg` attribute. In the subsequent calls to printf(), the compiler checks that the types of the supplied arguments `a` and `b` are consistent with the format string argument to `myFormatText2()`. The compiler produces a warning when a float is provided where an int is expected.

```c
#include <stdio.h>

// Function used by printf. No format type checking.
extern char *myFormatText1 (const char *);

// Function used by printf. Format type checking on argument 1.
extern char *myFormatText2 (const char *) __attribute__((format_arg(1)));

int main(void) {
    int a;
    float b;
    a = 5;
    b = 9.099999;
    printf(myFormatText1("Here is an integer: %d\n"), a); // No type checking. Types match anyway.
    printf(myFormatText1("Here is an integer: %d\n"), b); // No type checking. Type mismatch, but no warning
    printf(myFormatText2("Here is an integer: %d\n"), a); // Type checking. Types match.
    printf(myFormatText2("Here is an integer: %d\n"), b); // Type checking. Type mismatch results in warning
}
```

```
$ armclang --target=aarch64-arm-none-eabi -mcpu=cortex-a53 -c format_arg_test.c
format_arg_test.c:21:53: warning: format specifies type 'int' but the argument has type 'float' [-Wformat]
    printf(myFormatText2("Here is an integer: %d\n"), b); // Type checking. Type mismatch results in warning
               ^
    %f
1 warning generated.
```
3.8 __attribute__((interrupt("type"))) function attribute

This attribute instructs the compiler to generate a function in a manner that is suitable for use as an exception handler.

**Syntax**

```
__attribute__((interrupt("type")))
```

Where `type` is one of the following:
- IRQ.
- FIQ.
- SWI.
- ABORT.
- UNDEF.

**Usage**

This attribute affects the code generation of a function as follows:
- If the function is AAPCS, the stack is realigned to 8 bytes on entry.
- For processors that are not based on the M-profile, preserves all processor registers, rather than only the registers that the AAPCS requires to be preserved. Floating-point registers are not preserved.
- For processors that are not based on the M-profile, the function returns using an instruction that is architecturally defined as a return from exception.

**Restrictions**

When using `__attribute__((interrupt("type")))` functions:
- No arguments or return values can be used with the functions.
- The functions are incompatible with `-frwpi`.

**Note**

In Armv6-M, Armv7-M, and Armv8-M, the architectural exception handling mechanism preserves all processor registers, and a standard function return can cause an exception return. Therefore, specifying this attribute does not affect the behavior of the compiled output. However, Arm recommends using this attribute on exception handlers for clarity and easier software porting.

**Note**

- For architectures that support A32 and T32 instructions, functions specified with this attribute compile to A32 or T32 code depending on whether the compile option specifies A32 code or T32 code.
- For T32 only architectures, for example the Armv6-M architecture, functions specified with this attribute compile to T32 code.
- This attribute is not available for A64 code.
__attribute__((malloc)) function attribute

This function attribute indicates that the function can be treated like malloc and the compiler can perform the associated optimizations.

Example

```c
void * foo(int b) __attribute__((malloc));
```
3.10 __attribute__((naked)) function attribute

This attribute tells the compiler that the function is an embedded assembly function. You can write the body of the function entirely in assembly code using __asm statements.

The compiler does not generate prologue and epilogue sequences for functions with __attribute__((naked)).

The compiler only supports basic __asm statements in __attribute__((naked)) functions. Using extended assembly, parameter references or mixing C code with __asm statements might not work reliably.

---

Example 3-1 Examples

```c
__attribute__((naked)) int add(int i, int j); /* Declaring a function with __attribute__((naked)). */
__attribute__((naked)) int add(int i, int j)
{
    __asm("ADD r0, r1, #1"); /* Basic assembler statements are supported. */
    /* Parameter references are not supported inside naked functions: */
    /* __asm ("ADD r0, %[input_i], %[input_j]" /* Assembler statement with parameter references */
    /* : [input_i] "r" (i), [input_j] "r" (j) /* Input operand parameter */
    /* ); */
    /* Mixing C code is not supported inside naked functions: */
    /* int res = 0;
    return res;
    */
}
```

Related reference

2.3 __asm on page 2-123
3.11 __attribute__((noinline)) function attribute

This attribute suppresses the inlining of a function at the call points of the function.

__attribute__((noinline)) can also be applied to constant data, to prevent the compiler from using the value for optimization purposes, without affecting its placement in the object. This is a feature that can be used for patchable constants, that is, data that is later patched to a different value. It is an error to try to use such constants in a context where a constant value is required.

Example

/* Prevent y being used for optimization */
const int y = 5 __attribute__((noinline));
/* Suppress inlining of foo() wherever foo() is called */
int foo(void) __attribute__((noinline));
3.12 __attribute__((nonnull)) function attribute

This function attribute specifies function parameters that are not supposed to be null pointers. This enables the compiler to generate a warning on encountering such a parameter.

Syntax

__attribute__((nonnull[(arg-index, ...)]))

Where [(arg-index, ...)] denotes an optional argument index list.

If no argument index list is specified, all pointer arguments are marked as nonnull.

Note

The argument index list is 1-based, rather than 0-based.

Examples

The following declarations are equivalent:

```c
void * my_memcpy(void *dest, const void *src, size_t len) __attribute__((nonnull (1, 2)));
void * my_memcpy(void *dest, const void *src, size_t len) __attribute__((nonnull));
```
3.13 __attribute__((noreturn)) function attribute

This attribute asserts that a function never returns.

Usage

Use this attribute to reduce the cost of calling a function that never returns, such as exit(). If a noreturn function returns to its caller, the behavior is undefined.

Restrictions

The return address is not preserved when calling the noreturn function. This limits the ability of a debugger to display the call stack.
3.14 __attribute__((nothrow)) function attribute

This attribute asserts that a call to a function never results in a C++ exception being sent from the callee to the caller.

The Arm library headers automatically add this qualifier to declarations of C functions that, according to the ISO C Standard, can never throw an exception. However, there are some restrictions on the unwinding tables produced for the C library functions that might throw an exception in a C++ context, for example, `bsearch` and `qsort`.

If the compiler knows that a function can never throw an exception, it might be able to generate smaller exception-handling tables for callers of that function.
3.15 __attribute__((pcs("calling_convention"))) function attribute

This function attribute specifies the calling convention on targets with hardware floating-point.

**Syntax**

```
__attribute__((pcs("calling_convention")))
```

Where `calling_convention` is one of the following:

- **aapcs**
  - uses integer registers.

- **aapcs-vfp**
  - uses floating-point registers.

**Example**

```c
double foo (float) __attribute__((pcs("aapcs")));
```
3.16 __attribute__((pure)) function attribute

Many functions have no effects except to return a value, and their return value depends only on the parameters and global variables. Functions of this kind can be subject to data flow analysis and might be eliminated.

Example

```c
int bar(int b) __attribute__((pure));
int bar(int b)
{
    return b++;
}
int foo(int b)
{
    int aLocal=0;
    aLocal += bar(b);
    aLocal += bar(b);
    return 0;
}
```

The call to `bar` in this example might be eliminated because its result is not used.
3.17 __attribute__((section("name"))) function attribute

The section function attribute enables you to place code in different sections of the image.

Example

In the following example, the function foo is placed into an RO section named new_section rather than .text.

```c
int foo(void) __attribute__((section("new_section")));
int foo(void)
{
  return 2;
}
```

Note

Section names must be unique. You must not use the same section name for different section types. If you use the same section name for different section types, then the compiler merges the sections into one and gives the section the type of whichever function or variable is first allocated to that section.
3.18 __attribute__((unused)) function attribute

The unused function attribute prevents the compiler from generating warnings if the function is not referenced. This does not change the behavior of the unused function removal process.

--- Note ---

By default, the compiler does not warn about unused functions. Use -Wunused-function to enable this warning specifically, or use an encompassing -W value such as -Wall.

The __attribute__((unused)) attribute can be useful if you usually want to warn about unused functions, but want to suppress warnings for a specific set of functions.

--- Example ---

```c
static int unused_no_warning(int b) __attribute__((unused));
static int unused_no_warning(int b) {
    return b++;
}

static int unused_with_warning(int b);
static int unused_with_warning(int b) {
    return b++;
}
```

Compiling this example with -Wall results in the following warning:

```bash
armclang --target=aarch64-arm-none-eabi -c test.c -Wall
test.c:10:12: warning: unused function 'unused_with_warning' [-Wunused-function]
  static int unused_with_warning(int b)
^
1 warning generated.
```

--- Related reference ---

3.34 __attribute__((unused)) variable attribute on page 3-168
3.19 __attribute__((used)) function attribute

This function attribute informs the compiler that a static function is to be retained in the object file, even if it is unreferenced.

Functions marked with __attribute__((used)) are tagged in the object file to avoid removal by linker unused section removal.

Note

Static variables can also be marked as used, by using __attribute__((used)).

Example

```c
static int lose_this(int);
static int keep_this(int) __attribute__((used)); // retained in object file
static int keep_this (int arg) {
    return (arg+1);
}
static int keep_this_too(int) __attribute__((used)); // retained in object file
static int keep_this_too (int arg) {
    return (arg-1);
}
int main (void) {
    for (;;);
}
```

Related information

Elimination of unused sections
3.20 __attribute__((value_in_regs)) function attribute

The `value_in_regs` function attribute is compatible with functions whose return type is a structure. It alters the calling convention of a function so that the returned structure is stored in the argument registers rather than being written to memory using an implicit pointer argument.

________ Note ________
When using `__attribute__((value_in_regs))`, the calling convention only uses integer registers.

Syntax

```
__attribute__((value_in_regs)) return-type function-name([argument-list]);
```

Where:

- `return-type` is the type of the returned structure that conforms to certain restrictions as described in `Restrictions on page 3-153`.

Usage

Declaring a function `__attribute__((value_in_regs))` can be useful when calling functions that return more than one result.

Restrictions

When targeting AArch32, the returned structure can be up to 16 bytes to fit in four 32-bit argument registers. When targeting AArch64, the returned structure can be up to 64 bytes to fit in eight 64-bit argument registers. If the structure returned by a function qualified by `__attribute__((value_in_regs))` is too big, the compiler generates an error.

Each field of the returned structure must occupy exactly one or two integer registers, and must not require implicit padding of the structure. Anything else, including bitfields, is incompatible.

Nested structures are allowed with the same restriction that the nested structure as a whole and its individual members must occupy exactly one or two integer registers.

Unions are allowed if they have at least one maximal-size member that occupies exactly one or two integer registers. The other fields within the union can have any field type.

The allowed field types are:

- signed int (AArch32 only).
- unsigned int (AArch32 only).
- signed long.
- unsigned long.
- signed long long.
- unsigned long long.
- pointer.
- structure containing any of the types in this list.
- union whose maximal-size member is any of the types in this list.

If the structure type returned by a function qualified by `__attribute__((value_in_regs))` violates any of the above rules, then the compiler generates the corresponding error.

If a virtual function declared as `__attribute__((value_in_regs))` is to be overridden, the overriding function must also be declared as `__attribute__((value_in_regs))`. If the functions do not match, the compiler generates an error.

A function declared as `__attribute__((value_in_regs))` is not function-pointer-compatible with a normal function of the same type signature. If a pointer to a function that is declared as
__attribute__((value_in_regs)) is initialized with a pointer to a function that is not declared as
__attribute__((value_in_regs)), then the compiler generates a warning.

The return type of a function declared as __attribute__((value_in_regs)) must be known at the point
of the function declaration. The compiler generates a corresponding error if the return type is an
incomplete type.

Example

```c
struct ReturnType
{
    long a;
    void *ptr;
    union U
    {
        char c;
        short s;
        int i;
        float f;
        double d;
        struct S1 {long long ll;} s1;
    } u;
};
extern __attribute__((value_in_regs)) struct retType g(long y);
```
__attribute__((visibility("visibility_type"))) function attribute

This function attribute affects the visibility of ELF symbols.

Syntax

__attribute__((visibility("visibility_type")))

Where visibility_type is one of the following:

default
  Default visibility corresponds to external linkage.

hidden
  The symbol is not placed into the dynamic symbol table, so no other executable or shared
  library can directly reference it. Indirect references are possible using function pointers.

protected
  The symbol is placed into the dynamic symbol table, but references within the defining module
  bind to the local symbol. That is, another module cannot override the symbol.

Usage

This attribute overrides other settings that determine the visibility of symbols.

You can apply this attribute to functions and variables in C and C++. In C++, it can also be applied to
  class, struct, union, and enum types, and namespace declarations.

In the case of namespace declarations, the visibility attribute applies to all function and variable
  definitions.

Default

If you do not specify visibility, then the default type is default for extern declarations and hidden for
  everything else.

Example

void __attribute__((visibility("protected"))) foo()
{
  ...
}

Related reference

1.31 -fvisibility on page 1-60
3.36 __attribute__((visibility("visibility_type"))) variable attribute on page 3-170
3.22 __attribute__((weak)) function attribute

Functions defined with __attribute__((weak)) export their symbols weakly.

Functions declared with __attribute__((weak)) and then defined without __attribute__((weak)) behave as weak functions.

Example

extern int Function_Attributes_weak_0 (int b) __attribute__((weak));
3.23 \texttt{\_attribute__((\_\_weakref\("target\"\))) function attribute}

This function attribute marks a function declaration as an alias that does not by itself require a function definition to be given for the target symbol.

\textbf{Syntax}

\begin{verbatim}
_attribute__((weakref("target")))
\end{verbatim}

Where \texttt{target} is the target symbol.

\textbf{Example}

In the following example, \texttt{foo()} calls \texttt{y()} through a weak reference:

\begin{verbatim}
extern void y(void);
static void x(void) __attribute__((weakref("y")))
void foo (void)
{
  ...
  x();
  ...
}
\end{verbatim}

\textbf{Restrictions}

This attribute can only be used on functions with static linkage.
3.24 Type attributes

The __attribute__ keyword enables you to specify special attributes of variables or structure fields, functions, and types.

The keyword format is either of the following:

```
__attribute__((attribute1, attribute2, ...))
__attribute__((__attribute1__, __attribute2__, ...))
```

For example:

```
typedef union { int i; float f; } U __attribute__((transparent_union));
```

The available type attributes are as follows:

- __attribute__((aligned))
- __attribute__((packed))
- __attribute__((transparent_union))

Related reference

3.25 __attribute__((aligned)) type attribute on page 3-159
3.27 __attribute__((transparent_union)) type attribute on page 3-161
3.26 __attribute__((packed)) type attribute on page 3-160
3.25 **attribute__((aligned)) type attribute**

The aligned type attribute specifies a minimum alignment for the type.
3.26 __attribute__((packed)) type attribute

The packed type attribute specifies that a type must have the smallest possible alignment. This attribute only applies to struct and union types.

_________ Note _________

You must access a packed member of a struct or union directly from a variable of the containing type. Taking the address of such a member produces a normal pointer which might be unaligned. The compiler assumes that the pointer is aligned. Dereferencing such a pointer can be unsafe even when unaligned accesses are supported by the target, because certain instructions always require word-aligned addresses.

_________ Note _________

If you take the address of a packed member, in most cases, the compiler generates a warning.

When you specify __attribute__((packed)) to a structure or union, it applies to all members of the structure or union. If a packed structure has a member that is also a structure, then this member structure has an alignment of 1-byte. However, the packed attribute does not apply to the members of the member structure. The members of the member structure continue to have their natural alignment.

Example 3-2 Examples

```c
struct __attribute__((packed)) foobar
{
    char x;
    short y;
};
short get_y(struct foobar *s)
{
    // Correct usage: the compiler will not use unaligned accesses
    // unless they are allowed.
    return s->y;
}
short get2_y(struct foobar *s)
{
    short *p = &s->y; // Incorrect usage: 'p' might be an unaligned pointer.
    return *p; // This might cause an unaligned access.
}
```

Related reference

1.55 -mualigned-access, -mno-unaligned-access on page 1-94
3.27 __attribute__((transparent_union)) type attribute

The transparent_union type attribute enables you to specify a transparent union type.

When a function is defined with a parameter having transparent union type, a call to the function with an argument of any type in the union results in the initialization of a union object whose member has the type of the passed argument and whose value is set to the value of the passed argument.

When a union data type is qualified with __attribute__((transparent_union)), the transparent union applies to all function parameters with that type.

Example

typedef union { int i; float f; } U __attribute__((transparent_union));
void foo(U u)
{
    static int s;
    s += u.i; /* Use the 'int' field */
}
void caller(void)
{
    foo(1); /* u.i is set to 1 */
    foo(1.0f); /* u.f is set to 1.0f */
}
3.28 Variable attributes

The `__attribute__` keyword enables you to specify special attributes of variables or structure fields, functions, and types.

The keyword format is either of the following:

\[
\text{__attribute__(}}(\text{attribute1, attribute2, ...}) \\
\text{__attribute__(}}(\text{__attribute1__, __attribute2__, ...}) \\
\]

For example:

\[
\text{static int b __attribute__((__unused__))};
\]

The available variable attributes are as follows:

- `__attribute__((alias))`
- `__attribute__((aligned("x")))`
- `__attribute__((deprecated))`
- `__attribute__((packed))`
- `__attribute__((section("name")))`
- `__attribute__((unused))`
- `__attribute__((used))`
- `__attribute__((visibility("visibility_type")))`
- `__attribute__((weak))`
- `__attribute__((weakref("target")))`

Related reference

- 3.29 `__attribute__((alias))` variable attribute on page 3-163
- 3.30 `__attribute__((aligned))` variable attribute on page 3-164
- 3.31 `__attribute__((deprecated))` variable attribute on page 3-165
- 3.32 `__attribute__((packed))` variable attribute on page 3-166
- 3.33 `__attribute__((section("name")))` variable attribute on page 3-167
- 3.34 `__attribute__((unused))` variable attribute on page 3-168
- 3.35 `__attribute__((used))` variable attribute on page 3-169
- 3.36 `__attribute__((visibility("visibility_type")))` variable attribute on page 3-170
- 3.37 `__attribute__((weak))` variable attribute on page 3-171
- 3.38 `__attribute__((weakref("target")))` variable attribute on page 3-172
3.29 __attribute__((alias)) variable attribute

This variable attribute enables you to specify multiple aliases for a variable.

Aliases must be declared in the same translation unit as the definition of the original variable.

Note

Aliases cannot be specified in block scope. The compiler ignores aliasing attributes attached to local variable definitions and treats the variable definition as a normal local definition.

In the output object file, the compiler replaces alias references with a reference to the original variable name, and emits the alias alongside the original name. For example:

```c
int oldname = 1;
extern int newname __attribute__((alias("oldname")));
```

This code compiles to:

```assembly
.type   oldname,%object         @ @oldname
.data
.globl  oldname
.align  2
oldname:
.long   1                       @ 0x1
.size   oldname, 4              @ @oldname
(...
.newname = oldname
```

Note

Function names can also be aliased using the corresponding function attribute __attribute__((alias)).

Syntax

```c
type newname __attribute__((alias("oldname")));
```

Where:

*oldname*

is the name of the variable to be aliased

*newname*

is the new name of the aliased variable.

Example

```c
#include <stdio.h>
int oldname = 1;
extern int newname __attribute__((alias("oldname"))); // declaration
void foo(void){
    printf("newname = %d\n", newname); // prints 1
}
```
3.30 __attribute__((aligned)) variable attribute

The aligned variable attribute specifies a minimum alignment for the variable or structure field, measured in bytes.

Example

```c
/* Aligns on 16-byte boundary */
int x __attribute__((aligned (16)));

/* In this case, the alignment used is the maximum alignment for a scalar data type. For ARM, this is 8 bytes. */
short my_array[3] __attribute__((aligned));
```
3.31 __attribute__((deprecated)) variable attribute

The deprecated variable attribute enables the declaration of a deprecated variable without any warnings or errors being issued by the compiler. However, any access to a deprecated variable creates a warning but still compiles.

The warning gives the location where the variable is used and the location where it is defined. This helps you to determine why a particular definition is deprecated.

Example

```c
extern int deprecated_var __attribute__((deprecated));
void foo()
{
  deprecated_var = 1;
}
```

Compiling this example generates a warning:

```
armclang --target=aarch64-arm-none-eabi -c test_deprecated.c

test_deprecated.c:4:3: warning: 'deprecated_var' is deprecated [-Wdeprecated-declarations]
  deprecated_var = 1;
  ^

1 warning generated.
```
3.32 __attribute__((packed)) variable attribute

You can specify the packed variable attribute on fields that are members of a structure or union. It specifies that a member field has the smallest possible alignment. That is, one byte for a variable field, and one bit for a bitfield, unless you specify a larger value with the aligned attribute.

Example

```c
struct {
    char a;
    int b __attribute__((packed));
} Variable_Attributes_packed_0;
```

Note

You must access a packed member of a structure or union directly from a variable of the structure or union. Taking the address of such a member produces a normal pointer which might be unaligned. The compiler assumes that the pointer is aligned. Dereferencing such a pointer can be unsafe even when unaligned accesses are supported by the target, because certain instructions always require word-aligned addresses.

Note

If you take the address of a packed member, in most cases, the compiler generates a warning.

Related reference

3.30 __attribute__((aligned)) variable attribute on page 3-164
3.33 __attribute__((section("name"))) variable attribute

The section attribute specifies that a variable must be placed in a particular data section.

Normally, the Arm compiler places the data it generates in sections like .data and .bss. However, you might require additional data sections or you might want a variable to appear in a special section, for example, to map to special hardware.

If you use the section attribute, read-only variables are placed in RO data sections, writable variables are placed in RW data sections.

To place ZI data in a named section, the section must start with the prefix .bss. Non-ZI data cannot be placed in a section named .bss.

Example

/* in RO section */
const int descriptor[3] __attribute__((section("descr"))) = { 1,2,3 };
/* in RW section */
long long rw_initialized[10] __attribute__((section("INITIALIZED_RW"))) = {5};
/* in RW section */
long long rw[10] __attribute__((section("RW")));
/* in ZI section */
int my_zi __attribute__((section(".bss.my_zi_section")));

——— Note ———

Section names must be unique. You must not use the same section name for different section types. If you use the same section name for different section types, then the compiler merges the sections into one and gives the section the type of whichever function or variable is first allocated to that section.

——— Related information ———

Manually placing __at sections
### 3.34 `__attribute__((unused))` variable attribute

The compiler can warn if a variable is declared but is never referenced. The `__attribute__((unused))` attribute informs the compiler to expect an unused variable, and tells it not to issue a warning.

---

**Note**

By default, the compiler does not warn about unused variables. Use `-Wunused-variable` to enable this warning specifically, or use an encompassing `-W` value such as `-Weverything`.

The `__attribute__((unused))` attribute can be used to warn about most unused variables, but suppress warnings for a specific set of variables.

---

**Example**

```c
void foo()
{
    static int aStatic = 0;
    int aUnused __attribute__((unused));
    int bUnused;
    aStatic++;
}
```

When compiled with a suitable `-W` setting, the compiler warns that `bUnused` is declared but never referenced, but does not warn about `aUnused`:

```
armclang --target=aarch64-arm-none-eabi -c test_unused.c -Wall
```

```
test_unused.c:5:7: warning: unused variable 'bUnused' [-Wunused-variable]
    int bUnused;
1 warning generated.
```

**Related reference**

3.18 `__attribute__((unused))` function attribute on page 3-151
3.35 __attribute__((used)) variable attribute

This variable attribute informs the compiler that a static variable is to be retained in the object file, even if it is unreferenced.

Data marked with __attribute__((used)) is tagged in the object file to avoid removal by linker unused section removal.

----------- Note -----------
Static functions can also be marked as used, by using __attribute__((used)).

Example

```c
static int lose_this = 1;
static int keep_this __attribute__((used)) = 2;     // retained in object file
static int keep_this_too __attribute__((used)) = 3; // retained in object file
```

Related information

Elimination of unused sections
### 3.36 __attribute__((visibility("visibility_type"))) variable attribute

This variable attribute affects the visibility of ELF symbols.

**Syntax**

```
__attribute__((visibility("visibility_type")))
```

Where `visibility_type` is one of the following:

- **default**
  
  Default visibility corresponds to external linkage.

- **hidden**
  
  The symbol is not placed into the dynamic symbol table, so no other executable or shared library can directly reference it. Indirect references are possible using function pointers.

- **protected**
  
  The symbol is placed into the dynamic symbol table, but references within the defining module bind to the local symbol. That is, another module cannot override the symbol.

**Usage**

This attribute overrides other settings that determine the visibility of symbols.

You can apply this attribute to functions and variables in C and C++. In C++, it can also be applied to class, struct, union, and enum types, and namespace declarations.

In the case of namespace declarations, the visibility attribute applies to all function and variable definitions.

**Default**

If you do not specify visibility, then the default type is `default` for `extern` declarations and `hidden` for everything else.

**Example**

```
int __attribute__((visibility("hidden"))) foo = 1;  // hidden in object file
```

**Related reference**

- [1.31 -fvisibility on page 1-60](#)
- [3.21 __attribute__((visibility("visibility_type"))) function attribute on page 3-155](#)
3.37 \texttt{\_\_attribute\_\((\texttt{weak})\)} variable attribute

Generates a weak symbol for a variable, rather than the default symbol.

\begin{verbatim}
extern int foo \texttt{\_\_attribute\_\((\texttt{weak})\)};
\end{verbatim}

At link time, strong symbols override weak symbols. This attribute replaces a weak symbol with a strong symbol, by choosing a particular combination of object files to link.
3.38 __attribute__((weakref("target"))) variable attribute

This variable attribute marks a variable declaration as an alias that does not by itself require a definition to be given for the target symbol.

**Syntax**

```
__attribute__((weakref("target")))
```

Where target is the target symbol.

**Example**

In the following example, a is assigned the value of y through a weak reference:

```c
extern int y;
static int x __attribute__((weakref("y")));  
void foo (void)
{  
   int a = x;  
   ...  
}
```

**Restrictions**

This attribute can only be used on variables that are declared as static.
Chapter 4
Compiler-specific Intrinsics

Summarizes the Arm compiler-specific intrinsics that are extensions to the C and C++ Standards.
To use these intrinsics, your source file must contain \#include <arm_compat.h>.

It contains the following sections:
• 4.1 __breakpoint intrinsic on page 4-174.
• 4.2 __current_pc intrinsic on page 4-175.
• 4.3 __current_sp intrinsic on page 4-176.
• 4.4 __disable_fiq intrinsic on page 4-177.
• 4.5 __disable_irq intrinsic on page 4-178.
• 4.6 __enable_fiq intrinsic on page 4-179.
• 4.7 __enable_irq intrinsic on page 4-180.
• 4.8 __force_stores intrinsic on page 4-181.
• 4.9 __memory_changed intrinsic on page 4-182.
• 4.10 __schedule_barrier intrinsic on page 4-183.
• 4.11 __semihost intrinsic on page 4-184.
• 4.12 __vfp_status intrinsic on page 4-186.
This intrinsic inserts a BKPT instruction into the instruction stream generated by the compiler.

To use this intrinsic, your source file must contain `#include <arm_compat.h>`. This is only available for targets in AArch32 state.

It enables you to include a breakpoint instruction in your C or C++ code.

**Syntax**

```c
void __breakpoint(int val)
```

Where:

`val`

is a compile-time constant integer whose range is:

- `0 ... 65535` if you are compiling source as A32 code
- `0 ... 255` if you are compiling source as T32 code.

**Errors**

The `__breakpoint` intrinsic is not available when compiling for a target that does not support the BKPT instruction. The compiler generates an error in this case.

**Example**

```c
void func(void)
{
    ...
    __breakpoint(0xF02C);
    ...
}
```
4.2 __current_pc intrinsic

This intrinsic enables you to determine the current value of the program counter at the point in your program where the intrinsic is used.

To use this intrinsic, your source file must contain `#include <arm_compat.h>`. This is only available for targets in AArch32 state.

**Syntax**

```c
unsigned int __current_pc(void)
```

**Return value**

The `__current_pc` intrinsic returns the current value of the program counter at the point in the program where the intrinsic is used.
4.3 **__current_sp intrinsic**

This intrinsic returns the value of the stack pointer at the current point in your program.

To use this intrinsic, your source file must contain `#include <arm_compat.h>`. This is only available for targets in AArch32 state.

**Syntax**

```c
unsigned int __current_sp(void)
```

**Return value**

The `__current_sp` intrinsic returns the current value of the stack pointer at the point in the program where the intrinsic is used.
4.4 __disable_fiq intrinsic

This intrinsic disables FIQ interrupts.

To use this intrinsic, your source file must contain #include <arm_compat.h>. This is only available for targets in AArch32 state.

Note

Typically, this intrinsic disables FIQ interrupts by setting the F-bit in the CPSR. However, for v7-M and v8-M.mainline, it sets the fault mask register (FAULTMASK). This intrinsic is not supported for v6-M and v8-M.baseline.

Syntax

int __disable_fiq(void)

Usage

int __disable_fiq(void); disables fast interrupts and returns the value the FIQ interrupt mask has in the PSR before disabling interrupts.

Return value

int __disable_fiq(void); returns the value the FIQ interrupt mask has in the PSR before disabling FIQ interrupts.

Restrictions

The __disable_fiq intrinsic can only be executed in privileged modes, that is, in non-user modes. In User mode this intrinsic does not change the interrupt flags in the CPSR.

Example

```c
void foo(void)
{
    int was_masked = __disable_fiq();
    /* ... */
    if (!was_masked)
        __enable_fiq();
}
```
4.5 __disable_irq intrinsic

This intrinsic disables IRQ interrupts.

To use this intrinsic, your source file must contain `#include <arm_compat.h>`. This is only available for targets in AArch32 state.

------- Note -------

Typically, this intrinsic disables IRQ interrupts by setting the I-bit in the CPSR. However, for M-profile it sets the exception mask register (PRIMASK).

Syntax

```c
int __disable_irq(void)
```

Usage

```c
int __disable_irq(void); disables interrupts and returns the value the IRQ interrupt mask has in the PSR before disabling interrupts.
```

Return value

```c
int __disable_irq(void); returns the value the IRQ interrupt mask has in the PSR before disabling IRQ interrupts.
```

Example

```c
void foo(void)
{
    int was_masked = __disable_irq();
    /* ... */
    if (!was_masked)
        __enable_irq();
}
```

Restrictions

The __disable_irq intrinsic can only be executed in privileged modes, that is, in non-user modes. In User mode this intrinsic does not change the interrupt flags in the CPSR.
4.6 __enable_fiq intrinsic

This intrinsic enables FIQ interrupts.

