

# Addenda to, and Errata in, the ABI for the Arm® Architecture

**2023Q3**

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**arm**

# 1 Preamble

## 1.1 Abstract

This document describes late additions (addenda) to the ABI for the Arm Architecture version 2.0, and errors (errata) discovered in it after publication.

## 1.2 Keywords

Addenda to the ABI for the Arm Architecture, errata in the ABI for the Arm Architecture

## 1.3 Latest release and defects report

Please check [Application Binary Interface for the Arm® Architecture](#) for the latest release of this document.

Please report defects in this specification to the [issue tracker page on GitHub](#).

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# Contents

<b>1 Preamble</b>	<b>2</b>
1.1 Abstract	2
1.2 Keywords	2
1.3 Latest release and defects report	2
1.4 Licence	3
1.5 About the license	3
1.6 Contributions	3
1.7 Trademark notice	3
1.8 Copyright	3
<b>2 About this document</b>	<b>7</b>
2.1 Change Control	7
2.1.1 Current Status and Anticipated Changes	7
2.1.2 Change history	7
2.2 References	9
2.3 Terms and abbreviations	10
<b>3 ADDENDUM: Build Attributes</b>	<b>11</b>
3.1 Introduction to build attributes	11
3.1.1 About build attributes and compatibility	11
3.1.2 The kinds of compatibility modeled by build attributes	12
3.1.3 The scope of build attributes	13
3.1.4 Build attributes and conformance to the ABI	13
3.1.5 Combining attribute values	14
3.2 Representing build attributes in ELF files	15
3.2.1 Encoding	15
3.2.2 Structure of an ELF attributes section	15
3.2.3 Formal syntax of an ELF attributes section	15
3.2.4 Formal syntax of a public ("aeabi") attributes subsection	16
3.2.5 Conformance constraints	16
3.2.6 Coding extensibility and compatibility	17
3.3 Public ("aeabi") attribute tags	17
3.3.1 About public tags	17
3.3.2 Default values for public tags	17
3.3.3 Inheritance of public tag values	17
3.3.4 How this specification describes public attributes	18
3.3.5 Target-related attributes	18
3.3.6 Procedure call-related attributes	22
3.3.7 Miscellaneous attributes	25

3.4	Arm CPU names recognized by Arm Compiler 5.01 (armcc)	29
3.5	Attributes summary and history	29
<b>4</b>	<b>ADDENDUM: Thread Local Storage</b>	<b>34</b>
4.1	Introduction to thread local storage	34
4.2	Introduction to TLS addressing	34
4.3	Linux for Arm TLS addressing	34
4.3.1	Linux for Arm general dynamic model	35
4.3.2	Linux for Arm static (initial exec) model	37
<b>5</b>	<b>Reserved Names</b>	<b>39</b>
<b>6</b>	<b>Errata and Minor Addenda</b>	<b>41</b>
6.1	DWARF for the Arm Architecture	41
6.1.1	Clarifications	41
6.1.2	Errors fixed	41
6.1.3	Additions and omissions fixed	41
6.2	ELF for the Arm Architecture	41
6.2.1	Clarifications	41
6.2.2	Errors fixed	42
6.2.3	Additions and omissions fixed	42
6.3	Procedure Call Standard for the Arm Architecture	43
6.3.1	Clarifications	43
6.3.2	Errors fixed	44
6.3.3	Additions and omissions fixed	44
6.4	Base Platform ABI for the Arm Architecture	44
6.4.1	Clarifications	44
6.4.2	Errors fixed	45
6.5	C Library ABI for the Arm Architecture	45
6.5.1	Clarifications	45
6.5.2	Errors fixed	45
6.5.3	Additions and omissions fixed	45
6.6	C++ ABI for the Arm Architecture	46
6.6.1	Clarifications	46
6.6.2	Errors fixed	46
6.6.3	Additions and omissions fixed	46
6.7	Exception Handling ABI for the Arm Architecture	46
6.7.1	Clarifications	46
6.7.2	Errors fixed	47
6.7.3	Additions and omissions fixed	47
6.8	Run-time ABI for the Arm Architecture	48
6.8.1	Clarifications	48