To use this intrinsic, your source file must contain `#include <arm_compat.h>`. This is only available for targets in AArch32 state.

Note

Typically, this intrinsic enables FIQ interrupts by clearing the F-bit in the CPSR. However, for v7-M and v8-M.mainline, it clears the fault mask register (FAULTMASK). This intrinsic is not supported in v6-M and v8-M.baseline.

Syntax

```c
void __enable_fiq(void)
```

Restrictions

The __enable_fiq intrinsic can only be executed in privileged modes, that is, in non-user modes. In User mode this intrinsic does not change the interrupt flags in the CPSR.
4.7 __enable_irq intrinsic

This intrinsic enables IRQ interrupts.

To use this intrinsic, your source file must contain `#include <arm_compat.h>`. This is only available for targets in AArch32 state.

Note

Typically, this intrinsic enables IRQ interrupts by clearing the I-bit in the CPSR. However, for Cortex M-profile processors, it clears the exception mask register (PRIMASK).

Syntax

```c
void __enable_irq(void)
```

Restrictions

The __enable_irq intrinsic can only be executed in privileged modes, that is, in non-user modes. In User mode this intrinsic does not change the interrupt flags in the CPSR.
4.8 __force_stores intrinsic

This intrinsic causes all variables that are visible outside the current function, such as variables that have
pointers to them passed into or out of the function, to be written back to memory if they have been
changed.

To use this intrinsic, your source file must contain #include <arm_compat.h>. This is only available for
targets in AArch32 state.

This intrinsic also acts as a __schedule_barrier intrinsic.

Syntax

void __force_stores(void)
4.9 __memory_changed intrinsic

This intrinsic causes the compiler to behave as if all C objects had their values both read and written at that point in time.

To use this intrinsic, your source file must contain `#include <arm_compat.h>`. This is only available for targets in AArch32 state.

The compiler ensures that the stored value of each C object is correct at that point in time and treats the stored value as unknown afterwards.

This intrinsic also acts as a __schedule_barrier intrinsic.

**Syntax**

```c
void __memory_changed(void)
```

4.10 __schedule_barrier intrinsic

This intrinsic creates a special sequence point that prevents operations with side effects from moving past it under all circumstances. Normal sequence points allow operations with side effects past if they do not affect program behavior. Operations without side effects are not restricted by the intrinsic, and the compiler can move them past the sequence point.

Operations with side effects cannot be reordered above or below the __schedule_barrier intrinsic. To use this intrinsic, your source file must contain #include <arm_compat.h>. This is only available for targets in AArch32 state.

Unlike the __force_stores intrinsic, the __schedule_barrier intrinsic does not cause memory to be updated. The __schedule_barrier intrinsic is similar to the __nop intrinsic, only differing in that it does not generate a NOP instruction.

Syntax

void __schedule_barrier(void)
4.11  __semihost intrinsic

This intrinsic inserts an SVC or BKPT instruction into the instruction stream generated by the compiler. It enables you to make semihosting calls from C or C++ that are independent of the target architecture.

To use this intrinsic, your source file must contain `#include <arm_compat.h>`. This is only available for targets in AArch32 state.

**Syntax**

```c
int __semihost(int val, const void *ptr)
```

Where:

- `val` is the request code for the semihosting request.
- `ptr` is a pointer to an argument/result block.

**Return value**

The results of semihosting calls are passed either as an explicit return value or as a pointer to a data block.

**Usage**

Use this intrinsic from C or C++ to generate the appropriate semihosting call for your target and instruction set:

- SVC 0x123456
  - In A32 state, excluding M-profile architectures.
- SVC 0xAB
  - In T32 state, excluding M-profile architectures. This behavior is not guaranteed on all debug targets from Arm or from third parties.
- HLT 0xF000
  - In A32 state, excluding M-profile architectures.
- HLT 0x3C
  - In T32 state, excluding M-profile architectures.
- BKPT 0xAB
  - For M-profile architectures (T32 only).

**Implementation**

For Arm processors that are not Cortex-M profile, semihosting is implemented using the SVC or HLT instruction. For Cortex-M profile processors, semihosting is implemented using the BKPT instruction.

To use HLT-based semihosting, you must define the pre-processor macro `__USE_HLT_SEMIHOSTING` before `#include <arm_compat.h>`. By default, Arm Compiler emits SVC instructions rather than HLT instructions for semihosting calls. If you define this macro, `__USE_HLT_SEMIHOSTING`, then Arm Compiler emits HLT instructions rather than SVC instructions for semihosting calls.

The presence of this macro, `__USE_HLT_SEMIHOSTING`, does not affect the M-profile architectures that still use BKPT for semihosting.

**Example**

```c
char buffer[100];
...
void foo(void)
{
```
Compiling this code with the option `-mthumb` shows the generated SVC instruction:

```assembly
foo:
...
  MOVW r0, :lower16:buffer
  MOVT r0, :upper16:buffer
...
SVC  #0xab
...
buffer:
  .zero    100
  .size    buffer, 100
```

**Related information**

*Using the C and C++ libraries with an application in a semihosting environment*
4.12  __vfp_status intrinsic

This intrinsic reads or modifies the FPSCR.

To use this intrinsic, your source file must contain #include <arm_compat.h>. This is only available for targets in AArch32 state.

Syntax

unsigned int __vfp_status(unsigned int mask, unsigned int flags)

Usage

Use this intrinsic to read or modify the flags in FPSCR.

The intrinsic returns the value of FPSCR, unmodified, if *mask* and *flags* are 0.

You can clear, set, or toggle individual flags in FPSCR using the bits in *mask* and *flags*, as shown in the following table. The intrinsic returns the modified value of FPSCR if *mask* and *flags* are not both 0.

<table>
<thead>
<tr>
<th>mask bit</th>
<th>flags bit</th>
<th>Effect on FPSCR flag</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>Does not modify the flag</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>Toggles the flag</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>Sets the flag</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>Clears the flag</td>
</tr>
</tbody>
</table>

Note

If you want to read or modify only the exception flags in FPSCR, then Arm recommends that you use the standard C99 features in `<fenv.h>`.

Errors

The compiler generates an error if you attempt to use this intrinsic when compiling for a target that does not have VFP.
Chapter 5
Compiler-specific Pragmas

Summarizes the Arm compiler-specific pragmas that are extensions to the C and C++ Standards.

It contains the following sections:
- 5.1 #pragma clang system_header on page 5-188.
- 5.2 #pragma clang diagnostic on page 5-189.
- 5.3 #pragma clang section on page 5-191.
- 5.4 #pragma once on page 5-193.
- 5.5 #pragma pack(...) on page 5-194.
- 5.6 #pragma unroll[(n)], #pragma unroll_completely on page 5-196.
- 5.7 #pragma weak symbol, #pragma weak symbol1 = symbol2 on page 5-197.
5.1 #pragma clang system_header

Causes subsequent declarations in the current file to be marked as if they occur in a system header file. This pragma suppresses the warning messages that the file produces, from the point after which it is declared.
5.2  #pragma clang diagnostic

Allows you to suppress, enable, or change the severity of specific diagnostic messages from within your code.

For example, you can suppress a particular diagnostic message when compiling one specific function.

Note

Alternatively, you can use the command-line option, `-Wname`, to suppress or change the severity of messages, but the change applies for the entire compilation.

#pragma clang diagnostic ignored

This pragma disables the diagnostic message specified by `name`.

#pragma clang diagnostic warning

This pragma sets the diagnostic message specified by `name` to warning severity.

#pragma clang diagnostic error

This pragma sets the diagnostic message specified by `name` to error severity.

#pragma clang diagnostic fatal

This pragma sets the diagnostic message specified by `name` to fatal error severity. Fatal error causes compilation to fail without processing the rest of the file.

#pragma clang diagnostic push, #pragma clang diagnostic pop

#pragma clang diagnostic push saves the current pragma diagnostic state so that it can restored later.
#pragma clang diagnostic pop restores the diagnostic state that was previously saved using #pragma clang diagnostic push.

Examples of using pragmas to control diagnostics

The following example shows four identical functions, `foo1()`, `foo2()`, `foo3()`, and `foo4()`. All these functions would normally provoke diagnostic message warning: multi-character character constant [-Wmultichar] on the source lines `char c = (char) 'ab';`

Using pragmas, you can suppress or change the severity of these diagnostic messages for individual functions.

For `foo1()`, the current pragma diagnostic state is pushed to the stack and `#pragma clang diagnostic ignored` suppresses the message. The diagnostic message is then re-enabled by `#pragma clang diagnostic pop`.

For `foo2()`, the diagnostic message is not suppressed because the original pragma diagnostic state has been restored.
For foo3(), the message is initially suppressed by the preceding #pragma clang diagnostic ignored "-Wmultichar", however, the message is then re-enabled as an error, using #pragma clang diagnostic error "-Wmultichar". The compiler therefore reports an error in foo3().

For foo4(), the pragma diagnostic state is restored to the state saved by the preceding #pragma clang diagnostic push. This state therefore includes #pragma clang diagnostic ignored "-Wmultichar" and therefore the compiler does not report a warning in foo4().

```c
#pragma clang diagnostic push
#pragma clang diagnostic ignored "-Wmultichar"
void foo1( void )
{
    /* Here we do not expect a diagnostic message, because it is suppressed by #pragma clang diagnostic ignored "-Wmultichar". */
    char c = (char) 'ab';
}
#pragma clang diagnostic pop

void foo2( void )
{
    /* Here we expect a warning, because the suppression was inside push and then the diagnostic message was restored by pop. */
    char c = (char) 'ab';
}

#pragma clang diagnostic ignored "-Wmultichar"
#pragma clang diagnostic push
void foo3( void )
{
    #pragma clang diagnostic error "-Wmultichar"
    /* Here, the diagnostic message is elevated to error severity. */
    char c = (char) 'ab';
}
#pragma clang diagnostic pop

void foo4( void )
{
    /* Here, there is no diagnostic message because the restored diagnostic state only includes the #pragma clang diagnostic ignored "-Wmultichar".
    It does not include the #pragma clang diagnostic error "-Wmultichar" that is within the push and pop pragmas. */
    char c = (char) 'ab';
}
```

Diagnostic messages use the pragma state that is present at the time they are generated. If you use pragmas to control a diagnostic message in your code, you must be aware of when, in the compilation process, that diagnostic message is generated.

If a diagnostic message for a function, functionA, is only generated after all the functions have been processed, then the compiler controls this diagnostic message using the pragma diagnostic state that is present after processing all the functions. This diagnostic state might be different from the diagnostic state immediately before or within the definition of functionA.

**Related reference**

1.73 -W on page 1-114
5.3 #pragma clang section

Specifies names for one or more section types. The compiler places subsequent functions, global variables, or static variables in the named section depending on the section type. The names only apply within the compilation unit.

Syntax

```c
#pragma clang section [section_type_list]
```

Where:

- `section_type_list` specifies an optional list of section names to be used for subsequent functions, global variables, or static variables. The syntax of `section_type_list` is:

```c
section_type="name"[ section_type="name"
```

You can revert to the default section name by specifying an empty string, "", for `name`.

Valid section types are:

- bss.
- data.
- rodata.
- text.

Usage

Use `#pragma clang section [section_type_list]` to place functions and variables in separate named sections. You can then use the scatter-loading description file to locate these at a particular address in memory.

- If you specify a section name with `#attribute((section("myname")))`, then the attribute name has priority over any applicable section name that you specify with `#pragma clang section`.
- `#pragma clang section` has priority over the `-ffunction-section` and `-fdata-section` command-line options.
- Global variables, including basic types, arrays, and struct that are initialized to zero are placed in the .bss section. For example, `int x = 0;`
- `armclang` does not try to infer the type of section from the name. For example, assigning a section `.bss.mysec` does not mean it is placed in a .bss section.
- If you specify the `-ffunction-section` and `-fdata-section` command-line options, then each global variable is in a unique section.

Example

```c
int x1 = 5;                     // Goes in .data section (default)
int y1;                         // Goes in .bss section (default)
const int z1 = 42;              // Goes in .rodata section (default)
char *s1 = "abc1";              // s1 goes in .data section (default). String "abc1" goes in .conststring section.
```

```c
#pragma clang section bss="myBSS" data="myData" rodata="myRodata"
```

```c
int x2 = 5;                     // Goes in myData section.
int y2;                         // Goes in myBss section.
const int z2 = 42;              // Goes in myRodata section.
char *s2 = "abc2";              // s2 goes in myData section. String "abc2" goes in .conststring section.
```

```c
#pragma clang section rodata=""   // Use default name for rodata section.
```

```c
int x3 = 5;                     // Goes in myData section.
int y3;                         // Goes in myBss section.
const int z3 = 42;              // Goes in .rodata section (default).
char *s3 = "abc3";              // s3 goes in myData section. String "abc3" goes in .conststring section.
```

```c
#pragma clang section text="myText"
```

```c
int add1(int x)                 // Goes in myText section.
    
(```
return x+1;
}
#pragma clang section bss="" data="" text="" // Use default name for bss, data, and text sections.
5.4 #pragma once

Enable the compiler to skip subsequent includes of that header file.

#pragma once is accepted for compatibility with other compilers, and enables you to use other forms of header guard coding. However, Arm recommends using #ifndef and #define coding because this is more portable.

Example

The following example shows the placement of a #ifndef guard around the body of the file, with a #define of the guard variable after the #ifndef.

```c
#ifndef FILE_H
#define FILE_H
#pragma once      // optional
... body of the header file ...
#endif
```

The #pragma once is marked as optional in this example. This is because the compiler recognizes the #ifndef header guard coding and skips subsequent includes even if #pragma once is absent.
5.5  

#pragma pack(...)  

This pragma aligns members of a structure to the minimum of \( n \) and their natural alignment. Packed objects are read and written using unaligned accesses. You can optionally push and restore alignment settings to an internal stack.

--- Note ---

This pragma is a GNU compiler extension that the Arm compiler supports.

---

Syntax

#pragma pack([n])  
#pragma pack(push[,n])  
#pragma pack(pop)

Where:

\( n \)

Is the alignment in bytes, valid alignment values are 1, 2, 4, and 8. If omitted, sets the alignment to the one that was in effect when compilation started.

\( \text{push[,n]} \)

Pushes the current alignment setting on an internal stack and then optionally sets the new alignment.

\( \text{pop} \)

Restores the alignment setting to the one saved at the top of the internal stack, then removes that stack entry.

--- Note ---

#pragma pack([n]) does not influence this internal stack. Therefore, it is possible to have #pragma pack(push) followed by multiple #pragma pack([n]) instances, then finalized by a single #pragma pack(pop).

---

Default

The default is the alignment that was in effect when compilation started.

Example

This example shows how pack(2) aligns integer variable \( b \) to a 2-byte boundary.

```c
typedef struct
{
    char a;
    int b;
} S;
#pragma pack(2)
typedef struct
{
    char a;
    int b;
} SP;
S var = {0x11, 0x44444444};
SP pvar = {0x11, 0x44444444};
```

The layout of \( S \) is:
The layout of SP is:

--- Note ---
In this layout, x denotes one byte of padding.
SP is a 6-byte structure. There is no padding after b.
5.6 \#pragma unroll[(n)], \#pragma unroll_completely

Instructs the compiler to unroll a loop by \(n\) iterations.

**Syntax**

\#pragma unroll
\#pragma unroll\_completely
\#pragma unroll \(n\)
\#pragma unroll\((n)\)

Where:

\(n\)

is an optional value indicating the number of iterations to unroll.

**Default**

If you do not specify a value for \(n\), the compiler attempts to fully unroll the loop. The compiler can only fully unroll loops where it can determine the number of iterations.

\#pragma unroll\_completely will not unroll a loop if the number of iterations is not known at compile time.

**Usage**

This pragma only has an effect with optimization level \(-O2\) and higher.

When compiling with \(-O3\), the compiler automatically unrolls loops where it is beneficial to do so. This pragma can be used to ask the compiler to unroll a loop that has not been unrolled automatically.

\#pragma unroll\((n)\) can be used immediately before a \texttt{for} loop, a \texttt{while} loop, or a \texttt{do} ... \texttt{while} loop.

**Restrictions**

This pragma is a request to the compiler to unroll a loop that has not been unrolled automatically. It does not guarantee that the loop is unrolled.
5.7  \#pragma weak symbol, \#pragma weak symbol1 = symbol2

This pragma is a language extension to mark symbols as weak or to define weak aliases of symbols.

Example

In the following example, weak_fn is declared as a weak alias of __weak_fn:

```c
extern void weak_fn(int a);
#pragma weak weak_fn = __weak_fn
void __weak_fn(int a)
{
    ...
}
```
Chapter 6
Other Compiler-specific Features

Summarizes compiler-specific features that are extensions to the C and C++ Standards, such as predefined macros.

It contains the following sections:

- 6.1 ACLE support on page 6-199.
- 6.2 Predefined macros on page 6-200.
- 6.3 Inline functions on page 6-205.
- 6.4 Half-precision floating-point data types on page 6-206.
- 6.5 Half-precision floating-point number format on page 6-208.
- 6.6 Half-precision floating-point intrinsics on page 6-209.
- 6.7 Library support for _Float16 data type on page 6-210.
- 6.8 TT instruction intrinsics on page 6-211.
- 6.9 Non-secure function pointer intrinsics on page 6-214.
6.1 ACLE support

Arm Compiler 6 supports the Arm C Language Extensions 2.0 with a few exceptions.

--- Note ---

This topic includes descriptions of [BETA] features. See Support level definitions on page 1-19.

Arm Compiler 6 does not support:

• __attribute__((target("arm"))) attribute.
• __attribute__((target("thumb"))) attribute.
• __ARM_ALIGN_MAX_PWR macro.
• __ARM_ALIGN_MAX_STACK_PWR macro.
• __cls intrinsic.
• __cls1 intrinsic.
• __cls1l intrinsic.
• __saturation_occurred intrinsic.
• __set_saturation_occurred intrinsic.
• __ignore_saturation intrinsic.
• Patchable constants.
• 16-bit multiplication intrinsics.
• Floating-point data-processing intrinsics.
• Intrinsics for the 32-bit SIMD instructions introduced in the Armv6 architecture.

Arm Compiler 6 does not model the state of the Q (saturation) flag correctly in all situations.

Arm Compiler 6 provides [BETA] support for the ACLE defined Armv8.2-A half-precision floating-point intrinsics in AArch64 state.

Related reference

6.6 Half-precision floating-point intrinsics on page 6-209

Related information

List of intrinsics

Arm C Language Extensions
6.2 Predefined macros

The Arm Compiler predefines a number of macros. These macros provide information about toolchain version numbers and compiler options.

In general, the predefined macros generated by the compiler are compatible with those generated by GCC. See the GCC documentation for more information.

The following table lists Arm-specific macro names predefined by the Arm compiler for C and C++, together with a number of the most commonly used macro names. Where the value field is empty, the symbol is only defined.

Note Use -E -dM to see the values of predefined macros.

Macros beginning with __ARM_ are defined by the Arm* C Language Extensions 2.0 (ACLE 2.0).

Note armclang does not fully implement ACLE 2.0.

<table>
<thead>
<tr>
<th>Name</th>
<th>Value</th>
<th>When defined</th>
</tr>
</thead>
<tbody>
<tr>
<td>__APCS_ROPI</td>
<td>1</td>
<td>Set when you specify the -fropi option.</td>
</tr>
<tr>
<td>__APCS_RWPI</td>
<td>1</td>
<td>Set when you specify the -frwpi option.</td>
</tr>
<tr>
<td>__ARM_64BIT_STATE</td>
<td>1</td>
<td>Set for targets in AArch64 state only.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Set to 1 if code is for 64-bit state.</td>
</tr>
<tr>
<td>__ARM_ALIGN_MAX_STACK_PWR</td>
<td>4</td>
<td>Set for targets in AArch64 state only.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>The log of the maximum alignment of the stack object.</td>
</tr>
<tr>
<td>__ARM_ARCH</td>
<td>ver</td>
<td>Specifies the version of the target architecture, for example 8.</td>
</tr>
<tr>
<td><strong>ARM_ARCH_EXT_IDIV</strong></td>
<td>1</td>
<td>Set for targets in AArch32 state only.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Set to 1 if hardware divide instructions are available.</td>
</tr>
<tr>
<td>__ARM_ARCH_ISA_A64</td>
<td>1</td>
<td>Set for targets in AArch64 state only.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Set to 1 if the target supports the A64 instruction set.</td>
</tr>
<tr>
<td>__ARM_ARCH_PROFILE</td>
<td>ver</td>
<td>Specifies the profile of the target architecture, for example 'A'.</td>
</tr>
<tr>
<td>__ARM_BIG_ENDIAN</td>
<td>-</td>
<td>Set if compiling for a big-endian target.</td>
</tr>
<tr>
<td>__ARM_FEATURE_CLZ</td>
<td>1</td>
<td>Set to 1 if the CLZ (count leading zeroes) instruction is supported in hardware.</td>
</tr>
<tr>
<td>Name</td>
<td>Value</td>
<td>When defined</td>
</tr>
<tr>
<td>------------------------------</td>
<td>-------</td>
<td>-----------------------------------------------------------------------------</td>
</tr>
<tr>
<td>__ARM_FEATURE_CMSE</td>
<td>num</td>
<td>Indicates the availability of the Armv8-M Security Extension related extensions:</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0: The Armv8-M TT instruction is not available.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1: The TT instruction is available. It is not part of Armv8-M Security Extension, but is closely related.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3: The Armv8-M Security Extension for secure executable files is available. This implies that the TT instruction is available.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>See 6.8 TT instruction intrinsics on page 6-211 for more information.</td>
</tr>
<tr>
<td>__ARM_FEATURE_CRC32</td>
<td>1</td>
<td>Set to 1 if the target has CRC extension.</td>
</tr>
<tr>
<td>__ARM_FEATURE_CRYPTO</td>
<td>1</td>
<td>Set to 1 if the target has cryptographic extension.</td>
</tr>
<tr>
<td>__ARM_FEATURE_DIRECTED_ROUNDING</td>
<td>1</td>
<td>Set to 1 if the directed rounding and conversion vector instructions are supported. Only available when __ARM_ARCH &gt;= 8.</td>
</tr>
<tr>
<td>__ARM_FEATURE_DSP</td>
<td>1</td>
<td>Set for targets in AArch32 state only.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Set to 1 if DSP instructions are supported. This feature also implies support for the Q flag.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Note: This macro is deprecated in ACLE 2.0 for A-profile. It is fully supported for M and R-profiles.</td>
</tr>
<tr>
<td>__ARM_FEATURE_IDIV</td>
<td>1</td>
<td>Set to 1 if the target supports 32-bit signed and unsigned integer division in all available instruction sets.</td>
</tr>
<tr>
<td>__ARM_FEATURE_FMA</td>
<td>1</td>
<td>Set to 1 if the target supports fused floating-point multiply-accumulate.</td>
</tr>
<tr>
<td>__ARM_FEATURE_NUMERIC_MAXMIN</td>
<td>1</td>
<td>Set to 1 if the target supports floating-point maximum and minimum instructions. Only available when __ARM_ARCH &gt;= 8.</td>
</tr>
<tr>
<td>__ARM_FEATURE_QBIT</td>
<td>1</td>
<td>Set for targets in AArch32 state only.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Set to 1 if the Q (saturation) flag exists.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Note: This macro is deprecated in ACLE 2.0 for A-profile.</td>
</tr>
</tbody>
</table>
### Table 6-1 Predefined macros (continued)

<table>
<thead>
<tr>
<th>Name</th>
<th>Value</th>
<th>When defined</th>
</tr>
</thead>
<tbody>
<tr>
<td>__ARM_FEATURE_SAT</td>
<td>1</td>
<td>Set for targets in AArch32 state only.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Set to 1 if the SSAT and USAT instructions are supported. This feature also</td>
</tr>
<tr>
<td></td>
<td></td>
<td>implies support for the Q flag.</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Note</strong></td>
</tr>
<tr>
<td></td>
<td></td>
<td>This macro is deprecated in ACLE 2.0 for A-profile.</td>
</tr>
<tr>
<td>__ARM_FEATURE_SIMD32</td>
<td>1</td>
<td>Set for targets in AArch32 state only.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Set to 1 if the target supports 32-bit SIMD instructions.</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Note</strong></td>
</tr>
<tr>
<td></td>
<td></td>
<td>This macro is deprecated in ACLE 2.0 for A-profile, use Arm NEON intrinsics</td>
</tr>
<tr>
<td></td>
<td></td>
<td>instead.</td>
</tr>
<tr>
<td>__ARM_FEATURE_UNALIGNED</td>
<td>1</td>
<td>Set to 1 if the target supports unaligned access in hardware.</td>
</tr>
<tr>
<td>__ARM_FP</td>
<td>val</td>
<td>Set if hardware floating-point is available.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Bits 1-3 indicate the supported floating-point precision levels. The other</td>
</tr>
<tr>
<td></td>
<td></td>
<td>bits are reserved.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Bit 1 - half precision (16-bit).</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Bit 2 - single precision (32-bit).</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Bit 3 - double precision (64-bit).</td>
</tr>
<tr>
<td></td>
<td></td>
<td>These bits can be bitwise or-ed together. Permitted values include:</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• 0x04 for single-support.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• 0x0C for single- and double-support.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• 0x0E for half-, single-, and double-support.</td>
</tr>
<tr>
<td>__ARM_FP_FAST</td>
<td>1</td>
<td>Set if -ffast-math or -ffp-mode=fast is specified.</td>
</tr>
<tr>
<td>__ARM_NEON</td>
<td>1</td>
<td>Set to 1 when the compiler is targeting an architecture or processor with</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Advanced SIMD available.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Use this macro to conditionally include arm_neon.h, to permit the use of</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Advanced SIMD intrinsics.</td>
</tr>
<tr>
<td>__ARM_NEON_FP</td>
<td>val</td>
<td>This is the same as __ARM_FP, except that the bit to indicate double-</td>
</tr>
<tr>
<td></td>
<td></td>
<td>precision is not set for targets in AArch32 state. Double-precision is</td>
</tr>
<tr>
<td></td>
<td></td>
<td>always set for targets in AArch64 state.</td>
</tr>
<tr>
<td>__ARM_PCS</td>
<td>1</td>
<td>Set for targets in AArch32 state only.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Set to 1 if the default procedure calling standard for the translation unit</td>
</tr>
<tr>
<td></td>
<td></td>
<td>conforms to the base PCS.</td>
</tr>
<tr>
<td>__ARM_PCS_VFP</td>
<td>1</td>
<td>Set for targets in AArch32 state only.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Set to 1 if the default procedure calling standard for the translation unit</td>
</tr>
<tr>
<td></td>
<td></td>
<td>conforms to the VFP PCS. That is, -mfloat-abi=hard.</td>
</tr>
<tr>
<td>Name</td>
<td>Value</td>
<td>When defined</td>
</tr>
<tr>
<td>-------------------------------</td>
<td>-------</td>
<td>------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>__ARM_SIZEOF_MINIMAL_ENUM</td>
<td>value</td>
<td>Specifies the size of the minimal enumeration type. Set to either 1 or 4 depending on whether -fshort-enums is specified or not.</td>
</tr>
<tr>
<td>__ARM_SIZEOF_WCHAR_T</td>
<td>value</td>
<td>Specifies the size of wchar in bytes. Set to 2 if -fshort-wchar is specified, or 4 if -fno-short-wchar is specified. Note: The default size is 4, because -fno-short-wchar is set by default.</td>
</tr>
<tr>
<td>__ARMCOMPILER_VERSION</td>
<td>Mmmuu xx</td>
<td>Always set. Specifies the version number of the compiler, armclang. The format is Mmmuu xx, where: M is the major version number, 6. mm is the minor version number. uu is the update number. xx is reserved for Arm internal use. You can ignore this for the purposes of checking whether the current release is a specific version or within a range of versions. For example, version 6.3 update 1 is displayed as 6030154, where 54 is a number for Arm internal use.</td>
</tr>
<tr>
<td>__ARMCC_VERSION</td>
<td>Mmmuu xx</td>
<td>A synonym for __ARMCOMPILER_VERSION.</td>
</tr>
<tr>
<td><strong>arm</strong></td>
<td>1</td>
<td>Defined when targeting AArch32 state with --target=arm-arm-none-eabi. See also <strong>aarch64</strong>.</td>
</tr>
<tr>
<td><strong>aarch64</strong></td>
<td>1</td>
<td>Defined when targeting AArch64 state with --target=aarch64-arm-none-eabi. See also <strong>arm</strong>.</td>
</tr>
<tr>
<td>__cplusplus</td>
<td>ver</td>
<td>Defined when compiling C++ code, and set to a value that identifies the targeted C++ standard. For example, when compiling with -xc++ -std=gnu++98, the compiler sets this macro to 199711L. You can use the __cplusplus macro to test whether a file was compiled by a C compiler or a C++ compiler.</td>
</tr>
<tr>
<td><strong>CHAR_UNSIGNED</strong></td>
<td>1</td>
<td>Defined if and only if char is an unsigned type.</td>
</tr>
<tr>
<td>__EXCEPTIONS</td>
<td>1</td>
<td>Defined when compiling a C++ source file with exceptions enabled.</td>
</tr>
<tr>
<td><strong>GNUC</strong></td>
<td>ver</td>
<td>Always set. It is an integer that shows the current major version of the compatible GCC version.</td>
</tr>
<tr>
<td><strong>GNUC_MINOR</strong></td>
<td>ver</td>
<td>Always set. It is an integer that shows the current minor version of the compatible GCC version.</td>
</tr>
<tr>
<td><strong>INTMAX_TYPE</strong></td>
<td>type</td>
<td>Always set. Defines the correct underlying type for the intmax_t typedef.</td>
</tr>
<tr>
<td>Name</td>
<td>Value</td>
<td>When defined</td>
</tr>
<tr>
<td>--------------------</td>
<td>-------</td>
<td>-----------------------------------------------------------------------------</td>
</tr>
<tr>
<td><strong>NO_INLINE</strong></td>
<td>1</td>
<td>Defined if no functions have been inlined. The macro is always defined with optimization level -O0 or if the -fno-inline option is specified.</td>
</tr>
<tr>
<td><strong>OPTIMIZE</strong></td>
<td>1</td>
<td>Defined when -O1, -O2, -O3, -Ofast, -Oz, or -Os is specified.</td>
</tr>
<tr>
<td><strong>OPTIMIZE_SIZE</strong></td>
<td>1</td>
<td>Defined when -Os or -Oz is specified.</td>
</tr>
<tr>
<td><strong>PTRDIFF_TYPE</strong></td>
<td>type</td>
<td>Always set. Defines the correct underlying type for the ptrdiff_t typedef.</td>
</tr>
<tr>
<td><strong>SIZE_TYPE</strong></td>
<td>type</td>
<td>Always set. Defines the correct underlying type for the size_t typedef.</td>
</tr>
<tr>
<td><strong>SOFTFP</strong></td>
<td>1</td>
<td>Set to 1 when compiling with -mfloat-abi=softfp for targets in AArch32 state. Set to 0 otherwise.</td>
</tr>
<tr>
<td><strong>STDC</strong></td>
<td>1</td>
<td>Always set. Signifies that the compiler conforms to ISO Standard C.</td>
</tr>
<tr>
<td><strong>STRICT_ANSI</strong></td>
<td>1</td>
<td>Defined if you specify the --ansi option or specify one of the --std=c* options.</td>
</tr>
<tr>
<td><strong>thumb</strong></td>
<td>1</td>
<td>Defined if you specify the -mthumb option.</td>
</tr>
<tr>
<td><strong>UINTMAX_TYPE</strong></td>
<td>type</td>
<td>Always set. Defines the correct underlying type for the uintmax_t typedef.</td>
</tr>
<tr>
<td><strong>VERSION</strong></td>
<td>ver</td>
<td>Always set. A string that shows the underlying Clang version.</td>
</tr>
<tr>
<td><strong>WCHAR_TYPE</strong></td>
<td>type</td>
<td>Always set. Defines the correct underlying type for the wchar_t typedef.</td>
</tr>
<tr>
<td><strong>WINT_TYPE</strong></td>
<td>type</td>
<td>Always set. Defines the correct underlying type for the wint_t typedef.</td>
</tr>
</tbody>
</table>

**Related reference**

1.71 --version_number on page 1-112
1.65 -std on page 1-105
1.60 -O on page 1-99
1.66 --target on page 1-107
1.45 -marm on page 1-77
1.56 -mthumb on page 1-95
6.3 Inline functions

Inline functions offer a trade-off between code size and performance. By default, the compiler decides whether to inline functions.

With regards to optimization, by default the compiler optimizes for performance with respect to time. If the compiler decides to inline a function, it makes sure to avoid large code growth. When compiling to restrict code size, through the use of -Oz or -Os, the compiler makes sensible decisions about inlining and aims to keep code size to a minimum.

In most circumstances, the decision to inline a particular function is best left to the compiler. Qualifying a function with the __inline__ or inline keywords suggests to the compiler that it inlines that function, but the final decision rests with the compiler. Qualifying a function with __attribute__((always_inline)) forces the compiler to inline the function.

The linker is able to apply some degree of function inlining to short functions.

Note

The default semantic rules for C-source code follow C99 rules. For inlining, it means that when you suggest a function is inlined, the compiler expects to find another, non-qualified, version of the function elsewhere in the code, to use when it decides not to inline. If the compiler cannot find the non-qualified version, it fails with the following error:

"Error: L6218E: Undefined symbol <symbol> (referred from <file>)".

To avoid this problem, there are several options:

- Provide an equivalent, non-qualified version of the function.
- Change the qualifier to static inline.
- Remove the inline keyword, because it is only acting as a suggestion.
- Compile your program using the GNU C90 dialect, using the -std=gnu90 option.

Related reference

2.8 __inline on page 2-129
1.65 -std on page 1-105
3.2 __attribute__((always_inline)) function attribute on page 3-135
6.4 Half-precision floating-point data types

Use the _Float16 data type for 16-bit floating-point values in your C and C++ source files.

Arm Compiler 6 supports two half-precision (16-bit) floating-point scalar data types:
- The IEEE 754-2008 __fp16 data type, defined in the Arm C Language Extensions.
- The _Float16 data type, defined in the C11 extension ISO/IEC TS 18661-3:2015

The __fp16 data type is not an arithmetic data type. The __fp16 data type is for storage and conversion only. Operations on __fp16 values do not use half-precision arithmetic. The values of __fp16 automatically promote to single-precision float (or double-precision double) floating-point data type when used in arithmetic operations. After the arithmetic operation, these values are automatically converted to the half-precision __fp16 data type for storage. The __fp16 data type is available in both C and C++ source language modes.

The _Float16 data type is an arithmetic data type. Operations on _Float16 values use half-precision arithmetic. The _Float16 data type is available in both C and C++ source language modes.

Arm recommends that for new code, you use the _Float16 data type instead of the __fp16 data type. __fp16 is an Arm C Language Extension and therefore requires compliance with the ACLE. _Float16 is defined by the C standards committee, and therefore using _Float16 does not prevent code from being ported to architectures other than Arm. Also, _Float16 arithmetic operations directly map to Armv8.2-A half-precision floating-point instructions when they are enabled on Armv8.2-A and later architectures. This avoids the need for conversions to and from single-precision floating-point, and therefore results in more performant code. If the Armv8.2-A half-precision floating-point instructions are not available, _Float16 values are automatically promoted to single-precision, similar to the semantics of __fp16 except that the results continue to be stored in single-precision floating-point format instead of being converted back to half-precision floating-point format.

To define a _Float16 literal, append the suffix f16 to the compile-time constant declaration. There is no implicit argument conversion between _Float16 and standard floating-point data types. Therefore, an explicit cast is required for promoting _Float16 to a single-precision floating-point format, for argument passing.

```c
extern void ReadFloatValue(float f);

void ReadValues(void)
{
    // Half-precision floating-point value stored in the _Float16 data type.
    const _Float16 h = 1.0f16;

    // There is no implicit argument conversion between _Float16 and standard floating-point data types.
    // Therefore, this call to the ReadFloatValue() function below is not a call to the declared function extern void ReadFloatValue(float f).
    ReadFloatValue(h);

    // An explicit cast is required for promoting a _Float16 value to a single-precision floating-point value.
    // Therefore, this call to the ReadFloatValue() function below is a call to the declared function extern void ReadFloatValue(float f).
    ReadFloatValue((float)h);
    return;
}
```

In an arithmetic operation where one operand is of __fp16 data type and the other is of _Float16 data type, the _Float16 value is first converted to __fp16 value and then the operation is completed as if both operands were of __fp16 data type.

```c
void AddValues(_Float16 a, __fp16 b)
{
    _Float16 c;
    __fp16 d;

    // This addition is evaluated in 16-bit half-precision arithmetic.
    // The result is stored in 16 bits using the _Float16 data type.
    return;
}
```
c = a+a;
// This addition is evaluated in 32-bit single-precision arithmetic.
// The result is stored in 16 bits using the __fp16 data type.
d = b+b;
// The value in variable 'a' in this addition is converted to a __fp16 value.
// And then the addition is evaluated in 32-bit single-precision arithmetic.
// The result is stored in 16 bits using the __fp16 data type.
d = a+b;
return;
}

To generate Armv8.2 half-precision floating-point instructions using armclang, you must use the +fp16 architecture extension, for example:

armclang --target=aarch64-arm-none-eabi -march=armv8.2-a+fp16
armclang --target=aarch64-arm-none-eabi -mcpu=cortex-a75+fp16
armclang --target=arm-arm-none-eabi -march=armv8.2-a+fp16
armclang --target=arm-arm-none-eabi -mcpu=cortex-a75+fp16

Related reference
1.44 -march on page 1-73
1.48 -mcpu on page 1-81
6.7 Library support for _Float16 data type on page 6-210

Related information
Using Assembly and Intrinsics in C or C++ Code
C language extensions
List of intrinsics
Arm C Language Extensions
6.5 Half-precision floating-point number format

Arm Compiler supports the half-precision floating-point __fp16 type.

Half-precision is a floating-point format that occupies 16 bits. Architectures that support half-precision floating-point values include:

- The Armv8 architecture.
- The Armv7 FPv5 architecture.
- The Armv7 VFPv4 architecture.
- The Armv7 VFPv3 architecture (as an optional extension).

If the target hardware does not support half-precision floating-point values, the compiler uses the floating-point library fplib to provide software support for half-precision.

--- Note ---
The __fp16 type is a storage format only. For purposes of arithmetic and other operations, __fp16 values in C or C++ expressions are automatically promoted to float.

--- Half-precision floating-point format ---

Arm Compiler uses the half-precision binary floating-point format defined by IEEE 754r, a revision to the IEEE 754 standard:

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

Where:

- S (bit[15]): Sign bit
- E (bits[14:10]): Biased exponent
- T (bits[9:0]): Mantissa.

The meanings of these fields are as follows:

- **IF E==31:**
  - IF T=0: Value = Signed infinity
  - IF T!=0: Value = Nan
    - T[9] determines Quiet or Signalling:
      - 0: Quiet NaN
      - 1: Signalling NaN
  - **IF 0<E<31:**
    - Value = (-1)^S x 2^(E-15) x (1 + (2^(-10) x T))
  - **IF E==0:**
    - IF T=0: Value = Signed zero
    - IF T!=0: Value = (-1)^S x 2^(-14) x (0 + (2^(-10) x T))

--- Note ---
See the Arm® C Language Extensions for more information.

--- Related information ---

Arm C Language Extensions
### 6.6 Half-precision floating-point intrinsics

Arm Compiler 6 provides BETA support for the ACLE defined Armv8.2-A half-precision floating-point intrinsics in AArch64 state.

--- **Note** ---

This topic describes a [BETA] feature. See [Support level definitions](#) on page 1-19.

---

To see the half-precision floating-point intrinsics, you can search for `float16` from the list of intrinsics on [Arm Developer](#).

`arm_neon.h` defines the intrinsics for the vector half-precision floating-point intrinsics.

`arm_fp16.h` defines the intrinsics for the scalar half-precision floating-point intrinsics.

The example below demonstrates the use of the half-precision floating-point intrinsics in AArch64 state.

```c
// foo.c
#include <arm_neon.h>
#include <arm_fp16.h>

_Float16 goo(void) {
    _Float16 a = 1.0f16;
    float16x4_t b = {1.0, 2.0, 3.0, 4.0};

    a = vabsh_f16(a); // scalar half-precision floating-point intrinsic
    b = vabs_f16(b);  // vector half-precision floating-point intrinsic

    return a;
}
```

To compile the example for AArch64 state, use the command:

```
armclang --target=aarch64-arm-none-eabi -march=armv8.2-a+fp16 -std=c99 -c foo.c -o foo.o
```

--- **Note** ---

Arm Compiler 6 does not support the half-precision floating-point intrinsics in AArch32 state. However, in AArch32, you can use the `_Float16` data type, or use the Armv8.2 half-precision floating-point instructions in `armclang` inline or integrated assembly.

---

**Related reference**

1.44 `-march` on page 1-73
1.48 `-mcpu` on page 1-81

**Related information**

* Using Assembly and Intrinsics in C or C++ Code
  * C language extensions
  * List of intrinsics
  * Arm C Language Extensions
6.7 Library support for _Float16 data type

The C standard library in Arm Compiler 6 does not support the _Float16 data type.

If you want to use any of the functions from the C standard library on the _Float16 data type, then you must manually cast the _Float16 value to a single-precision, or double-precision value, and then use the appropriate library function.

Also, the library function printf does not have a string format specifier for the _Float16 data type. Therefore an explicit cast is required for the _Float16 data type. The following example casts the _Float16 value to a double for use in the printf function.

```
// foo.c
#include <stdlib.h>
#include <stdio.h>
_Float16 goo(void)
{
    _Float16 n = 1.0f16;
    // Cast the _Float16 value n to a double because there is no string format specifier for half-precision floating-point values.
    printf ("Hello World %f \n", (double)n);
    return n;
}
```

To compile this example with armclang, use the command:

```
armclang --target=arm-arm-none-eabi -march=armv8.2-a+fp16 -std=c90 -c foo.c -o foo.o
```

The printf function does not automatically cast the _Float16 value. If you do not manually cast the _Float16 value, armclang produces the -Wformat diagnostic message.

```
warning: format specifies type 'double' but the argument has type '_Float16' [-Wformat]
printf ("Hello World %f\n", n);
```

Related reference
1.44 -march on page 1-73
1.48 -mcpu on page 1-81

Related information
C language extensions
List of intrinsics
Arm C Language Extensions
### 6.8 TT instruction intrinsics

Intrinsics are available to support TT instructions depending on the value of the predefined macro `__ARM_FEATURE_CMSE`.

#### TT intrinsics

The following table describes the TT intrinsics that are available when `__ARM_FEATURE_CMSE` is set to either 1 or 3:

<table>
<thead>
<tr>
<th>Intrinsic</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>cmse_address_info_t cmse_TT(void *p)</td>
<td>Generates a TT instruction.</td>
</tr>
<tr>
<td>cmse_address_info_t cmse_TT_fptr(p)</td>
<td>Generates a TT instruction. The argument p can be any function pointer type.</td>
</tr>
<tr>
<td>cmse_address_info_t cmse_TTT(void *p)</td>
<td>Generates a TT instruction with the T flag.</td>
</tr>
<tr>
<td>cmse_address_info_t cmse_TTT_fptr(p)</td>
<td>Generates a TT instruction with the T flag. The argument p can be any function pointer type.</td>
</tr>
</tbody>
</table>

When `__ARM_BIG_ENDIAN` is not set, the result of the intrinsics is returned in the following C type:

```c
typedef union {
  struct cmse_address_info {
    unsigned mpu_region:8;
    unsigned :8;
    unsigned mpu_region_valid:1;
    unsigned :1;
    unsigned read_ok:1;
    unsigned readwrite_ok:1;
    unsigned :12;
  } flags;
  unsigned value;
} cmse_address_info_t;
```

When `__ARM_BIG_ENDIAN` is set, the bit-fields in the type are reversed such that they have the same bit-offset as little-endian systems following the rules specified by *Procedure Call Standard for the Arm® Architecture*.

#### TT intrinsics for Armv8-M Security Extension

The following table describes the TT intrinsics for Armv8-M Security Extension that are available when `__ARM_FEATURE_CMSE` is set to 3:

<table>
<thead>
<tr>
<th>Intrinsic</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>cmse_address_info_t cmse_TTA(void *p)</td>
<td>Generates a TT instruction with the A flag.</td>
</tr>
<tr>
<td>cmse_address_info_t cmse_TTA_fptr(p)</td>
<td>Generates a TT instruction with the A flag. The argument p can be any function pointer type.</td>
</tr>
<tr>
<td>cmse_address_info_t cmse_TTAT(void *p)</td>
<td>Generates a TT instruction with the T and A flag.</td>
</tr>
<tr>
<td>cmse_address_info_t cmse_TTAT_fptr(p)</td>
<td>Generates a TT instruction with the T and A flag. The argument p can be any function pointer type.</td>
</tr>
</tbody>
</table>

When `__ARM_BIG_ENDIAN` is not set, the result of the intrinsics is returned in the following C type:

```c
typedef union {
  struct cmse_address_info {
    unsigned mpu_region:8;
    unsigned :8;
    unsigned mpu_region_valid:1;
    unsigned :1;
    unsigned read_ok:1;
    unsigned readwrite_ok:1;
    unsigned :12;
  } flags;
  unsigned value;
} cmse_address_info_t;
```
When \_\_ARM\_BIG\_Endian is set, the bit-fields in the type are reversed such that they have the same bit-offset as little-endian systems following the rules specified by Procedure Call Standard for the Arm\textsuperscript{\textregistered} Architecture.

In Secure state, the TT instruction returns the Security Attribute Unit (SAU) and Implementation Defined Attribute Unit (IDAU) configuration and recognizes the A flag.

**Address range check intrinsic**

Checking the result of the TT instruction on an address range is essential for programming in C. It is needed to check permissions on objects larger than a byte. You can use the address range check intrinsic to perform permission checks on C objects.

The syntax of this intrinsic is:

```c
void *cmse_check_address_range(void *p, size_t size, int flags)
```

The intrinsic checks the address range from \(p\) to \(p + \text{size} - 1\).

The address range check fails if \(p + \text{size} - 1 < p\).

Some SAU, IDAU and MPU configurations block the efficient implementation of an address range check. This intrinsic operates under the assumption that the configuration of the SAU, IDAU, and MPU is constrained as follows:

- An object is allocated in a single region.
- A stack is allocated in a single region.

These points imply that a region does not overlap other regions.

The TT instruction returns an SAU, IDAU and MPU region number. When the region numbers of the start and end of the address range match, the complete range is contained in one SAU, IDAU, and MPU region. In this case two TT instructions are executed to check the address range.

Regions are aligned at 32-byte boundaries. If the address range fits in one 32-byte address line, a single TT instruction suffices. This is the case when the following constraint holds:

\[(p \mod 32) + \text{size} <= 32\]

The address range check intrinsic fails if the range crosses any MPU region boundary.

The flags parameter of the address range check consists of a set of values defined by the macros shown in the following table:

<table>
<thead>
<tr>
<th>Macro</th>
<th>Value</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>(No macro)</td>
<td>0</td>
<td>The TT instruction without any flag is used to retrieve the permissions of an address, returned in a cmse_address_info_t structure.</td>
</tr>
<tr>
<td>CMSE_MPU_UNPRIV</td>
<td>4</td>
<td>Sets the T flag on the TT instruction used to retrieve the permissions of an address. Retrieves the unprivileged mode access permissions.</td>
</tr>
</tbody>
</table>
Macro | Value | Description
---|---|---
CMSE_MPU_READWRITE | 1 | Checks if the permissions have the `readwrite_ok` field set.
CMSE_MPU_READ | 8 | Checks if the permissions have the `read_ok` field set.

The address range check intrinsic returns `p` on a successful check, and `NULL` on a failed check. The check fails if any other value is returned that is not one of those listed in the table, or is not a combination of those listed.

Arm recommends that you use the returned pointer to access the checked memory range. This generates a data dependency between the checked memory and all its subsequent accesses and prevents these accesses from being scheduled before the check.

The following intrinsic is defined when the `__ARM_FEATURE_CMSE` macro is set to 1:

<table>
<thead>
<tr>
<th>Intrinsic</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>cmse_check_pointed_object(p, f)</td>
<td>Returns the same value as cmse_check_address_range(p, sizeof(*p), f)</td>
</tr>
</tbody>
</table>

Arm recommends that the return type of this intrinsic is identical to the type of parameter `p`.

**Address range check intrinsic for Armv8-M Security Extension**

The semantics of the intrinsic `cmse_check_address_range()` are extended to handle the extra flag and fields introduced by the Armv8-M Security Extension.

The address range check fails if the range crosses any SAU or IDAU region boundary.

If the macro `__ARM_FEATURE_CMSE` is set to 3, the values accepted by the `flags` parameter are extended with the values defined in the following table:

<table>
<thead>
<tr>
<th>Macro</th>
<th>Value</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>CMSE_AU_NONSECURE</td>
<td>2</td>
<td>Checks if the permissions have the <code>secure</code> field unset.</td>
</tr>
<tr>
<td>CMSE_MPU_NONSECURE</td>
<td>16</td>
<td>Sets the A flag on the TT instruction used to retrieve the permissions of an address.</td>
</tr>
<tr>
<td>CMSE_NONSECURE</td>
<td>18</td>
<td>Combination of CMSE_AU_NONSECURE and CMSE_MPU_NONSECURE.</td>
</tr>
</tbody>
</table>

**Related reference**

6.2 Predefined macros on page 6-200
6.9 Non-secure function pointer intrinsics

A non-secure function pointer is a function pointer that has its LSB unset.

The following table describes the non-secure function pointer intrinsics that are available when __ARM_FEATURE_CMSE is set to 3:

<table>
<thead>
<tr>
<th>Intrinsic</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>cmse_nsfptr_create(p)</td>
<td>Returns the value of p with its LSB cleared. The argument p can be any function pointer type. Arm recommends that the return type of this intrinsic is identical to the type of its argument.</td>
</tr>
<tr>
<td>cmse_is_nsfptr(p)</td>
<td>Returns non-zero if p has LSB unset, zero otherwise. The argument p can be any function pointer type.</td>
</tr>
</tbody>
</table>

Example

The following example shows how to use these intrinsics:

```
#include <arm_cmse.h>
typedef void __attribute__((cmse_nonsecure_call)) nsfnc(void);
void default_callback(void) { … }

// fp can point to a secure function or a non-secure function
nsfunc *fp = (nsfunc *) default_callback;           // secure function pointer

void __attribute__((cmse_nonsecure_entry)) entry(nsfunc *callback) {
   fp = cmse_nsfptr_create(callback);  // non-secure function pointer
}

void call_callback(void) {
   if (cmse_is_nsfptr(fp)) fp();       // non-secure function call
   else ((void (*)(void)) fp)();       // normal function call
}
```

Related reference

3.3 __attribute__((cmse_nonsecure_call)) function attribute on page 3-136
3.4 __attribute__((cmse_nonsecure_entry)) function attribute on page 3-137

Related information

Building Secure and Non-secure Images Using the Armv8-M Security Extension
Chapter 7
Standard C Implementation Definition

Provides information required by the ISO C standard for conforming C implementations.

It contains the following sections:

• 7.1 Implementation Definition on page 7-216.
• 7.2 Translation on page 7-217.
• 7.3 Translation limits on page 7-218.
• 7.4 Environment on page 7-220.
• 7.5 Identifiers on page 7-222.
• 7.6 Characters on page 7-223.
• 7.7 Integers on page 7-225.
• 7.8 Floating-point on page 7-226.
• 7.9 Arrays and pointers on page 7-227.
• 7.10 Hints on page 7-228.
• 7.11 Structures, unions, enumerations, and bitfields on page 7-229.
• 7.12 Qualifiers on page 7-230.
• 7.13 Preprocessing directives on page 7-231.
• 7.14 Library functions on page 7-233.
• 7.15 Architecture on page 7-238.
7.1 Implementation Definition

Appendix J of the ISO C standard (ISO/IEC 9899:2011 (E)) collates information about portability issues. Sub-clause J3 lists the behavior that each implementation must document. The following topics correspond to the relevant sections of sub-clause J3. They describe aspects of the Arm C Compiler and C library, not defined by the ISO C standard, that are implementation-defined. Whenever the implementation-defined behavior of the Arm C compiler or the C library can be altered and tailored to the execution environment by reimplementing certain functions, that behavior is described as "depends on the environment".

Related reference
7.2 Translation on page 7-217
7.3 Translation limits on page 7-218
7.4 Environment on page 7-220
7.5 Identifiers on page 7-222
7.6 Characters on page 7-223
7.7 Integers on page 7-225
7.8 Floating-point on page 7-226
7.9 Arrays and pointers on page 7-227
7.10 Hints on page 7-228
7.11 Structures, unions, enumerations, and bitfields on page 7-229
7.12 Qualifiers on page 7-230
7.13 Preprocessing directives on page 7-231
7.14 Library functions on page 7-233
7.15 Architecture on page 7-238
7.2 Translation

Describes implementation-defined aspects of the Arm C compiler and C library relating to translation, as required by the ISO C standard.

How a diagnostic is identified (3.10, 5.1.1.3).

Diagnostic messages that the compiler produces are of the form:

```
source-file:line-number:char-number: description [diagnostic-flag]
```

Here:

- **description**
  - Is a text description of the error.

- **diagnostic-flag**
  - Is an optional diagnostic flag of the form `-Wflag`, only for messages that can be suppressed.

Whether each nonempty sequence of white-space characters other than new-line is retained or replaced by one space character in translation phase 3 (5.1.1.2).

Each nonempty sequence of white-space characters, other than new-line, is replaced by one space character.
## 7.3 Translation limits

Describes implementation-defined aspects of the Arm C compiler and C library relating to translation, as required by the ISO C standard.

Section 5.2.4.1 Translation limits of the ISO/IEC 9899:2011 standard requires minimum translation limits that a conforming compiler must accept. The following table gives a summary of these limits. In this table, a limit of memory indicates that Arm Compiler 6 imposes no limit, other than that imposed by the available memory.

### Table 7-1 Translation limits

<table>
<thead>
<tr>
<th>Description</th>
<th>Translation limit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nesting levels of block.</td>
<td>256 (can be increased using the -fbracket-depth option.)</td>
</tr>
<tr>
<td>Nesting levels of conditional inclusion.</td>
<td>memory</td>
</tr>
<tr>
<td>Pointer, array, and function declarators (in any combination) modifying an arithmetic, structure, union, or void type in a declaration.</td>
<td>memory</td>
</tr>
<tr>
<td>Nesting levels of parenthesized declarators within a full declarator.</td>
<td>256 (can be increased using the -fbracket-depth option.)</td>
</tr>
<tr>
<td>Nesting levels of parenthesized expressions within a full expression.</td>
<td>256 (can be increased using the -fbracket-depth option.)</td>
</tr>
<tr>
<td>Significant initial characters in an internal identifier or a macro name.</td>
<td>memory</td>
</tr>
<tr>
<td>Significant initial characters in an external identifier.</td>
<td>memory</td>
</tr>
<tr>
<td>External identifiers in one translation unit.</td>
<td>memory</td>
</tr>
<tr>
<td>Identifiers with block scope declared in one block.</td>
<td>memory</td>
</tr>
<tr>
<td>Macro identifiers simultaneously defined in one preprocessing translation unit.</td>
<td>memory</td>
</tr>
<tr>
<td>Parameters in one function definition.</td>
<td>memory</td>
</tr>
<tr>
<td>Arguments in one function call.</td>
<td>memory</td>
</tr>
<tr>
<td>Parameters in one macro definition.</td>
<td>memory</td>
</tr>
<tr>
<td>Arguments in one macro invocation.</td>
<td>memory</td>
</tr>
<tr>
<td>Characters in a logical source line.</td>
<td>memory</td>
</tr>
<tr>
<td>Characters in a string literal.</td>
<td>memory</td>
</tr>
<tr>
<td>Bytes in an object.</td>
<td>SIZE_MAX</td>
</tr>
<tr>
<td>Nesting levels for #include files.</td>
<td>memory</td>
</tr>
<tr>
<td>Case labels for a switch statement.</td>
<td>memory</td>
</tr>
<tr>
<td>Members in a single structure or union.</td>
<td>memory</td>
</tr>
<tr>
<td>Enumeration constants in a single enumeration.</td>
<td>memory</td>
</tr>
<tr>
<td>Levels of nested structure or union definitions in a single struct-declaration-list.</td>
<td>256 (can be increased using the -fbracket-depth option.)</td>
</tr>
</tbody>
</table>
Related reference
1.9 -fbracket-depth=N on page 1-34
7.15 Architecture on page 7-238
7.4 Environment

Describes implementation-defined aspects of the Arm C compiler and C library relating to environment, as required by the ISO C standard.

The mapping between physical source file multibyte characters and the source character set in translation phase 1 (5.1.1.2).

The compiler interprets the physical source file multibyte characters as UTF-8.

The name and type of the function called at program startup in a freestanding environment (5.1.2.1).

When linking with microlib, the function main() must be declared to take no arguments and must not return.

The effect of program termination in a freestanding environment (5.1.2.1).

The function exit() is not supported by microlib and the function main() must not return.

An alternative manner in which the main function can be defined (5.1.2.2.1).

The main function can be defined in one of the following forms:

```c
int main(void)
int main()
int main(int)
int main(int, char **)
int main(int, char **, char **)
```

The values given to the strings pointed to by the argv argument to main (5.1.2.2.1).

In the generic Arm library the arguments given to main() are the words of the command line not including input/output redirections, delimited by whitespace, except where the whitespace is contained in double quotes.

What constitutes an interactive device (5.1.2.3).

What constitutes an interactive device depends on the environment and the _sys_istty function. The standard I/O streams stdin, stdout, and stderr are assumed to be interactive devices. They are line-buffered at program startup, regardless of what _sys_istty reports for them. An exception is if they have been redirected on the command line.

Whether a program can have more than one thread of execution in a freestanding environment (5.1.2.4).

Depends on the environment. The microlib C library is not thread-safe.
The set of signals, their semantics, and their default handling (7.14).

The `<signal.h>` header defines the following signals:

<table>
<thead>
<tr>
<th>Signal</th>
<th>Value</th>
<th>Semantics</th>
</tr>
</thead>
<tbody>
<tr>
<td>SIGABRT</td>
<td>1</td>
<td>Abnormal termination</td>
</tr>
<tr>
<td>SIGFPE</td>
<td>2</td>
<td>Arithmetic exception</td>
</tr>
<tr>
<td>SIGILL</td>
<td>3</td>
<td>Illegal instruction execution</td>
</tr>
<tr>
<td>SIGINT</td>
<td>4</td>
<td>Interactive attention signal</td>
</tr>
<tr>
<td>SIGSEGV</td>
<td>5</td>
<td>Bad memory access</td>
</tr>
<tr>
<td>SIGTERM</td>
<td>6</td>
<td>Termination request</td>
</tr>
<tr>
<td>SIGSTAK</td>
<td>7</td>
<td>Stack overflow (obsolete)</td>
</tr>
<tr>
<td>SIGRTRED</td>
<td>8</td>
<td>Run-time redirection error</td>
</tr>
<tr>
<td>SIGRTMEM</td>
<td>9</td>
<td>Run-time memory error</td>
</tr>
<tr>
<td>SIGUSR1</td>
<td>10</td>
<td>Available for the user</td>
</tr>
<tr>
<td>SIGUSR2</td>
<td>11</td>
<td>Available for the user</td>
</tr>
<tr>
<td>SIGPVFN</td>
<td>12</td>
<td>Pure virtual function called</td>
</tr>
<tr>
<td>SIGCPPL</td>
<td>13</td>
<td>Not normally used</td>
</tr>
<tr>
<td>SIGOUTOFHEAP</td>
<td>14</td>
<td><code>::operator new</code> or <code>::operator new[]</code> cannot allocate memory</td>
</tr>
</tbody>
</table>

The default handling of all recognized signals is to print a diagnostic message and call `exit()`.

Signal values other than SIGFPE, SIGILL, and SIGSEGV that correspond to a computational exception (7.14.1.1).

No signal values other than SIGFPE, SIGILL, and SIGSEGV correspond to a computational exception.

Signals for which the equivalent of `signal(sig, SIG_IGN)`; is executed at program startup (7.14.1.1).

No signals are ignored at program startup.

The set of environment names and the method for altering the environment list used by the `getenv` function (7.22.4.6).

The default implementation returns `NULL`, indicating that no environment information is available.

The manner of execution of the string by the system function (7.22.4.8).

Depends on the environment. The default implementation of the function uses semihosting.
7.5 Identifiers

Describes implementation-defined aspects of the Arm C compiler and C library relating to identifiers, as required by the ISO C standard.

Which additional multibyte characters may appear in identifiers and their correspondence to universal character names (6.4.2).

Multibyte characters, whose UTF-8 decoded value falls within one of the ranges in Appendix D of ISO/IEC 9899:2011 are allowed in identifiers and correspond to the universal character name with the short identifier (as specified by ISO/IEC 10646) having the same numeric value.

The dollar character $ is allowed in identifiers.

The number of significant initial characters in an identifier (5.2.4.1, 6.4.2).

There is no limit on the number of significant initial characters in an identifier.
7.6 **Characters**

Describes implementation-defined aspects of the Arm C compiler and C library relating to characters, as required by the ISO C standard.

**The number of bits in a byte (3.6).**

The number of bits in a byte is 8.

**The values of the members of the execution character set (5.2.1).**

The values of the members of the execution character set are all the code points defined by ISO/IEC 10646.

**The unique value of the member of the execution character set produced for each of the standard alphabetic escape sequences (5.2.2).**

Character escape sequences have the following values in the execution character set:

<table>
<thead>
<tr>
<th>Escape sequence</th>
<th>Char value</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>\a</td>
<td>7</td>
<td>Attention (bell)</td>
</tr>
<tr>
<td>\b</td>
<td>8</td>
<td>Backspace</td>
</tr>
<tr>
<td>\t</td>
<td>9</td>
<td>Horizontal tab</td>
</tr>
<tr>
<td>\n</td>
<td>10</td>
<td>New line (line feed)</td>
</tr>
<tr>
<td>\v</td>
<td>11</td>
<td>Vertical tab</td>
</tr>
<tr>
<td>\f</td>
<td>12</td>
<td>Form feed</td>
</tr>
<tr>
<td>\r</td>
<td>13</td>
<td>Carriage return</td>
</tr>
</tbody>
</table>

**The value of a char object into which has been stored any character other than a member of the basic execution character set (6.2.5).**

The value of a `char` object into which has been stored any character other than a member of the basic execution character set is the least significant 8 bits of that character, interpreted as unsigned.

**Which of signed char or unsigned char has the same range, representation, and behavior as plain char (6.2.5, 6.3.1.1).**

Data items of type `char` are unsigned by default. The type `unsigned char` has the same range, representation, and behavior as `char`.

**The mapping of members of the source character set (in character constants and string literals) to members of the execution character set (6.4.4.4, 5.1.1.2).**

The execution character set is identical to the source character set.

**The value of an integer character constant containing more than one character or containing a character or escape sequence that does not map to a single-byte execution character (6.4.4.4).**

In C all character constants have type `int`. Up to four characters of the constant are represented in the integer value. The last character in the constant occupies the lowest-order byte of the integer value. Up to three preceding characters are placed at higher-order bytes. Unused bytes are filled with the `\0` (NUL) character.

**The value of a wide-character constant containing more than one multibyte character or a single multibyte character that maps to multiple members of the extended execution character set, or containing a multibyte character or escape sequence not represented in the extended execution character set (6.4.4.4).**

If a wide-character constant contains more than one multibyte character, all but the last such character are ignored.
The current locale used to convert a wide-character constant consisting of a single multibyte character that maps to a member of the extended execution character set into a corresponding wide-character code (6.4.4.4).

Mapping of wide-character constants to the corresponding wide-character code is locale independent.

Whether differently-prefixed wide string literal tokens can be concatenated and, if so, the treatment of the resulting multibyte character sequence (6.4.5).

Differently prefixed wide string literal tokens cannot be concatenated.

The current locale used to convert a wide string literal into corresponding wide-character codes (6.4.5).

Mapping of the wide-characters in a wide string literal into the corresponding wide-character codes is locale independent.

The value of a string literal containing a multibyte character or escape sequence not represented in the execution character set (6.4.5).

The compiler does not check if the value of a multibyte character or an escape sequence is a valid ISO/IEC 10646 code point. Such a value is encoded like the values of the valid members of the execution character set, according to the kind of the string literal (character or wide-character).

The encoding of any of wchar_t, char16_t, and char32_t where the corresponding standard encoding macro (__STDC_ISO_10646__, __STDC_UTF_16__, or __STDC_UTF_32__) is not defined (6.10.8.2).

The symbol __STDC_ISO_10646__ is not defined. Nevertheless every character in the Unicode required set, when stored in an object of type wchar_t, has the same value as the short identifier of that character.

The symbols __STDC_UTF_16__ and __STDC_UTF_32__ are defined.
7.7 Integers

Describes implementation-defined aspects of the Arm C compiler and C library relating to integers, as required by the ISO C standard.

Any extended integer types that exist in the implementation (6.2.5).
No extended integer types exist in the implementation.

Whether signed integer types are represented using sign and magnitude, two’s complement, or ones’ complement, and whether the extraordinary value is a trap representation or an ordinary value (6.2.6.2).
Signed integer types are represented using two's complement with no padding bits. There is no extraordinary value.

The rank of any extended integer type relative to another extended integer type with the same precision (6.3.1.1).
No extended integer types exist in the implementation.

The result of, or the signal raised by, converting an integer to a signed integer type when the value cannot be represented in an object of that type (6.3.1.3).
When converting an integer to a N-bit wide signed integer type and the value cannot be represented in the destination type, the representation of the source operand is truncated to N-bits and the resulting bit patterns is interpreted as a value of the destination type. No signal is raised.

The results of some bitwise operations on signed integers (6.5).
In the bitwise right shift $E1 \gg E2$, if $E1$ has a signed type and a negative value, the value of the result is the integral part of the quotient of $E1 / 2^E2$, except that shifting the value $-1$ yields result $-1$. 


7.8 Floating-point

Describes implementation-defined aspects of the Arm C compiler and C library relating to floating-point operations, as required by the ISO C standard.

The accuracy of the floating-point operations and of the library functions in `<math.h>` and `<complex.h>` that return floating-point results (5.2.4.2.2).

- Floating-point quantities are stored in IEEE format:
  - `float` values are represented by IEEE single-precision values
  - `double` and `long double` values are represented by IEEE double-precision values.

The accuracy of the conversions between floating-point internal representations and string representations performed by the library functions in `<stdio.h>`, `<stdlib.h>`, and `<wchar.h>` (5.2.4.2.2).

The rounding behaviors characterized by non-standard values of `FLT_ROUNDS` (5.2.4.2.2).

- Arm Compiler does not define non-standard values for `FLT_ROUNDS`.

The evaluation methods characterized by non-standard negative values of `FLT_EVAL_METHOD` (5.2.4.2.2).

- Arm Compiler does not define non-standard values for `FLT_EVAL_METHOD`.

The direction of rounding when an integer is converted to a floating-point number that cannot exactly represent the original value (6.3.1.4).

- The direction of rounding when an integer is converted to a floating point number is "round to nearest even".

The direction of rounding when a floating-point number is converted to a narrower floating-point number (6.3.1.5).

- When a floating-point number is converted to a different floating-point type and the value is within the range of the destination type, but cannot be represented exactly, the rounding mode is "round to nearest even", by default.

How the nearest representable value or the larger or smaller representable value immediately adjacent to the nearest representable value is chosen for certain floating constants (6.4.4.2).

- When a floating-point literal is converted to a floating-point value, the rounding mode is "round to nearest even".

Whether and how floating expressions are contracted when not disallowed by the `FP_CONTRACT` pragma (6.5).

- If `-fp-mode=fast`, `-ffast-math`, or `-fp-contract=fast` options are in effect, a floating-point expression can be contracted.

The default state for the `FENV_ACCESS` pragma (7.6.1).

- The default state of the `FENV_ACCESS` pragma is OFF. The state ON is not supported.

Additional floating-point exceptions, rounding classifications, and their macro names (7.6, 7.12), modes, environments, and the default state for the `FP_CONTRACT` pragma (7.12.2).

- No additional floating-point exceptions, rounding classifications, modes, or environments are defined.

- The default state of `FP_CONTRACT` pragma is OFF.
7.9 **Arrays and pointers**

Describes implementation-defined aspects of the Arm C compiler and C library relating to arrays and pointers, as required by the ISO C standard.

**The result of converting a pointer to an integer or vice versa (6.3.2.3).**

Converting a pointer to an integer type with smaller bit width discards the most significant bits of the pointer. Converting a pointer to an integer type with greater bit width zero-extends the pointer. Otherwise the bits of the representation are unchanged.

Converting an unsigned integer to pointer with a greater bit-width zero-extends the integer. Converting a signed integer to pointer with a greater bit-width sign-extends the integer. Otherwise the bits of the representation are unchanged.

**The size of the result of subtracting two pointers to elements of the same array (6.5.6).**

The size of the result of subtracting two pointers to elements of the same array is 4 bytes for Arm instruction set architectures up to and including Armv6, Armv7, and Armv8 and AArch32 state, and 8 bytes for Armv8 and AArch64 state.
7.10 Hints

Describes implementation-defined aspects of the Arm C compiler and C library relating to registers, as required by the ISO C standard.

The extent to which suggestions made by using the register storage-class specifier are effective (6.7.1).

The register storage-class specifier is ignored as a means to control how fast the access to an object is. For example, an object might be allocated in register or allocated in memory regardless of whether it is declared with register storage-class.

The extent to which suggestions made by using the inline function specifier are effective (6.7.4).

The inline function specifier is ignored as a means to control how fast the calls to the function are made. For example, a function might be inlined or not regardless of whether it is declared inline.
### 7.11 Structures, unions, enumerations, and bitfields

Describes implementation-defined aspects of the Arm C compiler and C library relating to structures, unions, enumerations, and bitfields, as required by the ISO C standard.

**Whether a plain `int` bit-field is treated as a signed `int` bit-field or as an unsigned `int` bit-field (6.7.2, 6.7.2.1).**

Plain `int` bitfields are signed.

**Allowable bit-field types other than `_Bool`, `signed int`, and `unsigned int` (6.7.2.1).**

Enumeration types, `long` and `long long` (signed and unsigned) are allowed as bitfield types.

**Whether atomic types are permitted for bit-fields (6.7.2.1).**

Atomic types are not permitted for bitfields.

**Whether a bit-field can straddle a storage-unit boundary (6.7.2.1).**

A bitfield cannot straddle a storage-unit boundary.

**The order of allocation of bit-fields within a unit (6.7.2.1).**

Within a storage unit, successive bit-fields are allocated from low-order bits towards high-order bits when compiling for little-endian, or from the high-order bits towards low-order bits when compiling for big-endian.

**The alignment of non-bit-field members of structures (6.7.2.1). This should present no problem unless binary data written by one implementation is read by another.**

The non-bitfield members of structures of a scalar type are aligned to their size. The non-bitfield members of an aggregate type are aligned to the maximum of the alignments of each top-level member.

**The integer type compatible with each enumerated type (6.7.2.2).**

An enumerated type is compatible with `int` or `unsigned int`. If both the signed and the unsigned integer types can represent the values of the enumerators, the unsigned variant is chosen. If a value of an enumerator cannot be represented with `int` or `unsigned int`, then `long long` or `unsigned long long` is used.
7.12 Qualifiers

Describes implementation-defined aspects of the Arm C compiler and C library relating to qualifiers, as required by the ISO C standard.

What constitutes an access to an object that has volatile-qualified type (6.7.3).

- Modifications of an object that has a volatile qualified type constitutes an access to that object.
- Value computation of an lvalue expression with a volatile qualified type constitutes an access to the corresponding object, even when the value is discarded.
7.13 Preprocessing directives

Describes implementation-defined aspects of the Arm C compiler and C library relating to preprocessing directives, as required by the ISO C standard.

The locations within #pragma directives where header name preprocessing tokens are recognized (6.4, 6.4.7).

The compiler does not support pragmas, which refer to headers.

How sequences in both forms of header names are mapped to headers or external source file names (6.4.7).

In both forms of the #include directive, the character sequences are mapped to external header names.

Whether the value of a character constant in a constant expression that controls conditional inclusion matches the value of the same character constant in the execution character set (6.10.1).

The value of a character constant in conditional inclusion expression is the same as the value of the same constant in the execution character set.

Whether the value of a single-character character constant in a constant expression that controls conditional inclusion may have a negative value (6.10.1).

Single-character constants in conditional inclusion expressions have non-negative values.

The places that are searched for an included < > delimited header, and how the places are specified or the header is identified (6.10.2).

If the character sequence begins with the / character, it is interpreted as an absolute file path name.

Otherwise, the character sequence is interpreted as a file path, relative to one of the following directories:

- The sequence of the directories, given via the -I command line option, in the command line order.
- The include subdirectory in the compiler installation directory.

How the named source file is searched for in an included " " delimited header (6.10.2).

If the character sequence begins with the / character, it is interpreted as an absolute file path name.

Otherwise, the character sequence interpreted as a file path, relative to the parent directory of the source file, which contains the #include directive.

The method by which preprocessing tokens (possibly resulting from macro expansion) in a #include directive are combined into a header name (6.10.2).

After macro replacement, the sequence of preprocessing tokens should be in one of the following two forms:

- A single string literal. The escapes in the string are not processed and adjacent string literals are not concatenated. Then the rules for double-quoted includes apply.
- A sequence of preprocessing tokens, starting with < and terminating with >. Sequences of whitespace characters, if any, are replaced by a single space. Then the rules for angle-bracketed includes apply.

The nesting limit for #include processing (6.10.2).

There is no limit to the nesting level of files included with #include.

Whether the # operator inserts a \ character before the \ character that begins a universal character name in a character constant or string literal (6.10.3.2).

A \ character is inserted even before the \ character that begins a universal character name.
The behavior on each recognized non-standard C #pragma directive (6.10.6).

For the behavior of each non-standard C #pragma directive, see Chapter 5 Compiler-specific Pragmas on page 5-187.

The definitions for __DATE__ and __TIME__ when respectively, the date and time of translation are not available (6.10.8.1).

The date and time of the translation are always available on all supported platforms.
7.14 Library functions

Describes implementation-defined aspects of the Arm C compiler and C library relating to library functions, as required by the ISO C standard.

Any library facilities available to a freestanding program, other than the minimal set required by clause 4 (5.1.2.1).

The Arm Compiler provides the Arm C Micro-library. For information about facilities, provided by this library, see The Arm® C Micro-library in the Arm® C and C++ Libraries and Floating-Point Support User Guide.

The format of the diagnostic printed by the assert macro (7.2.1.1).

The assert macro prints a diagnostic in the format:

```
*** assertion failed: expression, filename, line number
```

The representation of the floating-points status flags stored by the fegetexceptflag function (7.6.2.2).

The `fegetexceptflag` function stores the floating-point status flags as a bit set as follows:

- Bit 0 (0x01) is for the Invalid Operation exception.
- Bit 1 (0x02) is for the Divide by Zero exception.
- Bit 2 (0x04) is for the Overflow exception.
- Bit 3 (0x08) is for the Underflow exception.
- Bit 4 (0x10) is for the Inexact Result exception.

Whether the `feraiseexcept` function raises the Inexact floating-point exception in addition to the Overflow or Underflow floating-point exception (7.6.2.3).

The `feraiseexcept` function does not raise by itself the Inexact floating-point exception when it raises either an Overflow or Underflow exception.

Strings other than "C" and "" that can be passed as the second argument to the setlocale function (7.11.1.1).

What other strings can be passed as the second argument to the `setlocale` function depends on which __use_X_ctype symbol is imported (__use_iso8859_ctype, __use_sjis_ctype, or __use_utf8_ctype), and on user-defined locales.

The types defined for `float_t` and `double_t` when the value of the FLT_EVAL_METHOD macro is less than 0 (7.12).

The types defined for `float_t` and `double_t` are float and double, respectively, for all the supported values of FLT_EVAL_METHOD.
Domain errors for the mathematics functions, other than those required by this International Standard (7.12.1).

The following functions return additional domain errors under the specified conditions (the function name refers to all the variants of the function. For example, the acos entry applies to acos, ascof, and acosl functions):

<table>
<thead>
<tr>
<th>Function</th>
<th>Condition</th>
<th>Return value</th>
<th>Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>acos(x)</td>
<td>abs(x) &gt; 1</td>
<td>NaN</td>
<td>EDOM</td>
</tr>
<tr>
<td>asin(x)</td>
<td>abs(x) &gt; 1</td>
<td>NaN</td>
<td>EDOM</td>
</tr>
<tr>
<td>cos(x)</td>
<td>x == Inf</td>
<td>NaN</td>
<td>EDOM</td>
</tr>
<tr>
<td>sin(x)</td>
<td>x == Inf</td>
<td>NaN</td>
<td>EDOM</td>
</tr>
<tr>
<td>tan(x)</td>
<td>x == Inf</td>
<td>NaN</td>
<td>EDOM</td>
</tr>
<tr>
<td>atanh(x)</td>
<td>abs(x) == 1</td>
<td>Inf</td>
<td>ERANGE</td>
</tr>
<tr>
<td>ilogb(x)</td>
<td>x == 0.0</td>
<td>-INT_MAX</td>
<td>EDOM</td>
</tr>
<tr>
<td>ilogb(x)</td>
<td>x == Inf</td>
<td>INT_MAX</td>
<td>EDOM</td>
</tr>
<tr>
<td>ilogb(x)</td>
<td>x == NaN</td>
<td>FP_ILOGBNAN</td>
<td>EDOM</td>
</tr>
<tr>
<td>log(x)</td>
<td>x &lt; 0</td>
<td>NaN</td>
<td>EDOM</td>
</tr>
<tr>
<td>log(x)</td>
<td>x == 0</td>
<td>-Inf</td>
<td>ERANGE</td>
</tr>
<tr>
<td>log10(x)</td>
<td>x &lt; 0</td>
<td>NaN</td>
<td>EDOM</td>
</tr>
<tr>
<td>log10(x)</td>
<td>x == 0</td>
<td>-Inf</td>
<td>ERANGE</td>
</tr>
<tr>
<td>log1p(x)</td>
<td>x &lt; -1</td>
<td>NaN</td>
<td>EDOM</td>
</tr>
<tr>
<td>log1p(x)</td>
<td>x == -1</td>
<td>-Inf</td>
<td>ERANGE</td>
</tr>
<tr>
<td>log2(x)</td>
<td>x &lt; 0</td>
<td>NaN</td>
<td>EDOM</td>
</tr>
<tr>
<td>log2(x)</td>
<td>x == 0</td>
<td>-Inf</td>
<td>ERANGE</td>
</tr>
<tr>
<td>logb(x)</td>
<td>x == Inf</td>
<td>-Inf</td>
<td>EDOM</td>
</tr>
<tr>
<td>logb(x)</td>
<td>x == Inf</td>
<td>+Inf</td>
<td>EDOM</td>
</tr>
<tr>
<td>pow(x, y)</td>
<td>y &lt; 0 and x == +0 or y is even</td>
<td>+Inf</td>
<td>ERANGE</td>
</tr>
<tr>
<td>pow(x, y)</td>
<td>y &lt; 0 and x == -0 and y is odd</td>
<td>-Inf</td>
<td>ERANGE</td>
</tr>
<tr>
<td>pow(x, y)</td>
<td>y &lt; 0 and x == -0 and y is non-integer</td>
<td>+Inf</td>
<td>ERANGE</td>
</tr>
<tr>
<td>pow(x, y)</td>
<td>x &lt; 0 and y is non-integer</td>
<td>NaN</td>
<td>EDOM</td>
</tr>
<tr>
<td>sqrt(x)</td>
<td>x &lt; 0</td>
<td>NaN</td>
<td>EDOM</td>
</tr>
<tr>
<td>lgamma(x)</td>
<td>x &lt;= 0</td>
<td>Inf</td>
<td>ERANGE</td>
</tr>
<tr>
<td>tgamma(x)</td>
<td>x &lt; 0 and x is integer</td>
<td>NaN</td>
<td>EDOM</td>
</tr>
<tr>
<td>tgamma(x)</td>
<td>x == 0</td>
<td>Inf</td>
<td>ERANGE</td>
</tr>
<tr>
<td>fmod(x, y)</td>
<td>x == Inf</td>
<td>NaN</td>
<td>EDOM</td>
</tr>
<tr>
<td>fmod(x, y)</td>
<td>y == 0</td>
<td>NaN</td>
<td>EDOM</td>
</tr>
<tr>
<td>remainder(x, y)</td>
<td>y == 0</td>
<td>NaN</td>
<td>EDOM</td>
</tr>
<tr>
<td>remquo(x, y, q)</td>
<td>y == 0</td>
<td>NaN</td>
<td>EDOM</td>
</tr>
</tbody>
</table>
The values returned by the mathematics functions on domain errors or pole errors (7.12.1).
See previous table.

The values returned by the mathematics functions on underflow range errors, whether errno is set to the value of the macro ERANGE when the integer expression math_errnohandling & MATH_ERRNO is nonzero, and whether the Underflow floating-point exception is raised when the integer expression math_errnohandling & MATH_ERREXCEPT is nonzero. (7.12.1).
On underflow, the mathematics functions return 0.0, the errno is set to ERANGE, and the Underflow and Inexact exceptions are raised.

Whether a domain error occurs or zero is returned when an fmod function has a second argument of zero (7.12.10.1).
When the second argument of fmod is zero, a domain error occurs.

Whether a domain error occurs or zero is returned when a remainder function has a second argument of zero (7.12.10.2).
When the second argument of the remainder function is zero, a domain error occurs and the function returns NaN.

The base-2 logarithm of the modulus used by the remquo functions in reducing the quotient (7.12.10.3).
The base-2 logarithm of the modulus used by the remquo functions in reducing the quotient is 4.

Whether a domain error occurs or zero is returned when a remquo function has a second argument of zero (7.12.10.3).
When the second argument of the remquo function is zero, a domain error occurs.

Whether the equivalent of signal(sig, SIG_DFL); is executed prior to the call of a signal handler, and, if not, the blocking of signals that is performed (7.14.1.1).
The equivalent of signal(sig, SIG_DFL) is executed before the call to a signal handler.

The null pointer constant to which the macro NULL expands (7.19).
The macro NULL expands to 0.

Whether the last line of a text stream requires a terminating new-line character (7.21.2).
The last line of text stream does not require a terminating new-line character.

Whether space characters that are written out to a text stream immediately before a new-line character appear when read in (7.21.2).
Space characters, written out to a text stream immediately before a new-line character, appear when read back.

The number of null characters that may be appended to data written to a binary stream (7.21.2).
No null characters are appended at the end of a binary stream.

Whether the file position indicator of an append-mode stream is initially positioned at the beginning or end of the file (7.21.3).
The file position indicator of an append-mode stream is positioned initially at the end of the file.

Whether a write on a text stream causes the associated file to be truncated beyond that point (7.21.3).
A write to a text stream causes the associated file to be truncated beyond the point where the write occurred if this is the behavior of the device category of the file.

The characteristics of file buffering (7.21.3).
The C Library supports unbuffered, fully buffered, and line buffered streams.

Whether a zero-length file actually exists (7.21.3).
A zero-length file exists, even if no characters are written by an output stream.

The rules for composing valid file names (7.21.3).
Valid file names depend on the execution environment.
Whether the same file can be simultaneously open multiple times (7.21.3).
A file can be opened many times for reading, but only once for writing or updating.

The nature and choice of encodings used for multibyte characters in files (7.21.3).
The character input and output functions on wide-oriented streams interpret the multibyte characters in the associated files according to the current chosen locale.

The effect of the remove function on an open file (7.21.4.1).
Depends on the environment.

The effect if a file with the new name exists prior to a call to the rename function (7.21.4.2).
Depends on the environment.

Whether an open temporary file is removed upon abnormal program termination (7.21.4.3).
Depends on the environment.

Which changes of mode are permitted (if any), and under what circumstances (7.21.5.4)
No changes of mode are permitted.

The style used to print an infinity or NaN, and the meaning of any n-char or n-wchar sequence printed for a NaN (7.21.6.1, 7.29.2.1).
A double argument to the printf family of functions, representing an infinity is converted to [-]inf. A double argument representing a NaN is converted to [-]nan. The F conversion specifier, produces [-]INF or [-]NAN, respectively.

The output for %p conversion in the fprintf or fwprintf function (7.21.6.1, 7.29.2.1).
The fprintf and fwprintf functions print %p arguments in lowercase hexadecimal format as if a precision of 8 (16 for 64-bit) had been specified. If the variant form (%#p) is used, the number is preceded by the character @.

Note
Using the # character with the p format specifier is undefined behavior in C11. armclang issues a warning.

The interpretation of a - character that is neither the first nor the last character, nor the second where a ^ character is the first, in the scanlist for %] conversion in the fscanf or fwscanf function (7.21.6.2, 7.29.2.1).
scanf and fwscanf always treat the character - in a %...[...] argument as a literal character.

The set of sequences matched by a %p conversion and the interpretation of the corresponding input item in the fscanf or fwscanf function (7.21.6.2, 7.29.2.2).
scanf and fwscanf treat %p arguments exactly the same as %x arguments.

The value to which the macro errno is set by the fgetpos, fseekpos, or ftell functions on failure (7.21.9.1, 7.21.9.3, 7.21.9.4).
On failure, the functions fgetpos, fseekpos, and ftell set the errno to EDOM.

The meaning of any n-char or n-wchar sequence in a string representing a NaN that is converted by the strtod, strtof, strtold, wcstod, wcstof, or wcstold function (7.22.1.3, 7.29.4.1.1).
Any n-char or n-wchar sequence in a string, representing a NaN, that is converted by the strtod, strtof, strtold, wcstod, wcstof, or wcstold functions, is ignored.

Whether or not the strtod, strtof, strtold, wcstod, wcstof, or wcstold function sets errno to ERANGE when underflow occurs (7.22.1.3, 7.29.4.1.1).
The strtod, strtold, wcstod, wcstof, or wcstold functions set errno to ERANGE when underflow occurs.

The strtof function sets the errno to ERANGE by default (equivalent to compiling with -ffp-mode=std) and doesn't, when compiling with -ffp-mode=full or -fno-fast-math.
Whether the calloc, malloc, and realloc functions return a null pointer or a pointer to an allocated object when the size requested is zero (7.22.3).

If the size of area requested is zero, malloc() and calloc() return a pointer to a zero-size block.

If the size of area requested is zero, realloc() returns NULL.

Whether open streams with unwritten buffered data are flushed, open streams are closed, or temporary files are removed when the abort or _Exit function is called (7.22.4.1, 7.22.4.5).

The function _Exit flushes the streams, closes all open files, and removes the temporary files.

The function abort() does not flush the streams and does not remove temporary files.

The termination status returned to the host environment by the abort, exit, _Exit(), or quick_exit function (7.22.4.1, 7.22.4.4, 7.22.4.5, 7.22.4.7).

The function abort() returns termination status 1 to the host environment. The functions exit() and _Exit() return the same value as the argument that was passed to them.

The value returned by the system function when its argument is not a null pointer (7.22.4.8).

The value returned by the system function when its argument is not a null pointer depends on the environment.

The range and precision of times representable in clock_t and time_t (7.27).

The types clock_t and time_t can represent integers in the range [0, 4294967295].

The local time zone and Daylight Saving Time (7.27.1).

Depends on the environment.

The era for the clock function (7.27.2.1).

Depends on the environment.

The TIME_UTC epoch (7.27.2.5).

TIME_UTC and timespec_get are not implemented.

The replacement string for the %Z specifier to the strftime and wcsftime functions in the "C" locale (7.27.3.5, 7.29.5.1).

The functions strftime and wcsftime replace %Z with an empty string.

Whether the functions in <math.h> honor the rounding direction mode in an IEC 60559 conformant implementation, unless explicitly specified otherwise (F.10).


Related information

The Arm C and C++ Libraries
7.15 Architecture

Describes implementation-defined aspects of the Arm C compiler and C library relating to architecture, as required by the ISO C standard.
The values or expressions assigned to the macros specified in the headers `<float.h>`, `<limits.h>`, and `<stdint.h>` (5.2.4.2, 7.20.2, 7.20.3).

--- Note ---
If the value column is empty, this means no value is assigned to the corresponding macro.
---

The values of the macros in `<float.h>` are:

<table>
<thead>
<tr>
<th>Macro name</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>FLT_ROUNDS</td>
<td>1</td>
</tr>
<tr>
<td>FLT_EVAL_METHOD</td>
<td>0</td>
</tr>
<tr>
<td>FLT_HAS_SUBNORM</td>
<td></td>
</tr>
<tr>
<td>DBL_HAS_SUBNORM</td>
<td></td>
</tr>
<tr>
<td>LDBL_HAS_SUBNORM</td>
<td></td>
</tr>
<tr>
<td>FLT_RADIX</td>
<td>2</td>
</tr>
<tr>
<td>FLT_MANT_DIG</td>
<td>24</td>
</tr>
<tr>
<td>DBL_MANT_DIG</td>
<td>53</td>
</tr>
<tr>
<td>LDBL_MANT_DIG</td>
<td>53</td>
</tr>
<tr>
<td>FLT_DECIMAL_DIG</td>
<td></td>
</tr>
<tr>
<td>DBL_DECIMAL_DIG</td>
<td></td>
</tr>
<tr>
<td>LDBL_DECIMAL_DIG</td>
<td></td>
</tr>
<tr>
<td>DECIMAL_DIG</td>
<td>17</td>
</tr>
<tr>
<td>FLT_DIG</td>
<td>6</td>
</tr>
<tr>
<td>DBL_DIG</td>
<td>15</td>
</tr>
<tr>
<td>LDBL_DIG</td>
<td>15</td>
</tr>
<tr>
<td>FLT_MIN_EXP</td>
<td>(-125)</td>
</tr>
<tr>
<td>DBL_MIN_EXP</td>
<td>(-1021)</td>
</tr>
<tr>
<td>LDBL_MIN_EXP</td>
<td>(-1021)</td>
</tr>
<tr>
<td>FLT_MIN_10_EXP</td>
<td>(-37)</td>
</tr>
<tr>
<td>DBL_MIN_10_EXP</td>
<td>(-307)</td>
</tr>
<tr>
<td>LDBL_MIN_10_EXP</td>
<td>(-307)</td>
</tr>
<tr>
<td>FLT_MAX_EXP</td>
<td>128</td>
</tr>
<tr>
<td>DBL_MAX_EXP</td>
<td>1024</td>
</tr>
<tr>
<td>LDBL_MAX_EXP</td>
<td>1024</td>
</tr>
<tr>
<td>FLT_MAX_10_EXP</td>
<td>38</td>
</tr>
<tr>
<td>DBL_MAX_10_EXP</td>
<td>308</td>
</tr>
<tr>
<td>LDBL_MAX_10_EXP</td>
<td>308</td>
</tr>
<tr>
<td>FLT_MAX</td>
<td>3.40282347e+38F</td>
</tr>
<tr>
<td>DBL_MAX</td>
<td>1.79769313486231571e+308</td>
</tr>
<tr>
<td>LDBL_MAX</td>
<td>1.79769313486231571e+308L</td>
</tr>
</tbody>
</table>
The values of the macros in `<limits.h>` are:

<table>
<thead>
<tr>
<th>Macro name</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>FLT_EPSILON</td>
<td>(1.19209290 \times 10^{-7})</td>
</tr>
<tr>
<td>DBL_EPSILON</td>
<td>(2.2204460492503131 \times 10^{-16})</td>
</tr>
<tr>
<td>LDBL_EPSILON</td>
<td>(2.2204460492503131 \times 10^{-16})</td>
</tr>
<tr>
<td>FLT_MIN</td>
<td>(1.175494351 \times 10^{-38})</td>
</tr>
<tr>
<td>DBL_MIN</td>
<td>(2.22507385850720138 \times 10^{-308})</td>
</tr>
<tr>
<td>LDBL_MIN</td>
<td>(2.22507385850720138 \times 10^{-308})</td>
</tr>
<tr>
<td>FLT_TRUE_MIN</td>
<td>\text{not defined}</td>
</tr>
<tr>
<td>DBL_TRUE_MIN</td>
<td>\text{not defined}</td>
</tr>
<tr>
<td>LDBL_TRUE_MIN</td>
<td>\text{not defined}</td>
</tr>
</tbody>
</table>

The values of the macros in `<stdint.h>` are:

<table>
<thead>
<tr>
<th>Macro name</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>CHAR_BIT</td>
<td>8</td>
</tr>
<tr>
<td>SCHAR_MIN</td>
<td>(-128)</td>
</tr>
<tr>
<td>SCHAR_MAX</td>
<td>127</td>
</tr>
<tr>
<td>UCHAR_MAX</td>
<td>255</td>
</tr>
<tr>
<td>CHAR_MIN</td>
<td>0</td>
</tr>
<tr>
<td>CHAR_MAX</td>
<td>255</td>
</tr>
<tr>
<td>MB_LEN_MAX</td>
<td>6</td>
</tr>
<tr>
<td>SHRT_MIN</td>
<td>(-0x8000)</td>
</tr>
<tr>
<td>SHRT_MAX</td>
<td>(0x7fff)</td>
</tr>
<tr>
<td>USHRT_MAX</td>
<td>(65535)</td>
</tr>
<tr>
<td>INT_MIN</td>
<td>(~0x7fffffff)</td>
</tr>
<tr>
<td>INT_MAX</td>
<td>(0x7fffffff)</td>
</tr>
<tr>
<td>UINT_MAX</td>
<td>(~0xffffffff)</td>
</tr>
<tr>
<td>LONG_MIN</td>
<td>(~0xffffffff)</td>
</tr>
<tr>
<td>LONG_MAX</td>
<td>(0x7fffffff)</td>
</tr>
<tr>
<td>LONG_MIN (64-bit)</td>
<td>(~0x7fffffffffffffff)</td>
</tr>
<tr>
<td>LONG_MAX (64-bit)</td>
<td>(0x7ffffffff)</td>
</tr>
<tr>
<td>ULONG_MAX</td>
<td>(~0xffffffff)</td>
</tr>
<tr>
<td>ULONG_MAX (64-bit)</td>
<td>(~0xffffffff)</td>
</tr>
<tr>
<td>ULONGLONG_MAX</td>
<td>(~0xffffffffffffffff)</td>
</tr>
<tr>
<td>LONGLONG_MIN</td>
<td>(~0xffffffffffffffff)</td>
</tr>
<tr>
<td>LONGLONG_MAX</td>
<td>(0xffffffffffffffff)</td>
</tr>
<tr>
<td>ULLONG_MAX</td>
<td>(~0xffffffffffffffff)</td>
</tr>
<tr>
<td>Macro name</td>
<td>Value</td>
</tr>
<tr>
<td>--------------------</td>
<td>-----------------------------------</td>
</tr>
<tr>
<td>INT8_MIN</td>
<td>-128</td>
</tr>
<tr>
<td>INT8_MAX</td>
<td>127</td>
</tr>
<tr>
<td>UINT8_MAX</td>
<td>255</td>
</tr>
<tr>
<td>INT16_MIN</td>
<td>-32768</td>
</tr>
<tr>
<td>INT16_MAX</td>
<td>32767</td>
</tr>
<tr>
<td>UINT16_MAX</td>
<td>65535</td>
</tr>
<tr>
<td>INT32_MIN</td>
<td>(~0x7fffffff)</td>
</tr>
<tr>
<td>INT32_MAX</td>
<td>2147483647</td>
</tr>
<tr>
<td>UINT32_MAX</td>
<td>4294967295u</td>
</tr>
<tr>
<td>INT64_MIN (64-bit)</td>
<td>(~0x7fffffffffffffffffL)</td>
</tr>
<tr>
<td>INT64_MAX (64-bit)</td>
<td>(9223372036854775807L)</td>
</tr>
<tr>
<td>UINT64_MAX (64-bit)</td>
<td>(18446744073709551615uL)</td>
</tr>
<tr>
<td>INT_LEAST8_MIN</td>
<td>-128</td>
</tr>
<tr>
<td>INT_LEAST8_MAX</td>
<td>127</td>
</tr>
<tr>
<td>UINT_LEAST8_MAX</td>
<td>255</td>
</tr>
<tr>
<td>INT_LEAST16_MIN</td>
<td>-32768</td>
</tr>
<tr>
<td>INT_LEAST16_MAX</td>
<td>32767</td>
</tr>
<tr>
<td>UINT_LEAST16_MAX</td>
<td>65535</td>
</tr>
<tr>
<td>INT_LEAST32_MIN</td>
<td>(~0x7fffffff)</td>
</tr>
<tr>
<td>INT_LEAST32_MAX</td>
<td>2147483647</td>
</tr>
<tr>
<td>UINT_LEAST64_MIN</td>
<td>(~0x7fffffffffffffffffLL)</td>
</tr>
<tr>
<td>INT_FAST8_MIN</td>
<td>(~0x7fffffff)</td>
</tr>
<tr>
<td>INT_FAST8_MAX</td>
<td>2147483647</td>
</tr>
<tr>
<td>UINT_FAST8_MAX</td>
<td>4294967295u</td>
</tr>
<tr>
<td>INT_FAST16_MIN</td>
<td>(~0x7fffffff)</td>
</tr>
<tr>
<td>INT_FAST16_MAX</td>
<td>2147483647</td>
</tr>
<tr>
<td>UINT_FAST16_MAX</td>
<td>4294967295u</td>
</tr>
<tr>
<td>Macro name</td>
<td>Value</td>
</tr>
<tr>
<td>---------------------------</td>
<td>------------------------------------------------</td>
</tr>
<tr>
<td>INT_FAST32_MIN</td>
<td>(~0x7fffffff)</td>
</tr>
<tr>
<td>INT_FAST32_MAX</td>
<td>2147483647</td>
</tr>
<tr>
<td>UINT_FAST32_MAX</td>
<td>4294967295u</td>
</tr>
<tr>
<td>INT_FAST64_MIN</td>
<td>(~0x7FFFFFFFFFFFFFFFFL)</td>
</tr>
<tr>
<td>INT_FAST64_MAX</td>
<td>(9223372036854775807LL)</td>
</tr>
<tr>
<td>UINT_FAST64_MAX</td>
<td>(18446744073709551615uLL)</td>
</tr>
<tr>
<td>INT_FAST64_MIN (64-bit)</td>
<td>(~0x7FFFFFFFFFFFFFFFFL)</td>
</tr>
<tr>
<td>INT_FAST64_MAX (64-bit)</td>
<td>(9223372036854775807L)</td>
</tr>
<tr>
<td>UINT_FAST64_MAX (64-bit)</td>
<td>(18446744073709551615uL)</td>
</tr>
<tr>
<td>INTPTR_MIN</td>
<td>(~0x7fffffff)</td>
</tr>
<tr>
<td>INTPTR_MIN (64-bit)</td>
<td>(~0x7FFFFFFFFFFFFFFFFL)</td>
</tr>
<tr>
<td>INTPTR_MAX</td>
<td>2147483647</td>
</tr>
<tr>
<td>INTPTR_MAX (64-bit)</td>
<td>(9223372036854775807LL)</td>
</tr>
<tr>
<td>UINTPTR_MAX</td>
<td>4294967295u</td>
</tr>
<tr>
<td>UINTPTR_MAX (64-bit)</td>
<td>(18446744073709551615uLL)</td>
</tr>
<tr>
<td>INTMAX_MIN</td>
<td>(~0x7FFFFFFFFFFFFFFFFL)</td>
</tr>
<tr>
<td>INTMAX_MAX</td>
<td>(9223372036854775807LL)</td>
</tr>
<tr>
<td>UINTMAX_MAX</td>
<td>(18446744073709551615uLL)</td>
</tr>
<tr>
<td>PTRDIFF_MIN</td>
<td>(~0x7fffffff)</td>
</tr>
<tr>
<td>PTRDIFF_MIN (64-bit)</td>
<td>(~0x7FFFFFFFFFFFFFFFFL)</td>
</tr>
<tr>
<td>PTRDIFF_MAX</td>
<td>2147483647</td>
</tr>
<tr>
<td>PTRDIFF_MAX (64-bit)</td>
<td>(9223372036854775807LL)</td>
</tr>
<tr>
<td>SIG_ATOMIC_MIN</td>
<td>(~0x7fffffff)</td>
</tr>
<tr>
<td>SIG_ATOMIC_MAX</td>
<td>2147483647</td>
</tr>
<tr>
<td>SIZE_MAX</td>
<td>4294967295u</td>
</tr>
<tr>
<td>SIZE_MAX (64-bit)</td>
<td>(18446744073709551615uLL)</td>
</tr>
<tr>
<td>WCHAR_MIN</td>
<td>0</td>
</tr>
<tr>
<td>WCHAR_MAX</td>
<td>0xffffffffU</td>
</tr>
<tr>
<td>WINT_MIN</td>
<td>(~0x7fffffff)</td>
</tr>
<tr>
<td>WINT_MAX</td>
<td>2147483647</td>
</tr>
</tbody>
</table>

The result of attempting to indirectly access an object with automatic or thread storage duration from a thread other than the one with which it is associated (6.2.4).

Access to automatic or thread storage duration objects from a thread other than the one with which the object is associated proceeds normally.
The number, order, and encoding of bytes in any object (when not explicitly specified in this International Standard) (6.2.6.1).

Defined in the Arm EABI.

Whether any extended alignments are supported and the contexts in which they are supported, and valid alignment values other than those returned by an _Alignof expression for fundamental types, if any (6.2.8).

Alignments, including extended alignments, that are a power of 2 and less than or equal to \(0x10000000\), are supported.

The value of the result of the sizeof and _Alignof operators (6.5.3.4).

<table>
<thead>
<tr>
<th>Type</th>
<th>sizeof</th>
<th>_Alignof</th>
</tr>
</thead>
<tbody>
<tr>
<td>char</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>short</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>int</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>long</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>long (64-bit)</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>long long</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>float</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>double</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>long double</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>long double (64-bit)</td>
<td>16</td>
<td>16</td>
</tr>
</tbody>
</table>
Chapter 8
Standard C++ Implementation Definition

Provides information required by the ISO C++ Standard for conforming C++ implementations.

It contains the following sections:
• 8.1 Implementation Definition on page 8-245.
• 8.2 General on page 8-246.
• 8.3 Lexical conventions on page 8-247.
• 8.4 Basic concepts on page 8-248.
• 8.5 Standard conversions on page 8-249.
• 8.6 Expressions on page 8-250.
• 8.7 Declarations on page 8-252.
• 8.8 Declarators on page 8-253.
• 8.9 Templates on page 8-254.
• 8.10 Exception handling on page 8-255.
• 8.11 Preprocessing directives on page 8-256.
• 8.12 Library introduction on page 8-257.
• 8.13 Language support library on page 8-258.
• 8.14 General utilities library on page 8-259.
• 8.15 Strings library on page 8-260.
• 8.16 Localization library on page 8-261.
• 8.17 Containers library on page 8-262.
• 8.18 Input/output library on page 8-263.
• 8.19 Regular expressions library on page 8-264.
• 8.20 Atomic operations library on page 8-265.
• 8.21 Thread support library on page 8-266.
• 8.22 Implementation quantities on page 8-267.
8.1 Implementation Definition

The ISO C++ Standard (ISO/IEC 14882:2014) defines the concept of implementation-defined behavior as the "behavior, for a well-formed program construct and correct data, that depends on the implementation and that each implementation documents".

The following topics document the behavior in the implementation of Arm Compiler 6 of the implementation-defined features of the C++ languages. Each topic provides information from a single chapter in the C++ Standard. The C++ Standard section number relevant to each implementation-defined aspect is provided in parentheses.
8.2 General

Describes general implementation-defined aspects of the Arm C++ compiler and C++ library, as required by the ISO C++ Standard.

How a diagnostic is identified (1.3.6).

Diagnostic messages that the compiler produces are of the form:

```
source-file:line-number:char-number: description [diagnostic-flag]
```

Here:
- **description**
  - Is a text description of the error.
- **diagnostic-flag**
  - Is an optional diagnostic flag of the form `-Wflag`, only for messages that can be suppressed.

Libraries in a freestanding implementation (1.4).
Arm Compiler supports the C99 and the C++11 standard libraries.

Bits in a byte (1.7).
The number of bits in a byte is 8.

What constitutes an interactive device (1.9).
What constitutes an interactive device depends on the environment and what the `_sys_istty` function reports. The standard I/O streams `stdin`, `stdout`, and `stderr` are assumed to be interactive devices. They are line-buffered at program startup, regardless of what `_sys_istty` reports for them. An exception is if they have been redirected on the command line.

Related reference

1.73 `-W` on page 1-114
8.3 Lexical conventions

Describes the lexical conventions of implementation-defined aspects of the Arm C++ compiler and C++ library, as required by the ISO C++ Standard.

**Mapping of the physical source file characters to the basic source character set (2.2).**

The input files are encoded in UTF-8. Due to the design of UTF-8 encoding, the basic source character set is represented in the source file in the same way as the ASCII encoding of the basic character set.

**Physical source file characters (2.2).**

The source file characters are encoded in UTF-8.

**Conversion of characters from source character set to execution character set (2.2).**

The source character set and the execution character set are the same.

**Requirement of source for translation units when locating template definitions (2.2).**

When locating the template definitions related to template instantiations, the source of the translation units that define the template definitions is not required.

**Values of execution character sets (2.3).**

Both the execution character set and the wide execution character set consist of all the code points defined by ISO/IEC 10646.

**Mapping the header name to external source files (2.8).**

In both forms of the `#include` preprocessing directive, the character sequences that specify header names are mapped to external header source file names.

**Semantics of non-standard escape sequences (2.13.3).**

The following non-standard escape sequences are accepted for compatibility with GCC:

<table>
<thead>
<tr>
<th>Escape sequence</th>
<th>Code point</th>
</tr>
</thead>
<tbody>
<tr>
<td>\e</td>
<td>U+001B</td>
</tr>
<tr>
<td>\E</td>
<td>U+001B</td>
</tr>
</tbody>
</table>

**Value of wide-character literals containing multiple characters (2.13.3).**

If a wide-character literal contains more than one character, only the right-most character in the literal is used.

**Value of an ordinary character literal outside the range of its corresponding type (2.13.3).**

This case is diagnosed and rejected.

**Floating literals (2.13.4).**

For a floating literal whose scaled value cannot be represented as a floating-point value, the nearest even floating-point value is chosen.

**String literal concatenation (2.13.5).**

Differently prefixed string literal tokens cannot be concatenated, except for the ones specified by the ISO C++ Standard.
8.4 Basic concepts

Describes basic concepts relating to implementation-defined aspects of the Arm C++ compiler and C++
library, as required by the ISO C++ Standard.

Start-up and termination in a freestanding environment (3.6.1).
describes the start-up and termination of programs.

Definition of main in a freestanding environment (3.6.1).
The main function must be defined.

Linkage of the main function (3.6.1).
The main function has external linkage.

Parameters of main (3.6.1).
The only permitted parameters for definitions of main of the form int main(parameters) are
void and int, char**.

Dynamic initialization of static objects (3.6.2).
Static objects are initialized before the first statement of main.

Dynamic initialization of thread-local objects (3.6.2).
Thread-local objects are initialized at the first odr-use.

Pointer safety (3.7.4.3).
This implementation has relaxed pointer safety.

Extended signed integer types (3.9.1).
No extended integer types exist in the implementation.

Representation and signedness of the char type (3.9.1).
The char type is unsigned and has the same values as unsigned char.

Representation of the values of floating-point types (3.9.1).
The values of floating-point types are represented using the IEEE format as follows:
• float values are represented by IEEE single-precision values.
• double and long double values are represented by IEEE double-precision values.

Representation of values of pointer type (3.9.2).
Values of pointer type are represented as 32-bit addresses in AArch32 state and 64-bit addresses
in AArch64 state.

Support of extended alignments (3.11).
Alignments, including extended alignments, that are a power of two and are less than or equal to
0x10000000 are supported.

Related information
Arm Compiler Arm C and C++ Libraries and Floating-Point Support User Guide
8.5 Standard conversions

Describes implementation-defined aspects of the Arm C++ compiler and C++ library relating to standard conversions, as required by the ISO C++ Standard.

Conversion to signed integer (4.7).
When an integer value is converted to a value of signed integer type, but cannot be represented by the destination type, the value is truncated to the number of bits of the destination type and then reinterpreted as a value of the destination type.

Result of inexact floating-point conversions (4.8).
When a floating-point value is converted to a value of a different floating-point type, and the value is within the range of the destination type but cannot be represented exactly, the value is rounded to the nearest floating-point value by default.

Result of inexact integer to floating-point conversion (4.9).
When an integer value is converted to a value of floating-point type, and the value is within the range of the destination type but cannot be represented exactly, the value is rounded to the nearest floating-point value by default.
8.6 Expressions

Describes implementation-defined aspects of the Arm C++ compiler and C++ library relating to expressions, as required by the ISO C++ Standard.

**Passing an argument of class type in a function call through ellipsis (5.2.2).**
For ellipsis arguments, passing an argument of class type having a non-trivial copy constructor, a non-trivial move constructor, or a non-trivial destructor, with no corresponding parameter, results in an abort at run time. A diagnostic is reported for this case.

**Result type of typeid expression (5.2.8).**
The type of a typeid expression is an expression with dynamic type std::type_info.

**Incrementing a bit-field that cannot represent the incremented value (5.2.6).**
The incremented value is truncated to the number of bits in the bit-field. The bit-field is updated with the bits of the truncated value.

**Conversions between pointers and integers (5.2.10).**
Converting a pointer to an integer type with a smaller bit width than the pointer, truncates the pointer to the number of bits of the destination type. Converting a pointer to an integer type with a greater bit width than the pointer, zero-extends the pointer. Otherwise, the bits of the representation are unchanged.

Converting an unsigned integer to a pointer type with a greater bit-width than the unsigned integer zero-extends the integer. Converting a signed integer to a pointer type with a greater bit-width than the signed integer sign-extends the integer. Otherwise, the bits of the representation are unchanged.

**Conversions from function pointers to object pointers (5.2.10).**
Such conversions are supported.

**sizeof applied to fundamental types other than char, signed char, and unsigned char (5.3.3).**

<table>
<thead>
<tr>
<th>Type</th>
<th>sizeof</th>
</tr>
</thead>
<tbody>
<tr>
<td>bool</td>
<td>1</td>
</tr>
<tr>
<td>char</td>
<td>1</td>
</tr>
<tr>
<td>wchar_t</td>
<td>4</td>
</tr>
<tr>
<td>char16_t</td>
<td>2</td>
</tr>
<tr>
<td>char32_t</td>
<td>4</td>
</tr>
<tr>
<td>short</td>
<td>2</td>
</tr>
<tr>
<td>int</td>
<td>4</td>
</tr>
<tr>
<td>long (AArch32 state only)</td>
<td>4</td>
</tr>
<tr>
<td>long (AArch64 state only)</td>
<td>8</td>
</tr>
<tr>
<td>long long</td>
<td>8</td>
</tr>
<tr>
<td>float</td>
<td>4</td>
</tr>
<tr>
<td>double</td>
<td>8</td>
</tr>
<tr>
<td>long double (AArch32 state only)</td>
<td>8</td>
</tr>
<tr>
<td>long long (AArch64 state only)</td>
<td>16</td>
</tr>
</tbody>
</table>
Support for over-aligned types in new expressions (5.3.4).
Over-aligned types are not supported in new expressions. The pointer for the allocated type will not fulfill the extended alignment.

Type of ptrdiff_t (5.7).
The type of ptrdiff_t is signed int for AArch32 state and signed long for AArch64 state.

Type of size_t (5.7).
The type of size_t is unsigned int for AArch32 state and unsigned long for AArch64 state.

Result of right shift of negative value (5.8).
In a bitwise right shift operation of the form E1 >> E2, if E1 is of signed type and has a negative value, the value of the result is the integral part of the quotient of E1 / (2 ** E2), except when E1 is –1.

Assignment of a value to a bit-field that the bit-field cannot represent (5.18).
When assigning a value to a bit-field that the bit-field cannot represent, the value is truncated to the number of bits of the bit-field. A diagnostic is reported in some cases.
8.7 Declarations

Describes implementation-defined aspects of the Arm C++ compiler and C++ library relating to declarations, as required by the ISO C++ Standard.

Meaning of attribute declaration (7).

Arm Compiler 6 is based on LLVM and Clang technology. Clang defines several attributes as specified by the Clang documentation at https://clang.llvm.org/docs/AttributeReference.html.

From these attributes, Arm Compiler 6 supports attributes that are scoped with gnu:: (for compatibility with GCC) and clang::.

Underlying type for enumeration (7.2).

The underlying type for enumerations without a fixed underlying type is int or unsigned int, depending on the values of the enumerators. The -fshort-enums command-line option uses the smallest unsigned integer possible, or the smallest signed integer possible if any enumerator is negative, starting with char.

Meaning of an asm declaration (7.4).

An asm declaration enables the direct use of T32, A32, or A64 instructions.

Semantics of linkage specifiers (7.5).

Only the string-literals "C" and "C++" can be used in a linkage specifier.
8.8 Declarators

Describes implementation-defined aspects of the Arm C++ compiler and C++ library relating to declarators, as required by the ISO C++ Standard.

String resulting from __func__ (8.4.1).
The value of __func__ is the same as in C99.

Initialization of a bit-field with a value that the bit-field cannot represent (8.5).
When initializing a bit-field with a value that the bit-field cannot represent, the value is truncated to the number of bits of the bit-field. A diagnostic is reported in some cases.

Allocation of bit-fields within a class (9.6).
Within a storage unit, successive bit-fields are allocated from low-order bits towards high-order bits when compiling for little-endian, or from the high-order bits towards low-order bits when compiling for big-endian.

Alignment of bit-fields within a class (9.6).
The storage unit containing the bit-fields is aligned to the alignment of the type of the bit-field.
8.9 Templates

Describes implementation-defined aspects of the Arm C++ compiler and C++ library relating to templates, as required by the ISO C++ Standard.

**Linkage specification in templates (14).**

Only the linkage specifiers "C" and "C++" can be used in template declarations.
8.10 Exception handling

Describes implementation-defined aspects of the Arm C++ compiler and C++ library relating to exception handling, as required by the ISO C++ Standard.

Stack unwinding before calling `std::terminate` when no suitable catch handler is found (15.3).
   The stack is not unwound in this case.

Stack unwinding before calling `std::terminate` when a `noexcept` specification is violated (15.5.1).
   The stack is unwound in this case.
8.11 Preprocessing directives

Describes implementation-defined aspects of the Arm C++ compiler and C++ library relating to preprocessing directives, as required by the ISO C++ Standard.

**Numeric values of character literals in #if preprocessing directives (16.1).**

Numeric values of character literals match the values that they have in expressions other than the #if or #elif preprocessing directives.

**Sign of character literals in #if preprocessing directives (16.1).**

Character literals in #if preprocessing directives are never negative.

**Manner in which #include <...> source files are searched (16.2).**

- If the character sequence begins with the / character, it is interpreted as an absolute file path.
- Otherwise, the character sequence is interpreted as a file path relative to one of the following directories:
  - The sequence of the directories specified using the -I command-line option, in the command-line order.
  - The include subdirectory in the compiler installation directory.

**Manner in which #include "..." source files are searched (16.2).**

- If the character sequence begins with the / character, it is interpreted as an absolute file path.
- Otherwise, the character sequence is interpreted as a file path relative to the parent directory of the source file that contains the #include preprocessing directive.

**Nesting limit for #include preprocessing directives (16.2).**

Limited only by the memory available at translation time.

**Meaning of pragmas (16.6).**

Arm Compiler 6 is based on LLVM and Clang technology. Clang defines several pragmas as specified by the Clang documentation at [http://clang.llvm.org/docs/LanguageExtensions.html](http://clang.llvm.org/docs/LanguageExtensions.html).

**Definition and meaning of __STDC__ (16.8).**

__STDC__ is predefined as #define __STDC__ 1.

**Definition and meaning of __STDC_VERSION__ (16.8).**

This macro is not predefined.

**Text of __DATE__ and __TIME__ when the date or time of a translation is not available (16.8).**

The date and time of the translation are always available on all supported platforms.
8.12 Library introduction

Describes implementation-defined aspects of the Arm C++ compiler and C++ library relating to the library introduction, as required by the ISO C++ Standard.

**Linkage of names from the Standard C library (17.6.2.3).**
Declarations from the C library have "C" linkage.

**Library functions that can be recursively reentered (17.6.5.8).**
Functions can be recursively reentered, unless specified otherwise by the ISO C++ Standard.

**Exceptions thrown by C++ Standard Library functions that do not have an exception specification (17.6.5.12).**
These functions do not throw any additional exceptions.

**Errors category for errors originating from outside the operating system (17.6.5.14).**
There is no additional error category.
8.13 Language support library

Describes implementation-defined aspects of the Arm C++ compiler and C++ library relating to the language support library, as required by the ISO C++ Standard.

Exit status (18.5).
Control is returned to the host environment using the _sys_exit function of the Arm C Library.

Returned value of std::bad_alloc::what (18.6.2.1).
The returned value is std::bad_alloc.

Returned value of std::type_info::name (18.7.1).
The returned value is a string containing the mangled name of the type that is used in the typeid expression. The name is mangled following the Itanium C++ ABI specification.

Returned value of std::bad_cast::what (18.7.2).
The returned value is std::bad_cast.

Returned value of std::bad_typeid::what (18.7.3).
The returned value is std::bad_typeid.

Returned value of std::bad_exception::what (18.8.1).
The returned value is std::bad_exception.

Returned value of std::exception::what (18.8.1).
The returned value is std::exception.

Use of non-POFs as signal handlers (18.10).
Non Plain Old Functions (POFs) can be used as signal handlers if no uncaught exceptions are thrown in the handler, and the execution of the signal handler does not trigger undefined behavior. For example, the signal handler may have to call std::_Exit instead of std::exit.
8.14 General utilities library

Describes implementation-defined aspects of the Arm C++ compiler and C++ library relating to the general utilities library, as required by the ISO C++ Standard.

*Return value of std::get_pointer_safety (20.7.4).*

This function always returns std::pointer_safety::relaxed.

**Support for over-aligned types by the allocator (20.7.9.1).**

The allocator does not support over-aligned types.

**Support for over-aligned types by get_temporary_buffer (20.7.11).**

Function std::get_temporary_buffer does not support over-aligned types.

*Returned value of std::bad_weak_ptr::what (20.8.2.2.1).*

The returned value is bad_weak_ptr.

**Exception type when the constructor of std::shared_ptr fails (20.8.2.2.1).**

std::bad_alloc is the only exception that the std::shared_ptr constructor throws that receives a pointer.

**Placeholder types (20.9.10.4).**

Placeholder types, such as std::placeholders::_1, are not CopyAssignable.

**Over-aligned types and type traits std::aligned_storage and std::aligned_union (20.10.7.6).**

These two traits support over-aligned types.

**Conversion between time_t and time_point (20.12.7.1).**

The values are truncated in either case.
8.15 Strings library

Describes implementation-defined aspects of the Arm C++ compiler and C++ library relating to the strings library, as required by the ISO C++ Standard.

**Type of std::streamoff (21.2.3.1).**
Type std::streamoff has type `long long`.

**Type of std::streampos (21.2.3.2).**
Type of std::streampos is `fpos<mbstate_t>`.  

**Returned value of char_traits<char16_t>::eof (21.2.3.2).**
This function returns `uint_least16_t(0xFFFF)`.

**Type of std::u16streampos (21.2.3.3).**
Type of std::u16streampos is `fpos<mbstate_t>`.  

**Returned value of char_traits<char32_t>::eof (21.2.3.3).**
This function returns `uint_least32_t(0xFFFFFFFF)`.

**Type of std::u32streampos (21.2.3.3).**
Type of std::u32streampos is `fpos<mbstate_t>`.  

**Type of std::wstreampos (21.2.3.4).**
Type of std::wstreampos is `fpos<mbstate_t>`.  

**Supported multibyte character encoding rules (21.2.3.4).**
UTF-8 and Shift-JIS are supported as multibyte character encodings.
8.16 Localization library

Describes implementation-defined aspects of the Arm C++ compiler and C++ library relating to the localization library, as required by the ISO C++ Standard.

Locale object (22.3.1.2).
There is one global locale object for the entire program.

Permitted locale names (22.3.1.2).
Valid locale values depend on which __use_X_ctype symbols are imported (__use_iso8859_ctype, __use_sjis_ctype, __use_utf8_ctype), and on user-defined locales.

Effect on C locale of calling locale::global (22.3.1.5).
Calling this function with an unnamed locale has no effect.

Value of ctype<char>::table_size (22.4.1.3.1).
The value of ctype<char>::table_size is 256.

Two-digit year numbers in the function std::time_get::do_get_year (22.4.5.1.2).
Two-digit year numbers are accepted. Years from 00 to 68 are assumed to mean years 2000 to 2068, while years from 69 to 99 are assumed to mean 1969 to 1999.

Additional formats for std::time_get::do_get_date (22.4.5.1.2).
No additional formats are defined.

Formatted character sequence that std::time_put::do_put generates in the C locale (22.4.5.3.2).
The behavior is the same as that of the Arm C library function strftime.

Mapping from name to catalog when calling std::messages::do_open (22.4.7.1.2).
No mapping happens as this function does not open any catalog.

Mapping to message when calling std::messages::do_get (22.4.7.1.2).
No mapping happens and dflt is always returned.
8.17 Containers library

Describes implementation-defined aspects of the Arm C++ compiler and C++ library relating to the containers library, as required by the ISO C++ Standard.

**Type of `std::array::iterator` and `std::array::const_iterator` (23.3.2.1).**

The types of `std::array<T>::iterator` and `std::array<T>::const_iterator` are `T*` and `const T*` respectively.

**Default number of buckets in `std::unordered_map` (23.5.4.2).**

When constructing a container with an iterator range and without specifying the number of buckets, the number of buckets that are used is equal to the size of the iterator range. Every element of the iterator range is inserted in an empty container.

**Default number of buckets in `std::unordered_multimap` (23.5.4.2).**

When constructing a container with an iterator range and without specifying the number of buckets, the number of buckets that are used is equal to the size of the iterator range. Every element of the iterator range is inserted in an empty container.

**Default number of buckets in `std::unordered_set` (23.5.6.2).**

When constructing a container with an iterator range and without specifying the number of buckets, the number of buckets that are used is equal to the size of the iterator range. Every element of the iterator range is inserted in an empty container.

**Default number of buckets in `std::unordered_multiset` (23.5.7.2).**

When constructing a container with an iterator range and without specifying the number of buckets, the number of buckets that are used is equal to the size of the iterator range. Every element of the iterator range is inserted in an empty container.


8.18 Input/output library

Describes implementation-defined aspects of the Arm C++ compiler and C++ library relating to the input/output library, as required by the ISO C++ Standard.

Behavior of iostream classes when traits::pos_type is not streampos or when traits::off_type is not streamoff (27.2.1).

There is no specific behavior implemented for this case.

Effect of calling std::ios_base::sync_with_stdio after any input or output operation on standard streams (27.5.3.4).

Previous input/output is not handled in any special way.

Exception thrown by basic_ios::clear (27.5.5.4).

When basic_ios::clear throws as exception, it throws an exception of type basic_ios::failure constructed with "ios_base::clear".

Move constructor of std::basic_stringbuf (27.8.2.1).

The constructor copies the sequence pointers.

Effect of calling std::basic_filebuf::setbuf with nonzero arguments (27.9.1.2).

The provided buffer replaces the internal buffer. The object can use up to the provided number of bytes of the buffer.

Effect of calling std::basic_filebuf::sync when a get area exists (27.9.1.5).

The get area is emptied and the current file position is moved back the corresponding number of bytes.
8.19 Regular expressions library

Describes implementation-defined aspects of the Arm C++ compiler and C++ library relating to the regular expressions library, as required by the ISO C++ Standard.

**Type of `std::regex_constants::error_type`**

The enum `std::regex_constants::error_type` is defined as follows:

```cpp
enum error_type {
    error_collate = 1,
    error_ctype,
    error_escape,
    error_backref,
    error_paren,
    error_brace,
    error_bradbrace,
    error_range,
    error_space,
    error_badrepeat,
    error_complexity,
    error_stack,
    __re_err_grammar,
    __re_err_empty,
    __re_err_unknown
};
```
8.20 Atomic operations library

Describes implementation-defined aspects of the Arm C++ compiler and C++ library relating to the atomic operations library, as required by the ISO C++ Standard.

Values of ATOMIC_...LOCK_FREE macros (29.4)

<table>
<thead>
<tr>
<th>Macro</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>ATOMIC_BOOL_LOCK_FREE</td>
<td>2</td>
</tr>
<tr>
<td>ATOMIC_CHAR_LOCK_FREE</td>
<td>2</td>
</tr>
<tr>
<td>ATOMIC_CHAR16_T_LOCK_FREE</td>
<td>2</td>
</tr>
<tr>
<td>ATOMIC_CHAR32_T_LOCK_FREE</td>
<td>2</td>
</tr>
<tr>
<td>ATOMIC_WCHAR_T_LOCK_FREE</td>
<td>2</td>
</tr>
<tr>
<td>ATOMIC_SHORT_LOCK_FREE</td>
<td>2</td>
</tr>
<tr>
<td>ATOMIC_INT_LOCK_FREE</td>
<td>2</td>
</tr>
<tr>
<td>ATOMIC_LONG_LOCK_FREE</td>
<td>2</td>
</tr>
<tr>
<td>ATOMIC_LLONG_LOCK_FREE</td>
<td>2</td>
</tr>
<tr>
<td>ATOMIC_POINTER_LOCK_FREE</td>
<td>2</td>
</tr>
</tbody>
</table>
8.21 Thread support library

Describes implementation-defined aspects of the Arm C++ compiler and C++ library relating to the thread support library, as required by the ISO C++ Standard.

Presence and meaning of native_handle_type and native_handle.
The library uses the following native handles as part of the thread portability mechanism, which is described elsewhere.

- __ARM_TPL_mutex_t used in std::mutex and std::recursive_mutex
- __ARM_TPL_condvar_t used in std::condition_variable
- __ARM_TPL_thread_id used in std::thread
- __ARM_TPL_thread_t used in std::thread
8.22 Implementation quantities

Describes limits in C++ implementations.

Note
Where a specific number is provided, this value is the recommended minimum quantity.

Nesting levels of compound statements, iteration control structures, and selection control structures.
256. Can be increased using the -fbracket-depth command-line option.

Nesting levels of conditional inclusion
Limited by memory.

Pointer, array, and function declarators (in any combination) modifying a class, arithmetic, or incomplete type in a declaration.
Limited by memory.

Nesting levels of parenthesized expressions within a full-expression.
256. Can be increased using the -fbracket-depth command-line option.

Number of characters in an internal identifier or macro name.
Limited by memory.

Number of characters in an external identifier.
Limited by memory.

External identifiers in one translation unit.
Limited by memory.

Identifiers with block scope declared in one block.
Limited by memory.

Macro identifiers that are simultaneously defined in one translation unit.
Limited by memory.

Parameters in one function definition.
Limited by memory.

Arguments in one function call.
Limited by memory.

Parameters in one macro definition.
Limited by memory.

Arguments in one macro invocation.
Limited by memory.

Characters in one logical source line.
Limited by memory.

Characters in a string literal (after concatenation).
Limited by memory.

Size of an object.
SIZE_MAX

Nesting levels for #include files.
Limited by memory.

Case labels for a switch statement (excluding case labels for any nested switch statements).
Limited by memory.
Data members in a single class.
   Limited by memory.

Enumeration constants in a single enumeration.
   Limited by memory.

Levels of nested class definitions in a single member-specification.
   256. Can be increased using the \texttt{-fbracket-depth} command-line option.

Functions that are registered by \texttt{atexit()}.
   Limited by memory.

Direct and indirect base classes.
   Limited by memory.

Direct base classes for a single class.
   Limited by memory.

Members declared in a single class.
   Limited by memory.

Final overriding virtual functions in a class, accessible or not.
   Limited by memory.

Direct and indirect virtual bases of a class.
   Limited by memory.

Static members of a class.
   Limited by memory.

Friend declarations in a class.
   Limited by memory.

Access control declarations in a class.
   Limited by memory.

Member initializers in a constructor definition.
   Limited by memory.

Scope qualifications of one identifier.
   Limited by memory.

Nested external specifications.
   Limited by memory.

Recursive constexpr function invocations.
   512. Can be changed using the \texttt{-fconstexpr-depth} command-line option.

Full-expressions that are evaluated within a core constant expression.
   Limited by memory.

Template arguments in a template declaration.
   Limited by memory.

Recursively nested template instantiations, including substitution during template argument deduction (14.8.2).
   1024. Can be changed using the \texttt{-ftemplate-depth} command-line option.

Handlers per try block.
   Limited by memory.

Throw specifications on a single function declaration.
   Limited by memory.

Number of placeholders (20.9.10.4).
   Ten placeholders from \texttt{_1} to \texttt{_10}.
Chapter 9
armclang Integrated Assembler Directives

Provides information on the directives you can use when writing assembly language source files in the armclang integrated assembler syntax.

It contains the following sections:
- 9.1 Syntax of assembly files for integrated assembler on page 9-270.
- 9.2 Assembly expressions on page 9-272.
- 9.3 Alignment directives on page 9-276.
- 9.4 Data definition directives on page 9-278.
- 9.5 String definition directives on page 9-280.
- 9.6 Floating-point data definition directives on page 9-282.
- 9.7 Section directives on page 9-283.
- 9.9 Macro directives on page 9-290.
- 9.10 Symbol binding directives on page 9-292.
- 9.15 Type directive on page 9-299.
9.1 Syntax of assembly files for integrated assembler

Assembly statements can include labels, instructions, directives, or macros.

Syntax

```
label:
instruction[;]
directive[;]
macro_invocation[;]
```

Description

**label**

For label statements, the statement ends after the : character. For the other forms of assembler statements, the statement ends at the first newline or ; character. This means that any number of labels can be defined on the same source line, and multiple of any other types of statements can be present in one source line if separated by ;.

Label names without double quotes:

- Must start with a period (.), _, a-z or A-Z.
- Can also contain numbers, _, $.  
- Must not contain white spaces.

You can have white spaces in label names by surrounding them with double quotes. Escape sequences are not interpreted within label names. It is also not possible to have double quotes as part of the label name.

**instruction**

The optional ; can be used to end the statement and start a new statement on the same line.

**directive**

The optional ; can be used to end the statement and start a new statement on the same line.

**macro_invocation**

The optional ; can be used to end the statement and start a new statement on the same line.

Comments

Comments are treated as equivalent to whitespace, their contents are ignored by the assembler.

There are two ways to include comments in an assembly file:

```
// single-line comment
@ single-line comment in AArch32 state only
/* multi-line
comment */
```

In single-line comments, the // marker starts a comment that runs to the end of the source line. Unlike when compiling C and C++ source, the end of the line cannot be escaped with \ to continue the comment.

@ starts a single-line comment in AArch32 state. @ is not a comment character in AArch64 state.

In multi-line comments, the /* marker starts a comment that runs to the first occurrence of */; even if that is on a later line. Like in C and C++ source, the comment always ends at the first */; so comments cannot be nested. This style of comments can be used anywhere within an assembly statement where whitespace is valid.

Examples

```
// Instruction on it's own line:
add r0, r1, r2
```
// Label and directive:
lab: .word 42

// Multiple labels on one line:
lab1: lab2:

/* Multiple instructions, directives or macro-invocations
must be separated by ';' */
add r0, r1, r2; bx lr

// Multi-line comments can be used anywhere whitespace can:
add /*dst*/r0, /*lhs*/r1, /*rhs*/r2
9.2 Assembly expressions

Expressions consist of one or more integer literals or symbol references, combined using operators.

You can use an expression when an instruction operand or directive argument expects an integer value or label.

Not all instruction operands and directive arguments accept all possible expressions. For example, the alignment directives require an absolute expression for the boundary to align to. Therefore, alignment directives cannot accept expressions involving labels, but can accept expressions involving only integer constants.

On the other hand, the data definition directives can accept a wider range of expressions, including references to defined or undefined symbols. However, the types of expressions accepted is still limited by the ELF relocations available to describe expressions involving undefined symbols. For example, it is not possible to describe the difference between two symbols defined in different sections. The assembler reports an error when an expression is not valid in the context in which it is used.

Expressions involving integer constants are evaluated as signed 64-bit values internally to the assembler. If an intermediate value in a calculation cannot be represented in 64 bits, the behavior is undefined. The assembler does not currently emit a diagnostic when this happens.

Constants

Numeric literals are accepted in the following formats:

- Decimal integer in range 0 to \((2^{64})-1\).
- Hexadecimal integer in range 0 to \((2^{64})-1\), prefixed with 0x.
- Octal integer in range 0 to \((2^{64})-1\), prefixed with 0.
- Binary integer in range 0 to \((2^{64})-1\), prefixed with 0b.

Some directives accept values larger than \((2^{64})-1\). These directives only accept simple integer literals, not expressions.

Note that the ranges above do not include negative numbers. Negative numbers can instead be represented using the unary operator, -.

Symbol References

References to symbols are accepted as expressions. Symbols do not need to be defined in the same assembly language source file, to be referenced in expressions.

The period symbol (.) is a special symbol that can be used to reference the current location in the output file.

For AArch32 targets, a symbol reference might optionally be followed by a modifier in parentheses. The following modifiers are supported:

<table>
<thead>
<tr>
<th>Modifier</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>None</td>
<td>Do not relocate this value.</td>
</tr>
<tr>
<td>got_pre1</td>
<td>Offset from this location to the GOT entry of the symbol.</td>
</tr>
<tr>
<td>target1</td>
<td>Defined by platform ABI.</td>
</tr>
<tr>
<td>target2</td>
<td>Defined by platform ABI.</td>
</tr>
<tr>
<td>plel31</td>
<td>Offset from this location to the symbol. Bit 31 is not modified.</td>
</tr>
<tr>
<td>sbrel</td>
<td>Offset to symbol from addressing origin of its output segment.</td>
</tr>
</tbody>
</table>
Table 9-1  Modifiers (continued)

<table>
<thead>
<tr>
<th>Modifier</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>got</td>
<td>Address of the GOT entry for the symbol.</td>
</tr>
<tr>
<td>gotoff</td>
<td>Offset from the base of the GOT to the symbol.</td>
</tr>
</tbody>
</table>

Operators

The following operators are valid expressions:

Table 9-2  Unary operators

<table>
<thead>
<tr>
<th>Unary operator</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>-expr</td>
<td>Arithmetic negation of expr.</td>
</tr>
<tr>
<td>+expr</td>
<td>Arithmetic addition of expr.</td>
</tr>
<tr>
<td>~expr</td>
<td>Bitwise negation of expr.</td>
</tr>
</tbody>
</table>

Table 9-3  Binary operators

<table>
<thead>
<tr>
<th>Binary operator</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>expr1 - expr2</td>
<td>Subtraction.</td>
</tr>
<tr>
<td>expr1 + expr2</td>
<td>Addition.</td>
</tr>
<tr>
<td>expr1 * expr2</td>
<td>Multiplication.</td>
</tr>
<tr>
<td>expr1 / expr2</td>
<td>Division.</td>
</tr>
<tr>
<td>expr1 % expr2</td>
<td>Modulo.</td>
</tr>
</tbody>
</table>

Table 9-4  Binary logical operators

<table>
<thead>
<tr>
<th>Binary logical operator</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>expr1 &amp;&amp; expr2</td>
<td>Logical and. 1 if both operands non-zero, 0 otherwise.</td>
</tr>
<tr>
<td>expr1</td>
<td></td>
</tr>
</tbody>
</table>

Table 9-5  Binary bitwise operators

<table>
<thead>
<tr>
<th>Binary bitwise operator</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>expr1 &amp; expr2</td>
<td>expr1 bitwise and expr2.</td>
</tr>
<tr>
<td>expr1</td>
<td>expr2</td>
</tr>
<tr>
<td>expr1 ^ expr2</td>
<td>expr1 bitwise exclusive-or expr2.</td>
</tr>
<tr>
<td>expr1 &gt;&gt; expr2</td>
<td>Logical shift right expr1 by expr2 bits.</td>
</tr>
<tr>
<td>expr1 &lt;&lt; expr2</td>
<td>Logical shift left expr1 by expr2 bits.</td>
</tr>
</tbody>
</table>
Table 9-6 Binary comparison operators

<table>
<thead>
<tr>
<th>Binary comparison operator</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>expr1 == expr2</code></td>
<td><code>expr1</code> equal to <code>expr2</code>.</td>
</tr>
<tr>
<td><code>expr1 != expr2</code></td>
<td><code>expr1</code> not equal to <code>expr2</code>.</td>
</tr>
<tr>
<td><code>expr1 &lt; expr2</code></td>
<td><code>expr1</code> less than <code>expr2</code>.</td>
</tr>
<tr>
<td><code>expr1 &gt; expr2</code></td>
<td><code>expr1</code> greater than <code>expr2</code>.</td>
</tr>
<tr>
<td><code>expr1 &lt;= expr2</code></td>
<td><code>expr1</code> less than or equal to <code>expr2</code>.</td>
</tr>
<tr>
<td><code>expr1 &gt;= expr2</code></td>
<td><code>expr1</code> greater than or equal to <code>expr2</code>.</td>
</tr>
</tbody>
</table>

The order of precedence for binary operators is as follows, with highest precedence operators listed first. Operators listed on the same line have equal precedence, and are evaluated from left to right. All unary operators have higher precedence than any binary operators. Note that the precedence rules for assembler expressions are not identical to those for C.
1. *, /, %, >>, <<
2. |, ^, &
3. +, -
4. ==, !=, <, >, <=, >=
5. &&
6. ||

### Relocation specifiers

For some instruction operands, a relocation specifier might be used to specify which bits of the expression should be used for the operand, and which type of relocation should be used.

These relocation specifiers can only be used at the start of an expression. They can only be used in operands of instructions that support them.

In AArch32 state, the following relocation specifiers are available:

Table 9-7 Relocation specifiers for AArch32 state

<table>
<thead>
<tr>
<th>Relocation specifier</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>:lower16:</td>
<td>Use the lower 16 bits of the expression value.</td>
</tr>
<tr>
<td>:upper16:</td>
<td>Use the upper 16 bits of the expression value.</td>
</tr>
</tbody>
</table>

These relocation specifiers are only valid for the operands of the `movw` and `movt` instructions. They can be combined with an expression involving the current place to create a place-relative relocation, and with the `sbrl1` symbol modifier to create a static-base-relative relocation. The current place is the location that the assembler is emitting code or data at. A place-relative relocation is a relocation that generates the offset from the relocated data to the symbol it references.

In AArch64 state, the following relocation specifiers are available:

Table 9-8 Relocation specifiers for AArch64 state

<table>
<thead>
<tr>
<th>Relocation specifier</th>
<th>Relocation type</th>
<th>Bits to use</th>
<th>Overflow checked</th>
</tr>
</thead>
<tbody>
<tr>
<td>:lo12:</td>
<td>Absolute</td>
<td>[11:0]</td>
<td>No</td>
</tr>
<tr>
<td>:abs_g3:</td>
<td>Absolute</td>
<td>[63:48]</td>
<td>Yes</td>
</tr>
<tr>
<td>:abs_g2:</td>
<td>Absolute</td>
<td>[47:32]</td>
<td>Yes</td>
</tr>
</tbody>
</table>
Table 9-8  Relocation specifiers for AArch64 state (continued)

<table>
<thead>
<tr>
<th>Relocation specifier</th>
<th>Relocation type</th>
<th>Bits to use</th>
<th>Overflow checked</th>
</tr>
</thead>
<tbody>
<tr>
<td>:abs_g2_s:</td>
<td>Absolute, signed</td>
<td>[47:32]</td>
<td>Yes</td>
</tr>
<tr>
<td>:abs_g2_nc:</td>
<td>Absolute</td>
<td>[47:32]</td>
<td>No</td>
</tr>
<tr>
<td>:abs_g1:</td>
<td>Absolute</td>
<td>[31:16]</td>
<td>Yes</td>
</tr>
<tr>
<td>:abs_g1_s:</td>
<td>Absolute, signed</td>
<td>[31:16]</td>
<td>Yes</td>
</tr>
<tr>
<td>:abs_g1_nc:</td>
<td>Absolute</td>
<td>[31:16]</td>
<td>No</td>
</tr>
<tr>
<td>:abs_g0:</td>
<td>Absolute</td>
<td>[15:0]</td>
<td>Yes</td>
</tr>
<tr>
<td>:abs_g0_s:</td>
<td>Absolute, signed</td>
<td>[15:0]</td>
<td>Yes</td>
</tr>
<tr>
<td>:abs_g0_nc:</td>
<td>Absolute</td>
<td>[15:0]</td>
<td>No</td>
</tr>
<tr>
<td>:got:</td>
<td>Global Offset Table Entry</td>
<td>[32:12]</td>
<td>Yes</td>
</tr>
<tr>
<td>:got_lo12:</td>
<td>Global Offset Table Entry</td>
<td>[11:0]</td>
<td>No</td>
</tr>
</tbody>
</table>

These relocation specifiers can only be used in the operands of instructions that have matching relocations defined in *ELF for the Arm 64-bit Architecture (AArch64)*. They can be combined with an expression involving the current place to create a place-relative relocation.

**Examples**

```asm
// Using an absolute expression in an instruction operand:
or r0, r0, #1<<23

// Using an expression in the memory operand of an LDR instruction to
// reference an offset from a symbol.
func:  
    ldr r0, #data+4 // Will load 2 into r0
    bx lr
data:
    .word 1
    .word 2

// Creating initialized data that contains the distance between two
// labels:
size:
    .word end - start
start:
    .word 123
    .word 42
    .word 4523534
end:

// Load the base-relative address of 'sym' (used for 'RwPI')
// position-independent code) into r0 using movw and movt:
mov r0, #:lower16:sym(sbrel)
mov r0, #:upper16:sym(sbrel)

// Load the address of 'sym' from the GOT using ADRP and LDR (used for
// position-independent code on AArch64):
adrp x0, #:got:sym
ldr x0, [x0, #:got_lo12:sym]

// Constant pool entry containing the offset between the location and a
// symbol defined elsewhere. The address of the symbol can be calculated
// at runtime by adding the value stored in the location of the address
// of the location. This is one technique for writing position-     
// independent code, which can be executed from an address chosen at
// runtime without re-linking it.
adr r0, address
ldr r1, [r0]
add r0, r0, r1
address:
    .word extern_symbol - .
```
9.3 Alignment directives

The alignment directives align the current location in the file to a specified boundary.

Syntax

<table>
<thead>
<tr>
<th>Directive</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>.balign num_bytes [, fill_value]</code></td>
<td></td>
</tr>
<tr>
<td><code>.balignl num_bytes [, fill_value]</code></td>
<td></td>
</tr>
<tr>
<td><code>.balignw num_bytes [, fill_value]</code></td>
<td></td>
</tr>
<tr>
<td><code>.p2align exponent [, fill_value]</code></td>
<td></td>
</tr>
<tr>
<td><code>.p2alignl exponent [, fill_value]</code></td>
<td></td>
</tr>
<tr>
<td><code>.p2alignw exponent [, fill_value]</code></td>
<td></td>
</tr>
<tr>
<td><code>.align exponent [, fill_value]</code></td>
<td></td>
</tr>
</tbody>
</table>

Description

- **num_bytes**: This specifies the number of bytes that must be aligned to. This must be a power of 2.
- **exponent**: This specifies the alignment boundary as an exponent. The actual alignment boundary is $2^\text{exponent}$.
- **fill_value**: The value to fill any inserted padding bytes with. This value is optional.

Operation

The alignment directives align the current location in the file to a specified boundary. The unused space between the previous and the new current location are filled with:

- Copies of `fill_value`, if it is specified. The width of `fill_value` can be controlled with the `w` and `l` suffixes, see below.
- NOP instructions appropriate to the current instruction set, if all the following conditions are specified:
  - The `fill_value` argument is not specified.
  - The `w` or `l` suffix is not specified.
  - The alignment directive follows an instruction.
- Zeroes otherwise.

The `.balign` directive takes an absolute number of bytes as its first argument, and the `.p2align` directive takes a power of 2. For example, the following directives align the current location to the next multiple of 16 bytes:

- `.balign 16`
- `.p2align 4`
- `.align 4`

The `w` and `l` suffixes modify the width of the padding value that will be inserted.

- By default, the `fill_value` is a 1-byte value.
- If the `w` suffix is specified, the `fill_value` is a 2-byte value.
- If the `l` suffix is specified, the `fill_value` is a 4-byte value.

If either of these suffixes are specified, the padding values are emitted as data (defaulting to a value of zero), even if following an instruction.
The .align directive is an alias for .p2align, but it does not accept the w and l suffixes.

Alignment is relative to the start of the section in which the directive occurs. If the current alignment of the section is lower than the alignment requested by the directive, the alignment of the section will be increased.

**Usage**

Use the alignment directives to ensure that your data and code is aligned to appropriate boundaries. This is typically required in the following circumstances:

- In T32 code, the ADR instruction and the PC-relative version of the LDR instruction can only reference addresses that are 4-byte aligned, but a label within T32 code might only be 2-byte aligned. Use .balign 4 to ensure 4-byte alignment of an address within T32 code.
- Use alignment directives to take advantage of caches on some Arm processors. For example, many processors have an instruction cache with 16-byte lines. Use .p2align 4 or .balign 16 to align function entry points on 16-byte boundaries to maximize the efficiency of the cache.

**Examples**

Aligning a constant pool value to a 4-byte boundary in T32 code:

```assembly
get_val:
  ldr r0, value
  adds r0, #1
  bx lr
// The above code is 6 bytes in size.
// Therefore the data defined by the .word directive below must be manually aligned
// to a 4-byte boundary to be able to use the LDR instruction.
.p2align 2
value:
  .word 42
```

Ensuring that the entry points to functions are on 16-byte boundaries, to better utilize caches:

```assembly
.p2align 4
.type func1, "function"
func1:
  // code
  .p2align 4
  .type func2, "function"
func2:
  // code
```

**Note**

In both of the examples above, it is important that the directive comes before the label that is to be aligned. If the label came first, then it would point at the padding bytes, and not the function or data it is intended to point to.
9.4 Data definition directives

These directives allocate memory in the current section, and define the initial contents of that memory.

Syntax

<table>
<thead>
<tr>
<th>Directive</th>
<th>Syntax</th>
</tr>
</thead>
<tbody>
<tr>
<td>.byte</td>
<td>expr[, expr]...</td>
</tr>
<tr>
<td>.hword</td>
<td>expr[, expr]...</td>
</tr>
<tr>
<td>.word</td>
<td>expr[, expr]...</td>
</tr>
<tr>
<td>.quad</td>
<td>expr[, expr]...</td>
</tr>
<tr>
<td>.octa</td>
<td>expr[, expr]...</td>
</tr>
</tbody>
</table>

Description

expr

An expression that has one of the following forms:

- A absolute value, or expression (not involving labels) which evaluates to one. For example:
  ```assembly
  .word (1<<17) | (1<<6)
  .word 42
  ```

- An expression involving one label, which may or not be defined in the current file, plus an optional constant offset. For example:
  ```assembly
  .word label
  .word label + 0x18
  ```

- A place-relative expression, involving the current location in the file (or a label in the current section) subtracted from a label which may either be defined in another section in the file, or undefined in the file. For example:
  ```assembly
  foo:
  .word label - .
  .word label - foo
  ```

- A difference between two labels, both of which are defined in the same section in the file. The section containing the labels need not be the same as the one containing the directive. For example:
  ```assembly
  .word end - start
  start: // ...
  end:
  ```

The number of bytes allocated by each directive is as follows:

<table>
<thead>
<tr>
<th>Directive</th>
<th>Size in bytes</th>
</tr>
</thead>
<tbody>
<tr>
<td>.byte</td>
<td>1</td>
</tr>
<tr>
<td>.hword</td>
<td>2</td>
</tr>
<tr>
<td>.word</td>
<td>4</td>
</tr>
<tr>
<td>.quad</td>
<td>8</td>
</tr>
<tr>
<td>.octa</td>
<td>16</td>
</tr>
</tbody>
</table>

If multiple arguments are specified, multiple memory locations of the specified size are allocated and initialized to the provided values in order.

The following table shows which expression types are accepted for each directive. In some cases, this varies between AArch32 and AArch64. This is because the two architectures have different relocation

Table 9-9 Data definition directives

<table>
<thead>
<tr>
<th>Directive</th>
<th>Size in bytes</th>
</tr>
</thead>
<tbody>
<tr>
<td>.byte</td>
<td>1</td>
</tr>
<tr>
<td>.hword</td>
<td>2</td>
</tr>
<tr>
<td>.word</td>
<td>4</td>
</tr>
<tr>
<td>.quad</td>
<td>8</td>
</tr>
<tr>
<td>.octa</td>
<td>16</td>
</tr>
</tbody>
</table>
codes available to describe expressions involving symbols defined elsewhere. For absolute expressions, the table gives the range of values that are accepted (inclusive on both ends).

### Table 9-10 Expression types supported by the data definition directives

<table>
<thead>
<tr>
<th>Directive</th>
<th>Absolute</th>
<th>Label</th>
<th>Place-relative</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>.byte</td>
<td>Within the range [-128, 255] only</td>
<td>AArch32 only</td>
<td>Not supported</td>
<td>AArch64 and AArch32</td>
</tr>
<tr>
<td>.hword</td>
<td>Within the range [-0x8000, 0xffff] only</td>
<td>AArch64 and AArch32</td>
<td>AArch64 only</td>
<td>AArch64 and AArch32</td>
</tr>
<tr>
<td>.word</td>
<td>Within the range [-2^31, 2^32-1] only</td>
<td>AArch64 and AArch32</td>
<td>AArch64 and AArch32</td>
<td>AArch64 and AArch32</td>
</tr>
<tr>
<td>.quad</td>
<td>Within the range [-2^63, 2^64-1] only</td>
<td>AArch64 only</td>
<td>AArch64 only</td>
<td>AArch64 only</td>
</tr>
<tr>
<td>.octa</td>
<td>Within the range [0, 2^128-1] only</td>
<td>Not supported</td>
<td>Not supported</td>
<td>Not supported</td>
</tr>
</tbody>
</table>

Note that, while most directives accept expressions, the .octa directive only accepts literal values. In the armclang inline assembler and integrated assembler, negative values are expressions (the unary negation operator and a positive integer literal), so negative values are not accepted by the .octa directive. If negative 16-byte values are needed, they can be rewritten using two's complement representation instead.

These directives do not align the start of the memory allocated. If this is required you must use one of the alignment directives.

The following aliases for these directives are also accepted:

### Table 9-11 Aliases for the data definition directives

<table>
<thead>
<tr>
<th>Directive</th>
<th>Aliases</th>
</tr>
</thead>
<tbody>
<tr>
<td>.byte</td>
<td>.1byte, .dc.b</td>
</tr>
<tr>
<td>.hword</td>
<td>.2byte, .dc, .dc.w, .short, .value</td>
</tr>
<tr>
<td>.word</td>
<td>.4byte, .long, .int, .dc.l, .dc.a (AArch32 only)</td>
</tr>
<tr>
<td>.quad</td>
<td>.8byte, .xword (AArch64 only), .dc.a (AArch64 only)</td>
</tr>
</tbody>
</table>

### Examples

```assembly
// 8-bit memory location, initialized to 42:
.byte 42

// 32-bit memory location, initialized to 15532:
.word 15532

// 32-bit memory location, initialized to the address of an externally defined symbol:
.word extern_symbol

// 16-bit memory location, initialized to the difference between the 'start' and 'end' labels. They must both be defined in this assembly file, and must be in the same section as each other, but not necessarily the same section as this directive:
.hword end - start

// 32-bit memory location, containing the offset between the current location in the file and an externally defined symbol.
.word extern_symbol - .
```
9.5 String definition directives

Allocates one or more bytes of memory in the current section, and defines the initial contents of the memory from a string literal.

Syntax

| .ascii "string" |
| .asciz "string" |
| .string "string" |

Description

.ascii

The .ascii directive does not append a null byte to the end of the string.

.asciz

The .asciz directive appends a null byte to the end of the string.

The .string directive is an alias for .asciz.

string

The following escape characters are accepted in the string literal:

<table>
<thead>
<tr>
<th>Escape character</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>\b</td>
<td>Backspace</td>
</tr>
<tr>
<td>\f</td>
<td>Form feed</td>
</tr>
<tr>
<td>\n</td>
<td>Newline</td>
</tr>
<tr>
<td>\r</td>
<td>Carriage return</td>
</tr>
<tr>
<td>\t</td>
<td>Horizontal tab</td>
</tr>
<tr>
<td>&quot;</td>
<td>Quote (&quot;)</td>
</tr>
<tr>
<td>\</td>
<td>Backslash ()</td>
</tr>
<tr>
<td>\Octal_Escape_Code</td>
<td>Three digit octal escape code for each ASCII character</td>
</tr>
</tbody>
</table>

Examples

Using a null-terminated string in a constant pool:

```
.text
hello:
    @d r0, str_hello
    b printf
str_hello:
    .asciz "Hello, world!\n"
```

Generating pascal-style strings (which are prefixed by a length byte, and have no null terminator), using a macro to avoid repeated code (see also macros on page 9-290 and temporary numeric labels):

```
.macro pascal_string, str
    .byte 2f - 1f
1:
    .ascii "\str"
2:
.endm
```
.data
hello:
    pascal_string "Hello"
goodbye:
    pascal_string "Goodbye"
9.6 Floating-point data definition directives

These directives allocate memory in the current section of the file, and define the initial contents of that memory using a floating-point value.

**Syntax**

`.float value [, value]`

`.double value [, value]`

**Description**

*.float*

The `.float` directive allocates 4 bytes of memory per argument, and stores the values in IEEE754 single-precision format.

*.double*

The `.double` directive allocates 8 bytes of memory per argument, and stores the values in IEEE754 double-precision format.

*value*

*value* is a floating-point literal.

**Operation**

If a floating-point value cannot be exactly represented by the storage format, it will be rounded to the nearest representable value using the *round to nearest, ties to even* rounding mode.

The following aliases for these directives are also accepted:

<table>
<thead>
<tr>
<th>Directive</th>
<th>Alias</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>.float</code></td>
<td><code>.single, .dc.s</code></td>
</tr>
<tr>
<td><code>.double</code></td>
<td><code>.dc.d</code></td>
</tr>
</tbody>
</table>

**Examples**

```
float_pi:
  .float 3.14159265359
double_pi:
  .double 3.14159265359
```
9.7 Section directives

The section directives instruct the assembler to change the ELF section that code and data is being emitted into.

Syntax

```
.section name [, "flags" [, %type [, entry_size] [, group_name [, linkage]] [, link_order_symbol] [, unique, unique_id]]]
.pushsection .section name [, "flags" [, %type [, entry_size] [, group_name [, linkage]] [, link_order_symbol] [, unique, unique_id]]]
.popsection
.text
.data
.rodata
.bss
```

Description

`name`

The `name` argument gives the name of the section to switch to.

By default, if the name is identical to a previous section, or one of the built-in sections, the assembler will switch back to that section, any code or data assembled will be appended to the end of that section. The unique-id argument can be used to override this behavior.
The optional flags argument is a quoted string containing any of the following characters, which correspond to the sh_flags field in the ELF section header.

<table>
<thead>
<tr>
<th>Flag</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>a</td>
<td>SHF_ALLOC: the section is allocatable.</td>
</tr>
<tr>
<td>w</td>
<td>SHF_WRITE: the section is writable.</td>
</tr>
<tr>
<td>y</td>
<td>SHF_ARM_PURECODE: the section is not readable.</td>
</tr>
<tr>
<td>x</td>
<td>SHF_EXECINSTR: the section is executable.</td>
</tr>
<tr>
<td>o</td>
<td>SHF_LINK_ORDER: the section has a link-order restriction.</td>
</tr>
<tr>
<td>M</td>
<td>SHF_MERGE: the section is mergeable.</td>
</tr>
<tr>
<td>S</td>
<td>SHF_STRINGS: the section contains null-terminated string.</td>
</tr>
<tr>
<td>T</td>
<td>SHF_TLS: the section is thread-local storage.</td>
</tr>
<tr>
<td>G</td>
<td>SHF_GROUP: the section is a member of a section group.</td>
</tr>
<tr>
<td>?</td>
<td>if the previous section was part of a group, this section is in the same group, otherwise ignored.</td>
</tr>
</tbody>
</table>

The flags can be specified as a numeric value, with the same encoding as the sh_flags field in the ELF section header. This cannot be combined with the flag characters listed above. When using this syntax, the quotes around the flags value are still required.

Note: Certain flags need extra arguments, as described in the respective arguments.
The optional type argument is accepted with two different syntaxes: %type and "type". It corresponds to the sh_type field in the ELF section header. The following values for the type argument are accepted:

<table>
<thead>
<tr>
<th>Argument</th>
<th>ELF type</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>%progbits</td>
<td>SHT_PROGBITS</td>
<td>Section contains initialized data and/or instructions.</td>
</tr>
<tr>
<td>%nobits</td>
<td>SHT_NOBITS</td>
<td>Section consists only of zero-initialized data.</td>
</tr>
<tr>
<td>%note</td>
<td>SHT_NOTE</td>
<td>Section contains information used by the linker or loader to check compatibility.</td>
</tr>
<tr>
<td>%init_array</td>
<td>SHT_INIT_ARRAY</td>
<td>Section contains an array of pointers to initialization functions.</td>
</tr>
<tr>
<td>%fini_array</td>
<td>SHT_FINI_ARRAY</td>
<td>Section contains an array of pointers to termination functions.</td>
</tr>
<tr>
<td>%preinit_array</td>
<td>SHT_PREINIT_ARRAY</td>
<td>Section contains an array of pointers to pre-initialization functions.</td>
</tr>
</tbody>
</table>

The type can be specified as a numeric value, with the same encoding as the sh_type field in the ELF section header. When using this syntax, the quotes around the type value are still required.

entry_size
If the M flag is specified, the entry_size argument is required. This must be an integer value, which is the size of the records contained within this section, that can be merged by the linker.

group_name
If the G flag is specified, the group_name argument is required. This is a symbol name to be used as the signature to identify the section group. All sections in the same object file and with the same group_name are part of the same section group.

If the ? flag is specified, the section is implicitly in the same group as the previous section, and the group_name and linkage options are not accepted.

It is an error to specify both the G and ? flags on the same section.

linkage
If the G flag is specified, the optional linkage argument is allowed. The only valid value for this is comdat, which has the same effect as not providing the linkage argument. If any arguments after the group_name and linkage arguments are to be provided, then the linkage argument must be provided.

If the ? flag is specified, the section is implicitly in the same group as the previous section, and the group_name and linkage options are not accepted.

It is an error to specify both the G and ? flags on the same section.

link_order_symbol
If the o flag is specified, the link_order_symbol argument is required. This must be a symbol which is defined earlier in the same file. If multiple sections with the o flag are present at link time, the linker ensures that they are in the same order in the image as the sections which define the symbols they reference here.
unique and unique_id

If the optional unique argument is provided, then the unique_id argument must also be provided. This should be a constant expression which evaluates to a positive integer. If a section has previously been created with the same name and unique ID, then the assembler will switch to the existing section, appending content to it. Otherwise, a new section is created. Sections without a unique ID specified will never be merged with sections that do have one. This allows creating multiple sections with the same name. The exact value of the unique ID is not important, and it has no effect on the generated object file.

Operation

The .section directive switches the current target section to the one described by its arguments. The .pushsection directive pushes the current target section onto a stack, and switches to the section described by its arguments. The .popsection directive takes no arguments, and reverts the current target section to the previous one on the stack. The rest of the directives (.text, .data, .rodata, .bss) switch to one of the built-in sections.

If continuing a previous section, and the flags, type, or other arguments do not match the previous definition of the section, then the arguments of the current .section directive will have no effect on the section. Instead, the assembler uses the arguments from the previous .section directive. The assembler does not currently emit a diagnostic when this happens.

Default

Some section names and section name prefixes implicitly have some flags set. Additional flags can be set using the flags argument, but it is not possible to clear these implicit flags. The section names that have implicit flags are listed in the table here. For sections names not mentioned in the table, the default is to have no flags.

If the %type argument is not provided, the type is inferred from the section name. For sections names not mentioned in the table here, the default section type is %progbits.

Table 9-16 Sections with implicit flags and default types

<table>
<thead>
<tr>
<th>Section name</th>
<th>Implicit Flags</th>
<th>Default Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>.rodata</td>
<td>a</td>
<td>%progbits</td>
</tr>
<tr>
<td>.rodata.*</td>
<td>a</td>
<td>%progbits</td>
</tr>
<tr>
<td>.rodata1</td>
<td>a</td>
<td>%progbits</td>
</tr>
<tr>
<td>.text</td>
<td>ax</td>
<td>%progbits</td>
</tr>
<tr>
<td>.text.*</td>
<td>ax</td>
<td>%progbits</td>
</tr>
<tr>
<td>.init</td>
<td>ax</td>
<td>%progbits</td>
</tr>
<tr>
<td>.fini</td>
<td>ax</td>
<td>%progbits</td>
</tr>
<tr>
<td>.data</td>
<td>aw</td>
<td>%progbits</td>
</tr>
<tr>
<td>.data.*</td>
<td>aw</td>
<td>%progbits</td>
</tr>
<tr>
<td>.data1</td>
<td>aw</td>
<td>%progbits</td>
</tr>
<tr>
<td>.bss</td>
<td>aw</td>
<td>%nobits</td>
</tr>
<tr>
<td>.bss.*</td>
<td>aw</td>
<td>%nobits</td>
</tr>
<tr>
<td>.init_array</td>
<td>aw</td>
<td>%init_array</td>
</tr>
<tr>
<td>.init_array.*</td>
<td>aw</td>
<td>%init_array</td>
</tr>
<tr>
<td>.fini_array</td>
<td>aw</td>
<td>%fini_array</td>
</tr>
</tbody>
</table>
Table 9-16 Sections with implicit flags and default types (continued)

<table>
<thead>
<tr>
<th>Section name</th>
<th>Implicit Flags</th>
<th>Default Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>.fini_array.*</td>
<td>aw</td>
<td>%fini_array</td>
</tr>
<tr>
<td>.preinit_array</td>
<td>aw</td>
<td>%preinit_array</td>
</tr>
<tr>
<td>.preinit_array.*</td>
<td>aw</td>
<td>%preinit_array</td>
</tr>
<tr>
<td>.tdata</td>
<td>awT</td>
<td>%progbits</td>
</tr>
<tr>
<td>.tdata.*</td>
<td>awT</td>
<td>%progbits</td>
</tr>
<tr>
<td>.tbss</td>
<td>awT</td>
<td>%nobits</td>
</tr>
<tr>
<td>.tbss.*</td>
<td>awT</td>
<td>%nobits</td>
</tr>
<tr>
<td>.note</td>
<td>No default</td>
<td>%note</td>
</tr>
</tbody>
</table>

Examples

Splitting code and data into the built-in .text and .data sections. These sections can be placed independently by the linker, for example to place the code in flash memory, and the writable data in RAM.

```asm
.text
    .section get_value:
        movw r0, #:lower16:value
        movt r0, #:upper16:value
        ldr r0, [r0]
        bx lr

.data
    .section value:
        .word 42
```

Creating a section consisting of constant, mergeable records. This section contains a series of 8-byte records, where the linker is allowed to merge two records with identical content (possibly coming from different object files) into one record to reduce the image size.

```asm
.section mergable, "aM", %progbits, 8
    entry1:
        .word label1
        .word 42
    entry2:
        .word label2
        .word 0x1234
```

Creating two sections with the same name:

```asm
.section .data, "aw", %progbits, unique, 1
    .word 1
.section .section .data, "aw", %progbits, unique, 2
    .word 2
```

Creating a section group containing two sections. Here, the G flag is used for the first section, using the group_signature symbol. The second section uses the ? flag to simplify making it part of the same group. Any further sections in this file using the G flag and group_signature symbol are placed in the same group.

```asm
.section foo, "axG", %progbits, group_signature
    .section bar, "aw?"
    .local value
    .section value:
        .word 42
```
9.8 Conditional assembly directives

These directives allow you to conditionally assemble sequences of instructions and directives.

**Syntax**

```
.if [modifier] expression
   // ...
[.elseif expression
   // ...
][.else
   // ...
].endif
```

**Operation**

There are a number of different forms of the `.if` directive which check different conditions. Each `.if` directive must have a matching `.endif` directive. A `.if` directive can optionally have one associated `.else` directive, and can optionally have any number of `.elseif` directives.

You can nest these directives, with the maximum nesting depth limited only by the amount of memory in your computer.

The following forms if the `.if` directive are available, which check different conditions:

<table>
<thead>
<tr>
<th><code>.if condition modifier</code></th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>.if expr</code></td>
<td>Assembles the following code if <code>expr</code> evaluates to non zero.</td>
</tr>
<tr>
<td><code>.ifne expr</code></td>
<td>Assembles the following code if <code>expr</code> evaluates to non zero.</td>
</tr>
<tr>
<td><code>.ifeq expr</code></td>
<td>Assembles the following code if <code>expr</code> evaluates to zero.</td>
</tr>
<tr>
<td><code>.ifge expr</code></td>
<td>Assembles the following code if <code>expr</code> evaluates to a value greater than or equal to zero.</td>
</tr>
<tr>
<td><code>.ifle expr</code></td>
<td>Assembles the following code if <code>expr</code> evaluates to a value less than or equal to zero.</td>
</tr>
<tr>
<td><code>.ifgt expr</code></td>
<td>Assembles the following code if <code>expr</code> evaluates to a value greater than zero.</td>
</tr>
<tr>
<td><code>.iflt expr</code></td>
<td>Assembles the following code if <code>expr</code> evaluates to a value less than zero.</td>
</tr>
<tr>
<td><code>.ifb text</code></td>
<td>Assembles the following code if the argument is blank.</td>
</tr>
<tr>
<td><code>.ifnb text</code></td>
<td>Assembles the following code if the argument is not blank.</td>
</tr>
<tr>
<td><code>.ifc string1 string2</code></td>
<td>Assembles the following code if the two strings are the same. The strings may be optionally surrounded by double quote characters (&quot;). If the strings are not quoted, the first string ends at the first comma character, and the second string ends at the end of the statement (newline or semicolon).</td>
</tr>
<tr>
<td><code>.ifnc string1 string2</code></td>
<td>Assembles the following code if the two strings are not the same. The strings may be optionally surrounded by double quote characters (&quot;). If the strings are not quoted, the first string ends at the first comma character, and the second string ends at the end of the statement (newline or semicolon).</td>
</tr>
<tr>
<td><code>.ifeqs string1 string2</code></td>
<td>Assembles the following code if the two strings are the same. Both strings must be quoted.</td>
</tr>
</tbody>
</table>
### Table 9-17 .if condition modifiers (continued)

<table>
<thead>
<tr>
<th>.if condition modifier</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>.ifnes string1 string2</td>
<td>Assembles the following code if the two strings are not the same. Both strings must be quoted.</td>
</tr>
<tr>
<td>.ifdef expr</td>
<td>Assembles the following code if symbol was defined earlier in this file.</td>
</tr>
<tr>
<td>.ifndef expr</td>
<td>Assembles the following code if symbol was not defined earlier in this file.</td>
</tr>
</tbody>
</table>

The .elseif directive takes an expression argument but does not take a condition modifier, and therefore always behaves the same way as .if, assembling the subsequent code if the expression is not zero, and if no previous conditions in the same .if .elseif chain were true.

The .else directive takes no argument, and the subsequent block of code is assembled if none of the conditions in the same .if .elseif chain were true.

#### Examples

```assembly
// A macro to load an immediate value into a register. This expands to one or two instructions, depending on the value of the immediate operand.
.macro get_imm, reg, imm
  .if \imm >= 0x10000
    movw \reg, #\imm & 0xffff
    movt \reg, #\imm >> 16
  .else
    movw \reg, #\imm
  .endif
.endm

// The first of these macro invocations expands to one movw instruction, the second expands to a movw and a movt instruction.
get_constants:
  get_imm r0, 42
  get_imm r1, 0x12345678
  bx lr
```

9 armclang Integrated Assembler Directives
9.8 Conditional assembly directives

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9.9 Macro directives

The .macro directive defines a new macro.

Syntax

```
.macro macro_name [, parameter_name]...
    // ...
    [.exitm]
.endm
```

Description

`macro_name`

The name of the macro.

`parameter_name`

Inside the body of a macro, the parameters can be referred to by their name, prefixed with \. When the macro is instantiated, parameter references will be expanded to the value of the argument.

Parameters can be qualified in these ways:

<table>
<thead>
<tr>
<th>Parameter qualifier</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>&lt;name&gt;:req</code></td>
<td>This marks the parameter as required, it is an error to instantiate the macro with a blank value for this parameter.</td>
</tr>
<tr>
<td><code>&lt;name&gt;:varag</code></td>
<td>This parameter consumes all remaining arguments in the instantiation. If used, this must be the last parameter.</td>
</tr>
<tr>
<td><code>&lt;name&gt;=&lt;value&gt;</code></td>
<td>Sets the default value for the parameter. If the argument in the instantiation is not provided or left blank, then the default value will be used.</td>
</tr>
</tbody>
</table>

Operation

The .macro directive defines a new macro with name `macro_name`, and zero or more named parameters. The body of the macro extends to the matching .endm directive.

Once a macro is defined, it can be instantiated by using it like an instruction mnemonic:

`macro_name argument[, argument]...`

Inside a macro body, \ expands to a counter value which is unique to each macro instantiation. This can be used to create unique label names, which will not interfere with other instantiations of the same macro.

The .exitm directive allows exiting a macro instantiation before reaching the end.

Examples

```
// Macro for defining global variables, with the symbol binding, type and size set appropriately. The 'value' parameter can be omitted, in which case the variable gets an initial value of 0. It is an error to not provide the 'name' argument.
.macro global_int, name:req, value=0
    .global \name
    .type \name, %object
    .size \name, 4
    \name:
    .word \value
.endm
```
.data
  global_int foo
  global_int bar, 42
9.10 Symbol binding directives

These directives modify the ELF binding of one or more symbols.

Syntax

<table>
<thead>
<tr>
<th>.global symbol[, symbol]...</th>
</tr>
</thead>
<tbody>
<tr>
<td>.local symbol[, symbol]...</td>
</tr>
<tr>
<td>.weak symbol[, symbol]...</td>
</tr>
</tbody>
</table>

Description

.global

The .global directive sets the symbol binding to STB_GLOBAL. These symbols will be visible to all object files being linked, so a definition in one object file can satisfy a reference in another.

.local

The .local directive sets the symbol binding in the symbol table to STB_LOCAL. These symbols are not visible outside the object file they are defined or referenced in, so multiple object files can use the same symbol names without interfering with each other.

.weak

The .weak directive sets the symbol binding to STB_WEAK. These symbols behave similarly to global symbols, with these differences:

• If a reference to a symbol with weak binding is not satisfied (no definition of the symbol is found), this is not an error.
• If multiple definitions of a weak symbol are present, this is not an error. If a definition of the symbol with strong binding is present, that one will satisfy all references to the symbol, otherwise one of the weak references will be chosen.

Operation

The symbol binding directive can be at any point in the assembly file, before or after any references or definitions of the symbol.

If the binding of a symbol is not specified using one of these directives, the default binding is:
• If a symbol is not defined in the assembly file, it will by default have global visibility.
• If a symbol is defined in the assembly file, it will by default have local visibility.

Note

.local and .L are different directives. Symbols starting with .L are not put into the symbol table.

Examples

```
// This function has global binding, so can be referenced from other object
// files. The symbol 'value' defaults to local binding, so other object
// files can use the symbol name 'value' without interfering with this
// definition and reference.
.global get_val
get_val:
  ldr r0, value
  bx lr
value:
  .word 0x12345678

// The symbol 'printf' is not defined in this file, so defaults to global
// binding, so the linker will search other object files and libraries to
// find a definition of it.
bl printf
```
// The debug_trace symbol is a weak reference. If a definition of it is
// found by the linker, this call will be relocated to point to it. If a
// definition is not found (e.g. in a release build, which does not include
// the debug code), the linker will point the bl instruction at the next
// instruction, so it has no effect.
.weak debug_trace
bl debug_trace
9.11 Org directive

The .org directive advances the location counter in the current section to new-location.

Syntax

.org new_location [, fill_value]

Description

new_location

The new_location argument must be one of:

• An absolute integer expression, in which case it is treated as the number of bytes from the start of the section.
• An expression which evaluates to a location in the current section. This could use a symbol in the current section, or the current location (\'\'.

fill_value

This is an optional 1-byte value.

Operation

The .org directive can only move the location counter forward, not backward.

By default, the .org directive inserts zero bytes in any locations that it skips over. This can be overridden using the optional fill_value argument, which sets the 1-byte value that will be repeated in each skipped location.

Examples

// Macro to create one AArch64 exception vector table entry. Each entry // must be 128 bytes in length. If the code is shorter than that, padding // will be inserted. If the code is longer than that, the .org directive // will report an error, as this would require the location counter to move // backwards.
.macro exc_tab_entry, num
1:
mov x0, #\num
b unhandled_exception
.org 1b + 0x80
.endm

// Each of these macro instantiations emits 128 bytes of code and padding.
.section vectors, "ax"
exc_tab_entry 0
exc_tab_entry 1
// More table entries...
9.12 AArch32 Target selection directives

The AArch32 target selection directives specify code generation parameters for AArch32 targets.

**Syntax**

<table>
<thead>
<tr>
<th>Directive</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>.arm</td>
<td>The .arm directive instructs the assembler to interpret subsequent instructions as A32 instructions, using the UAL syntax. The .code 32 directive is an alias for .arm.</td>
</tr>
<tr>
<td>.thumb</td>
<td>The .thumb directive instructs the assembler to interpret subsequent instructions as T32 instructions, using the UAL syntax. The .code 16 directive is an alias for .thumb.</td>
</tr>
<tr>
<td>.arch arch_name</td>
<td>The .arch directive changes the architecture that the assembler is generating instructions for. The arch_name argument accepts the same names as the -march option, but does not accept the optional architecture extensions accepted by the command-line option.</td>
</tr>
<tr>
<td>.cpu cpu_name</td>
<td>The .cpu directive changes the CPU that the assembler is generating instructions for. The cpu_name argument accepts the same names as the -mcpu option, but does not accept the optional architecture extensions accepted by the command-line option.</td>
</tr>
<tr>
<td>.fpu fpu_name</td>
<td>The .fpu directive changes the FPU that the assembler is generating instructions for. The fpu_name argument accepts the same names as the -mfpu option.</td>
</tr>
<tr>
<td>.arch_extension</td>
<td>The .arch_extension directive enables or disables optional extensions to the architecture or CPU that the assembler is generating instructions for. It accepts the following optional extensions, which can be prefixed with no to disable them: crc, fp16, ras</td>
</tr>
<tr>
<td>.eabi_attribute</td>
<td>The .eabi_attribute directive sets a build attribute in the output file. Build attributes are used by armlink to check for co-compatibility between object files, and to select suitable libraries.</td>
</tr>
</tbody>
</table>

The .eabi_attribute directive sets a build attribute in the output file. Build attributes are used by armlink to check for co-compatibility between object files, and to select suitable libraries.
The `.eabi_attribute` directive does not have any effect on which instructions the assembler will accept. It is recommended that the `.arch`, `.cpu`, `.fpu` and `.arch_extension` directives are used where possible, as they also check that no instructions not valid for the selected architecture are valid. These directives also set the relevant build attributes, so the `.eabi_attribute` directive is only needed for attributes not covered by them.

**tag**

The tag argument specifies the tag that is to be set. This can either be the tag name or tag number, but not both.

**value**

The value argument specifies the value to set for the **tag**. The value can either be of integer or string type. The type must match exactly the type expected for that tag.

---

**Note**

Tag_compatibility is a special tag that requires both an integer value and a string value:

```
.eabi_attribute Tag_compatibility, integer_value, string_value
```

---

**Examples**

```c
// Generate code for the Armv7-M architecture:
.arch armv7-m

// Generate code for the Cortex-R5, without an FPU:
.cpu cortex-r5
.fpu none

// Generate code for Armv8.2-A with the FP16 extension:
.arch armv8.2-a
.fpu neon-fp-armv8
.arch_extension fp16
```
9.13 AArch64 Target selection directives

The AArch64 target selection directives specify code generation parameters for AArch64 targets.

Syntax

```plaintext
.arch arch_name[+no]extension_ 
.cpu cpu_name[+no]extension_ 
```

Description

`.arch`

The `.arch` directive changes the architecture that the assembler is generating instructions for. The `arch_name` argument accepts the same names as the `-march` option, and accepts certain optional architecture extensions (`extension`) separated by `+`. The `extension` can be prefixed with `no` to disable it.

`.cpu`

The `.cpu` directive changes the CPU that the assembler is generating instructions for. The `cpu_name` argument accepts the same names as the `-mcpu` option, and accepts certain optional architecture extensions (`extension`) separated by `+`. The `extension` can be prefixed with `no` to disable it.

`extension`

Optional architecture extensions. The accepted architecture extensions are:

- `crc`
- `crypto`
- `fp`
- `ras`
- `simd`

Examples

```plaintext
// Generate code for Armv8-A without a floating-point unit. The assembler 
// will report an error if any instructions following this directive require 
// the floating-point unit.
.arch armv8-a+nofp
```
9.14 Space-filling directives

The `.space` directive emits `count` bytes of data, each of which has value `value`. If the `value` argument is omitted, it defaults to zero.

Syntax

```
.space count [, value]
.fill count [, size [, value]]
```

Description

`.space`

The `.space` directive emits `count` bytes of data, each of which has value `value`. If the `value` argument is omitted, it defaults to zero.

The `.skip` and `.zero` directives are aliases for the `.space` directive.

`.fill`

The `.fill` directive emits `count` data values, each with length `size` bytes and value `value`. If `size` is greater than 8, it will be truncated to 8. If the `size` argument is omitted, it defaults to one. If the `value` argument is omitted, it defaults to zero.

The `.fill` directive always interprets the `value` argument as a 32-bit value.

- If the `size` argument is less than or equal to 4, the `value` argument is truncated to `size` bytes, and emitted with the appropriate endianness for the target. The assembler does not emit a diagnostic if `value` is truncated in this case.
- If the `size` argument is greater than 4, the value is emitted as a 4-byte value with the appropriate endianness, in 4 bytes of the allocated memory with the lowest addresses. The remaining bytes in the allocated memory are then filled with zeroes. In this case, the assembler does emit a diagnostic if the value is truncated.
9.15 **Type directive**

The `.type` directive sets the type of a symbol.

**Syntax**

```
.type symbol, %type
```

**Description**

`.type`

The `.type` directive sets the type of a symbol.

`symbol`

The symbol name to set the type for.

`%type`

The following types are accepted:

- `%function`
- `%object`
- `%tls_object`

**Examples**

```assembly
// 'func' is a function
.type func, %function
func:
  bx lr

// 'value' is a data object:
.type value, %object
value:
  .word 42
```
Chapter 10
armclang Inline Assembler

Provides reference information on writing inline assembly.

It contains the following sections:

• 10.1 Inline Assembly on page 10-301.
• 10.2 File-scope inline assembly on page 10-302.
• 10.3 Inline assembly statements within a function on page 10-303.
• 10.4 Inline assembly constraint strings on page 10-307.
• 10.5 Inline assembly template modifiers on page 10-312.
• 10.6 Forcing inline assembly operands into specific registers on page 10-315.
• 10.7 Symbol references and branches into and out of inline assembly on page 10-316.
• 10.8 Duplication of labels in inline assembly statements on page 10-317.
10.1 Inline Assembly

armclang provides an inline assembler that enables you to write assembly language sequences in C and C++ language source files. The inline assembler also provides access to features of the target processor that are not available from C or C++.

You can use inline assembly in two contexts:

• File-scope inline assembly statements.

```asm(".global __use_realtime_heap");```

• Inline assembly statement within a function.

```c
void set_translation_table(void *table) {
    __asm("msr TTBR0_EL1, %0" :
          "r" (table));
}
```

Both syntaxes accept assembly code as a string. Write your assembly code in the syntax that the integrated assembler accepts. For both syntaxes, the compiler inserts the contents of the string into the assembly code that it generates. All assembly directives that the integrated assembler accepts are available to use in inline assembly. However, the state of the assembler is not reset after each block of inline assembly. Therefore, avoid using directives in a way that affects the rest of the assembly file, for example by switching the instruction set between A32 and T32. See Chapter 9 armclang Integrated Assembler Directives on page 9-269.

Implications for inline assembly with optimizations

You can write complex inline assembly that appears to work at some optimization levels, but the assembly is not correct. The following examples describe some situations when inline assembly is not guaranteed to work:

• Including an instruction that generates a literal pool. There is no guarantee that the compiler can place the literal pool in the range of the instruction.

• Using or referencing a function only from the inline assembly without telling the compiler that it is used. The compiler treats the assembly as text. Therefore, the compiler can remove the function that results in an unresolved reference during linking. The removal of the function is especially visible for LTO, because LTO performs whole program optimization and is able to remove more functions.

For file-scope inline assembly, you can use the `__attribute__((used))` function attribute to tell the compiler that a function is used. For inline assembly statements, use the input and output operands.

For large blocks of assembly code where the overhead of calling between C or C++ and assembly is not significant, Arm recommends using a separate assembly file, which does not have these limitations.

Related reference

10.2 File-scope inline assembly on page 10-302
10.3.2 Output and input operands on page 10-304

Related information

Optimizing across modules with link time optimization
10.2 File-scope inline assembly

Inline assembly can be used at file-scope to insert assembly into the output of the compiler.

All file-scope inline assembly code is inserted into the output of the compiler before the code for any functions or variables declared in the file, regardless of where they appear in the input. If multiple blocks of file-scope inline assembly code are present in one file, they are emitted in the same order as they appear in the source code.

Compiling multiple files containing file-scope inline assembly with the -flto option does not affect the ordering of the blocks within each file, but the ordering of blocks in different files is not defined.

Syntax

```
__asm("assembly code");
```

If you include multiple assembly statements in one file-scope inline assembly block, you must separate them by newlines or semicolons. The assembly string does not have to end in a new-line or semicolon.

Examples

```
// Simple file-scope inline assembly.
__asm(".global __use_realtime_heap");

// Multiple file-scope inline assembly statements in one block:
__asm("add_ints:
  add r0, r0, r1
  bx lr");

// C++11 raw string literals can be used for long blocks, without needing to
// include escaped newlines in the assembly string (requires C++11):
__asm(R"(
  sub_ints:
  sub r0, r0, r1
  bx lr
)");
```
10.3 Inline assembly statements within a function

Inline assembly statements can be used inside a function to insert assembly code into the body of a C or C++ function.

Inline assembly code allows for passing control-flow and values between C/C++ and assembly at a fine-grained level. The values that are used as inputs to and outputs from the assembly code must be listed, and special tokens in the assembly string are replaced with the registers that contain these values.

As with file-scope inline assembly, you can use any instructions or directives that are available in the integrated assembler in the assembly string. Use multiple assembly statements in the string of one inline assembly statement by separating them with newlines or semicolons. If you use multiple instructions in this way, the optimizer treats them as a complete unit, and does not split them up, reorder them, or omit some of them.

The compiler makes no guarantee that the ordering of multiple inline assembly statements will be preserved. It may also do the following:

- Merge two identical inline assembly statements into one inline assembly statement.
- Split one inline assembly statement into two inline assembly statements.
- Remove an inline assembly statement that has no apparent effect on the result of the program.

To prevent the compiler from doing any of these operations, you must use the input and output operands and the `volatile` keyword to indicate to the compiler which optimizations are valid.

The compiler does not parse the contents of the assembly string, except for replacing template strings, until code-generation is complete. It relies on the input and output operands, and clobbers to tell it about the requirements of the assembly code, and constraints on the surrounding generated code. Therefore the input and output operands, and clobbers must be accurate.

**Syntax**

```
__asm [volatile] {
  "<assembly string>
  [: <output operands>]
  [: <input operands>]
  [: <clobbers>] ]
};
```

This section contains the following subsections:

- [10.3.1 Assembly string](#assembly-string) on page 10-303.
- [10.3.2 Output and input operands](#output-and-input-operands) on page 10-304.
- [10.3.3 Clobber list](#clobber-list) on page 10-305.
- [10.3.4 volatile](#volatile) on page 10-306.

### 10.3.1 Assembly string

An assembly string is a string literal that contains the assembly code.

The assembly string can contain template strings, starting with `%`, which the compiler replaces. The main use of these strings is to use registers that the compiler allocates to hold the input and output operands.

**Syntax**

Template strings for operands can take one of the following forms:

```
"%<modifier><number>"
"%<modifier>[<name>]"
```

<modifier> is an optional code that modifies the format of the operand in the final assembly string. You can use the same operand multiple times with different modifiers in one assembly string. See [10.5 Inline assembly template modifiers](#inline-assembly-template-modifiers) on page 10-312.

For numbered template strings, the operands of the inline assembly statement are numbered, starting from zero, in the order they appear in the operand lists. Output operands appear before input operands.
If an operand has a name in the operand lists, you can use this name in the template string instead of the operand number. Square brackets must surround the name. Using names makes larger blocks of inline assembly easier to read and modify.

The %% template string emits a % character into the final assembly string.

The %= template string emits a number that is unique to the instance of the inline assembly statement. See 10.8 Duplication of labels in inline assembly statements on page 10-317.

10.3.2 Output and input operands

The inline assembly statement can optionally accept two lists of operand specifiers, the first for outputs and the second for inputs. These lists are used to pass values between the assembly code and the enclosing C/C++ function.

Syntax

Each list is a comma-separated list of operand specifiers. Each operand specifier can take one of the following two forms:

```
[<name>]"<constraint>" (<value>)
"<constraint>" (<value>)
```

Where:

- `<name>`
  Is a name for referring to the operand in templates inside the inline assembly string. If the name for an operand is omitted, it must be referred to by number instead.

- `<constraint>`
  Is a string that tells the compiler how the value will be used in the assembly string, including:
  - For output operands, whether it is only written to, or both read from and written to. Also whether it can be allocated to the same register as an input operand. See 10.4.1 Constraint modifiers on page 10-307.
  - Whether to store the value in a register or memory, or whether it is a compile-time constant. See 10.4.2 Constraint codes on page 10-307.

- `<value>`
  Is a C/C++ value that the operand corresponds to. For output operands, this value must be a writable value.

Example

foo.c:

```c
int saturating_add(int a, int b) {
    int result;
    __asm{
        // The assembly string uses templates for the registers which hold output
        // and input values. These will be replaced with the names of the
        // registers that the compiler chooses to hold the output and input
        // values.

        "qadd %0, %[lhs], %[rhs]"

        // The output operand, which corresponds to the "result" variable. This
        // does not have a name assigned, so must be referred to in the assembly
        // string by its number ("%0").
        // The "=" character in the constraint tells the compiler that the
        // register chosen to hold the result does not need to have any
        // particular value at the start of the inline assembly.
        // The "r" character in the constraint tells the compiler that the value
        // should be placed in a general-purpose register (r0-r12 or r14).
        : "=r" (result)

        // The two input operands also use the "r" character in their
        // constraints, so the compiler will place them in general-purpose
        // registers.
        // These have names specified, which can be used to refer to them in
        // the assembly string ("%[lhs]" and "%[rhs]").
    }
}
```
Build this example with the following command:

```
armclang --target=arm-arm-none-eabi -march=armv7-a -O2 -c -S foo.c -o foo.s
```

The assembly language source file `foo.s` that is generated contains:

```
.section .text.saturating_add,"ax",%progbits
.hidden saturating_add @ -- Begin function saturating_add
.globl saturating_add
.p2align 2
.type saturating_add,%function
.code 32 @ @saturating_add
saturating_add:
    .fnstart
    @ %bb.0:                            @ %entry
    @APP
    qadd r0,r0,r1
    @NO_APP
    bx lr
    .Lfunc_end0:
    .size saturating_add, .Lfunc_end0-saturating_add
    .cantunwind
    .fnend
```

In this example:

- The compiler places the C function `saturating_add()` in a section that is called `.text.saturating_add`.
- Within the body of the function, the compiler expands the inline assembly statement into the `qadd r0, r0, r1` instruction between the comments `@APP` and `@NO_APP`. In `-S` output, the compiler always places code that it expands from inline assembly statements within a function between a pair of `@APP` and `@NO_APP` comments.
- The compiler uses the general-purpose register R0 for:
  - The int a parameter of the `saturating_add()` function.
  - The inline assembly input operand `%[lhs]`.
  - The inline assembly output operand `%0`.
  - The return value of the `saturating_add()` function.
- The compiler uses the general-purpose register R1 for:
  - The int b parameter of the `saturating_add()` function.
  - The inline assembly input operand `%[rhs]`.

### 10.3.3 Clobber list

The clobber list is a comma-separated list of strings. Each string is the name of a register that the assembly code potentially modifies, but for which the final value is not important. To prevent the compiler from using a register for a template string in an inline assembly string, add the register to the clobber list.

For example, if a register holds a temporary value, include it in the clobber list. The compiler avoids using a register in this list as an input or output operand, or using it to store another value when the assembly code is executed.

You can also use the string `memory` in the clobber list. This string tells the compiler that the assembly code may modify any memory, not just variables that are included in the output constraints.

### Example

```c
void enable_aarch64() {
    // Set bit 10 of SCR_EL3, to enable AArch64 at EL2.
    __asm volatile("R"
        mrs x0, SCR_EL3
        orr x0, x0, #1<<10
        msr SCR_EL3, x0
    
```
10.3.4 volatile

The optional volatile keyword tells the compiler that the assembly code has side-effects that the output, input, and clobber lists do not represent. For example, use this keyword with inline assembly code that sets the value of a system register.

The compiler assumes that any inline assembly statement with no output operands is volatile, even if the keyword is not present. However, Arm recommends that you still use it for clarity, and to avoid a behavior change if an output is added later.

Example

```c
void *swap_ttbr0(void *new_table) {
  void *old_table;
  __asm volatile {
    "mrs %[old], TTBR0_EL1\n"
    "msr TTBR0_EL1, %[new]\n"
    : [old] "=&r" (old_table)
    : [new] "r"   (new_table);
  } return old_table;
}
```


10.4 Inline assembly constraint strings

A constraint string is a string literal, the contents of which are composed of two parts.

The contents of the constraint string are:

• A constraint modifier if the constraint string is for an output operand.
• One or more constraint codes.

This section contains the following subsections:

• 10.4.1 Constraint modifiers on page 10-307.
• 10.4.2 Constraint codes on page 10-307.
• 10.4.3 Constraint codes common to AArch32 state and AArch64 state on page 10-308.
• 10.4.4 Constraint codes for AArch32 state on page 10-308.
• 10.4.5 Constraint codes for AArch64 state on page 10-309.
• 10.4.6 Using multiple alternative operand constraints on page 10-310.

10.4.1 Constraint modifiers

All output operands require a constraint modifier. There are currently no supported constraint modifiers for input operands.

**Table 10-1 Constraint modifiers**

<table>
<thead>
<tr>
<th>Modifier</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>=</td>
<td>This operand is only written to, and only after all input operands have been read for the last time. Therefore the compiler can allocate this operand and an input to the same register or memory location.</td>
</tr>
<tr>
<td>+</td>
<td>This operand is both read from and written to.</td>
</tr>
<tr>
<td>=&amp;</td>
<td>This operand is only written to. It might be modified before the assembly block finishes reading the input operands. Therefore the compiler cannot use the same register to store this operand and an input operand. Operands with the =&amp; constraint modifier are known as early-clobber operands.</td>
</tr>
</tbody>
</table>

10.4.2 Constraint codes

Constraint codes define how to pass an operand between assembly code and the surrounding C or C++ code.

There are three categories of constraint codes:

**Constant operands**

You can only use these operands as input operands, and they must be compile-time constants. Use where a value will be used as an immediate operand to an instruction. There are target-specific constraints that accept the immediate ranges suitable for different instructions.

**Register operands**

You can use these operands as both input and output operands. The compiler allocates a register to store the value. As there are a limited number of registers, it is possible to write an inline assembly statement for which there are not enough available registers. In this case, the compiler reports an error. The exact number of available registers varies depending on the target architecture and the optimization level.

**Memory operands**

You can use these operands as both input and output operands. Use them with load and store instructions. Usually a register is allocated to hold a pointer to the operand. As there are a limited number of registers, it is possible to write an inline assembly statement for which there are not enough available registers. In this case, the compiler reports an error. The exact number of available registers can vary depending on the target architecture and the optimization level.
There are some common constraints, which can be used in both AArch32 state and AArch64 state. Other constraints are specific to AArch32 state or AArch64 state. In AArch32 state, there are some constraints that vary depending on the selected instruction set.

10.4.3 Constraint codes common to AArch32 state and AArch64 state

The following constraint codes are common to both AArch32 state and AArch64 state.

**Constants**

- **i**  
  A constant integer, or the address of a global variable or function.

- **n**  
  A constant integer.

**Note**  
The immediate constraints only check that their operand is constant after optimizations have been applied. Therefore it is possible to write code that you can only compile at higher optimization levels. Arm recommends that you test your code at multiple optimization levels to ensure it compiles.

**Memory**

- **m**  
  A memory reference. This constraint causes a general-purpose register to be allocated to hold the address of the value instead of the value itself. By default, this register is printed as the name of the register surrounded by square brackets, suitable for use as a memory operand. For example, [r4] or [x7]. In AArch32 state only, you can print the register without the surrounding square brackets by using the m template modifier. See 10.5.2 Template modifiers for AArch32 state on page 10-312.

**Other**

- **X**  
  If the operand is a constant after optimizations have been performed, this constraint is equivalent to the **i** constraint. Otherwise, it is equivalent to the **r** or **w** constraints, depending on the type of the operand.

**Note**  
Arm recommends that you use more precise constraints where possible. The **X** constraint does not perform any of the range checking or register restrictions that the other constraints perform.

10.4.4 Constraint codes for AArch32 state

The following constraint codes are specific to AArch32 state.

**Registers**

- **r**  
  Operand must be an integer or floating-point type.

  For targets that do not support Thumb-2 technology, the compiler can use R0-R7.

  For all other targets, the compiler can use R0-R12, or R14.

- **l**  
  Operand must be an integer or floating-point type.

  For T32 state, the compiler can use R0-R7.

  For A32 state, the compiler can use R0-R12, or R14.
h
Operand must be an integer or floating-point type.
For T32 state, the compiler can use R8-R12, or R14.
Not valid for A32 state.

w
Operand must be a floating-point or vector type, or a 64-bit integer.
The compiler can use S0-S31, D0-D31, or Q0-Q15, depending on the size of the operand type.

t
Operand must be a 32-bit floating-point or integer type.
The compiler can use S0-S31.

The compiler never selects a register that is not available for register allocation. Similarly, R9 is reserved when compiling with -frwpi, and is not selected. The compiler may also reserve one or two registers to use as a frame pointer and a base pointer. The number of registers available for inline assembly operands therefore may be less than the number implied by the ranges above. This number may also vary with the optimization level.

If you use a 64-bit value as an operand to an inline assembly statement in A32 or 32-bit T32 instructions, and you use the r constraint code, then an even/odd pair of general purpose registers is allocated to hold it. This register allocation is not guaranteed for the h constraint.

Using the r constraint code enables the use of instructions like LDREXD/STREXD, which require an even/odd register pair. You can reference the registers holding the most and least significant halves of the value with the Q and R template modifiers. For an example of using template modifiers, see \textit{10.5.2 Template modifiers for AArch32 state on page 10-312}.

\textbf{Constants}

The constant constraints accept different ranges depending on the selected instruction set. These ranges correspond to the ranges of immediate operands that are available for the different instruction sets. You can use them with a register constraint (see \textit{10.4.6 Using multiple alternative operand constraints on page 10-310}) to write inline assembly that emits optimal code for multiple architectures without having to change the assembly code. The emitted code uses immediate operands when possible.

<table>
<thead>
<tr>
<th>Constraint code</th>
<th>16-bit T32 instructions</th>
<th>32-bit T32 instructions</th>
<th>A32 instructions</th>
</tr>
</thead>
<tbody>
<tr>
<td>J</td>
<td>[-255, -1]</td>
<td>[-4095, 4095]</td>
<td>[-4095, 4095]</td>
</tr>
<tr>
<td>K</td>
<td>8-bit value shifted left any amount.</td>
<td>Bitwise inverse of a modified immediate value for a 32-bit T32 instruction.</td>
<td>Bitwise inverse of a modified immediate value for an A32 instruction.</td>
</tr>
</tbody>
</table>

\textbf{10.4.5 Constraint codes for AArch64 state}

The following constraint codes are specific to AArch64 state.
Registers

r

The compiler can use a 64-bit general purpose register, X0-X30.
If you want the compiler to use the 32-bit general purpose registers W0-W31 instead, use the w template modifier.

w

The compiler can use a SIMD or floating-point register, V0-V31.
The b, h, s, d, and q template modifiers can override this behavior.

x

Operand must be a 128-bit vector type.
The compiler can use a low SIMD register, V0-V15.

Constants

z

A constant with value zero, printed as the zero register (XZR or WZR). Useful when combined with r (see 10.4.6 Using multiple alternative operand constraints on page 10-310) to represent an operand that can be either a general-purpose register or the zero register.

I

[0, 4095], with an optional left shift by 12. The range that the ADD and SUB instructions accept.

J

[-4095, 0], with an optional left shift by 12.

K

An immediate that is valid for 32-bit logical instructions. For example, AND, ORR, EOR.

L

An immediate that is valid for 64-bit logical instructions. For example, AND, ORR, EOR.

M

An immediate that is valid for a MOV instruction with a destination of a 32-bit register. Valid values are all values that the K constraint accepts, plus the values that the MOVZ, MOVN, and MOVK instructions accept.

N

An immediate that is valid for a MOV instruction with a destination of a 64-bit register. Valid values are all values that the L constraint accepts, plus the values that the MOVZ, MOVN, and MOVK instructions accept.

Related reference

10.5 Inline assembly template modifiers on page 10-312

10.4.6 Using multiple alternative operand constraints

There are many instructions that can take either an immediate value with limited range or a register as one of their operands.

To generate optimal code for an instruction, use the immediate version of the instruction where possible. Using an immediate value avoids needing a register to hold the operand, and any extra instructions to load the operand into that register. However, you can only use an immediate value if the operand is a compile-time constant, and is in the appropriate range.

To generate the best possible code, you can provide multiple constraint codes for an operand. The compiler selects the most restrictive one that it can use.
Example

```c
int add(int a, int b) {
    int r;
    // Here, the "Ir" constraint string tells the compiler that operand b can be
    // an immediate, but if it is not a constant, or not in the appropriate
    // range for an arithmetic instruction, it can be placed in a register.
    __asm("add [%r], [%a], [%b]"
        : [r] "=r" (r)
        : [a] "r" (a),
        [b] "Ir" (b));
    return r;
}

// At -O2 or above, the call to add will be inlined and optimised, so that the
// immediate form of the add instruction can be used.
int add_42(int a) {
    return add(a, 42);
}

// Here, the immediate is not usable by the add instruction, so the compiler
// emits a movw instruction to load the value 12345 into a register.
int add_12345(int a) {
    return add(a, 12345);
}
```
10.5 **Inline assembly template modifiers**

Template modifiers are characters that you can insert into the assembly string, between the % character and the name or number of an operand reference. For example, %c1, where c is the template modifier, and 1 is the number of the operand reference. They change the way that the operand is printed in the string. This change is sometimes required so the operand is in the form that some instructions or directives expect.

This section contains the following subsections:
- 10.5.1 Template modifiers common to AArch32 state and AArch64 state on page 10-312.
- 10.5.2 Template modifiers for AArch32 state on page 10-312.
- 10.5.3 Template modifiers for AArch64 state on page 10-313.

10.5.1 **Template modifiers common to AArch32 state and AArch64 state**

The following template modifiers are common to both AArch32 state and AArch64 state.

- **c**
  
  Valid for an immediate operand. Prints it as a plain value without a preceding #. Use this template modifier when using the operand in .word, or another data-generating directive, which needs an integer without the #.

- **n**
  
  Valid for an immediate operand. Prints the arithmetic negation of the value without a preceding #.

**Example**

```c
// This uses an operand as the value in the .word directive. The .word // directive does not accept numbers with a preceding #, so we use the 'c' // template modifier to print just the value.
int foo() {
    int val;
    __asm (R"(
            ldr %0, 1f
            b 2f
            1: .word %c1
            2: )"
         : "r" (val)
         : "i" (0x12345678));
    return val;
}
```

10.5.2 **Template modifiers for AArch32 state**

The following template modifiers are specific to AArch32 state.

- **a**
  
  If the operand uses a register constraint, it is printed surrounded by square brackets. If it uses a constant constraint, it is printed as a plain immediate, with no preceding #.

- **y**
  
  The operand must be a 32-bit floating-point type, using a register constraint. It is printed as the equivalent D register with an index. For example, the register S2 is printed as d1[0], and the register S3 is printed as d1[1].

- **B**
  
  The operand must use a constant constraint, and is printed as the bitwise inverse of the value, without a preceding #.

- **L**
  
  The operand must use a constant constraint, and is printed as the least-significant 16 bits of the value, without a preceding #.
The operand must use the r constraint, and must be a 64-bit integer or floating-point type. The operand is printed as the register holding the least-significant half of the value.

The operand must use the r constraint, and must be a 64-bit integer or floating-point type. The operand is printed as the register holding the most-significant half of the value.

The operand must use the r constraint, and must be a 64-bit integer or floating-point type. The operand is printed as the highest-numbered register holding half of the value.

The operand must be a 128-bit vector type, using the w or x constraint. The operand is printed as the D register that overlaps the low half of the allocated Q register.

The operand must be a 128-bit vector type, using the w or x constraint. The operand is printed as the D register that overlaps the high half of the allocated Q register.

The operand must use the m constraint, and is printed as a register without the surrounding square brackets.

Example

```
// In AArch32 state, the 'Q' and 'R' template modifiers can be used to print
// the registers holding the least- and most-significant half of a 64-bit
// operand.
uint64_t atomic_swap(uint64_t new_val, uint64_t *addr) {
    uint64_t old_val;
    unsigned temp;
    __asm volatile(
        "dmb ish\n"
        "1:\n"
        "ldrexd %Q[old], %R[old], %[addr]\n"
        "strexd %[temp], %Q[new], %R[new], %[addr]\n"
        "cmp %[temp], #0\n"
        "bne 1b\n"
        "dmb ish\n"
        "@new" "+8c" (old_val),
        [temp] "+8r" (temp)
        "@old" "r" (new_val),
        [addr] "m" (*addr));
    return old_val;
}
```

10.5.3 Template modifiers for AArch64 state

The following template modifiers are specific to AArch64 state.

In AArch64 state, register operands are printed as X registers for integer types and V registers for floating-point and vector types by default. You can use the template modifiers to override this behavior.

```
a
Operand constraint must be r. Prints the register name surrounded by square brackets. Suitable for use as a memory operand.
```

```
w
Operand constraint must be r. Prints the register using its 32-bit w name.
```

```
x
Operand constraint must be r. Prints the register using its 64-bit x name.
```

```
b
Operand constraint must be w or x. Prints the register using its 8-bit b name.
```

```
h
Operand constraint must be w or x. Prints the register using its 16-bit h name.
```

```
s
Operand constraint must be w or x. Prints the register using its 32-bit s name.
```
Operand constraint must be \( w \) or \( x \). Prints the register using its 64-bit \( D \) name.

Operand constraint must be \( w \) or \( x \). Prints the register using its 128-bit \( Q \) name.

Example

```c
// In AArch64 state, the 's' template modifiers cause these operands to be printed as S registers, instead of the default of V registers.
float add(float a, float b) {
    float result;
    __asm("fadd %s0, %s1, %s2"
        : "=w" (result)
        : "w" (a), "w" (b));
    return result;
}
```
10.6 Forcing inline assembly operands into specific registers

Sometimes specifying the exact register that is used for an operand is preferable to letting the compiler allocate a register automatically.

For example, the inline assembly block may contain a call to a function or system call that expects an argument or return value in a particular register.

To specify the register to use, the operand of the inline assembly statement must be a local register variable, which you declare as follows:

\[
\begin{align*}
\text{register int } & \text{ foo } \_\text{asm}("r2") ; \\
\text{register float } & \text{ bar } \_\text{asm}("s4") = 3.141 ; \\
\end{align*}
\]

A local register variable is guaranteed to be held in the specified register in an inline assembly statement where it is used as an operand. Elsewhere it is treated as a normal variable, and can be stored in any register or in memory. Therefore a function can contain multiple local register variables that use the same register if only one local register variable is in any single inline assembly statement.

Example

```c
// This function uses named register variables to make a Linux 'read' system call.
// The three arguments to the system call are held in r0-r2, and the system call number is placed in r7.
int syscall_read(register int fd, void *buf, unsigned count) {
    register unsigned r0 __asm("r0") = fd;
    register unsigned r1 __asm("r1") = buf;
    register unsigned r2 __asm("r2") = count;
    register unsigned r7 __asm("r7") = 0x900003;
    __asm("svc #0"
               : "+r" (r0)
               : "r" (r1), "r" (r2), "r" (r7));
    return r0;
}
```
10.7 Symbol references and branches into and out of inline assembly

Symbols that are defined in an inline assembly statement can only be referred to from the same inline assembly statement.

The compiler can optimize functions containing inline assembly, which can result in the removal or duplication of the inline assembly statements. To define symbols in assembly and use them elsewhere, use file-scope inline assembly, or a separate assembly language source file.

With the exception of function calls, it is not permitted to branch out of an inline assembly block, including branching to other inline assembly blocks. The optimization passes of the compiler assume that inline assembly statements only exit by reaching the end of the assembly block, and optimize the surrounding function accordingly.

It is valid to call a function from inside inline assembly, as that function will return control-flow back to the inline assembly code.

Arm does not recommend directly referencing global data or functions from inside an assembly block by using their names in the assembly string. Often such references appear to work, but the compiler does not know about the reference.

If the global data or functions are only referenced inside inline assembly statements, then the compiler might remove these global data or functions.

To prevent the compiler from removing global data or functions which are referenced from inline assembly statements, you can:

- use __attribute__((used)) with the global data or functions.
- pass the reference to global data or functions as operands to inline assembly statements.

Arm recommends passing the reference to global data or functions as operands to inline assembly statements so that if the final image does not require the inline assembly statements and the referenced global data or function, then they can be removed.

Example

```c
static void foo(void) { /* ... */ }

// This function attempts to call the function foo from inside inline assembly.
// In some situations this may appear to work, but if foo is not referenced
// anywhere else (including if all calls to it from C got inlined), the
// compiler could remove the definition of foo, so this would fail to link.
void bar() {
  __asm volatile(
    "bl foo"
    : /* no outputs */
    : /* no inputs */
    : "r0", "r1", "r2", "r3", "r12", "lr";
}

// This function is the same as above, except it passes a reference to foo into
// the inline assembly as an operand. This lets the compiler know about the
// reference, so the definition of foo will not be removed (unless, the
// definition of bar_fixed can also be removed). In C++, this has the
// additional advantage that the operand uses the source name of the function,
// not the mangled name (_Zl3foo) which would have to be used if writing the
// symbol name directly in the assembly string.
void bar_fixed() {
  __asm volatile(
    "bl %[foo]"
    : /* no outputs */
    : [foo] "i" (foo)
    : "r0", "r1", "r2", "r3", "r12", "lr";
}
```
10.8 Duplication of labels in inline assembly statements

You can use labels inside inline assembly, for example as the targets of branches or PC-relative load instructions. However, you must ensure that the labels that you create are valid if the compiler removes or duplicates an inline assembly statement.

Duplication can happen when a function containing an inline assembly statement is inlined in multiple locations. Removal can happen if an inline assembly statement is not reachable, or its result is unused and it has no side-effects.

If regular labels are used inside inline assembly, then duplication of the assembly could lead to multiple definitions of the same symbol, which is invalid. Multiple definitions can be avoided either by using numeric local labels, or using the %= template string. The %= template string is expanded to a number that is unique to each instance of an inline assembly statement. Duplicated statements have different numbers. All uses of %= in an instance of the inline assembly statement have the same value. You can therefore create label names that can be referenced in the same inline assembly statement, but which do not conflict with other copies of the same statement.

Note

Unique numbers from the %= template string might still result in the creation of duplicate labels. For example, label names loop%= and loop1%= can result in duplicate labels. The label for instance number 0 of loop1%= evaluates to loop10. The label for instance number 10 of loop%= also evaluates to loop10.

To avoid such duplicate labels, choose the label names carefully.

Example

```c
void memcpy_words(int *src, int *dst, int len) {
    int tmp;
    // This uses the "%=" template string to create a label which can be used // elsewhere inside the assembly block, but which will not conflict with // inlined copies of it.
    // % is a C++11 raw string literal. See the example in 10.2 File-scope inline assembly on page 10-302.
    __asm(R"(
        .Lloop%=:
        ldr %[tmp], %[src], #4
        str %[tmp], %[dst], #4
        subs %[len], #4
        bne .Lloop%=)
        : [dst] "=&m" (*dst),
          [tmp] "=&r" (tmp),
          [len] "=r" (len)
        : [src] "m" (*src));
}
```