6.8.2	Errors fixed and features withdrawn or deprecated	48
6.8.3	Additions and omissions fixed	48
6.9	ABI for the Arm Architecture - The Base Standard	49
6.9.1	Clarifications	49

# 2 About this document

## 2.1 Change Control

### 2.1.1 Current Status and Anticipated Changes

The following support level definitions are used by the Arm ABI specifications:

#### Release

Arm considers this specification to have enough implementations, which have received sufficient testing, to verify that it is correct. The details of these criteria are dependent on the scale and complexity of the change over previous versions: small, simple changes might only require one implementation, but more complex changes require multiple independent implementations, which have been rigorously tested for cross-compatibility. Arm anticipates that future changes to this specification will be limited to typographical corrections, clarifications and compatible extensions.

#### Beta

Arm considers this specification to be complete, but existing implementations do not meet the requirements for confidence in its release quality. Arm may need to make incompatible changes if issues emerge from its implementation.

#### Alpha

The content of this specification is a draft, and Arm considers the likelihood of future incompatible changes to be significant.

All content in this document is at the **Release** quality level.

### 2.1.2 Change history

If there is no entry in the change history table for a release, there are no changes to the content of the document for that release.

Issue	Date	Change
v1.0 r2.0	24 <sup>th</sup> March 2005	First public release.
v1.01 r2.01	4 <sup>th</sup> July 2005	Added new <a href="#">Coding extensibility and compatibility</a> . Noted component errata omissions ( <a href="#">ELF for the Arm Architecture</a> , <a href="#">C Library ABI for the Arm Architecture</a> , and <a href="#">C++ ABI for the Arm Architecture</a> ).
v1.02	7 <sup>th</sup> October 2005	Added WMMX v2 architecture, TAG_CPU_unaligned_access ( <a href="#">Public ("aeabi") attribute tags</a> ); changed R_ARM_PC24 to R_ARM_CALL ( <a href="#">Linux for Arm general dynamic model</a> ); added list of reserved name-space prefixes ( <a href="#">Reserved Names</a> ); noted errata and omissions ( <a href="#">DWARF for the Arm Architecture</a> , <a href="#">Procedure Call Standard for the Arm Architecture</a> , <a href="#">C Library ABI for the Arm Architecture</a> , <a href="#">Exception Handling ABI for the Arm Architecture</a> , and <a href="#">Run-time ABI for the Arm Architecture</a> )
v1.03 r2.02	13 <sup>th</sup> October 2005	Minor typographical fixes.
v1.04 r2.03	6 <sup>th</sup> January 2006	Noted errata and omissions ( <a href="#">aelf32-clarifications</a> , <a href="#">aelf32-additions-omissions</a> , and <a href="#">cppabi32-clarifications</a> ).

Issue	Date	Change
v1.05 r2.04	8 <sup>th</sup> May 2006	Added missing Tag_FP_arch value for VFPv3 ( <a href="#">Target-related attributes</a> ). Noted errata and omissions ( <a href="#">aadwarf32-errors-fixed</a> , <a href="#">aaelf32-additions-omissions</a> , <a href="#">aapcs32-clarifications</a> , <a href="#">clibabi32-errors-fixed</a> , and <a href="#">cppabi32-clarifications</a> ).
v1.06 r2.05	18 <sup>th</sup> January 2007	Major clarification of, and some compatible extension to, <a href="#">ADDENDUM: Build Attributes</a> .
v1.07 r2.06	23 <sup>rd</sup> October 2007	Added: CPU_arch values for v6S-M and v6-M; and VFP_arch value for VFPv3-D16; added Tag_nodfaults, Tag_ABI_FP_16bit_format, and Tag_FP_HP_extension. Rewrote <a href="#">ADDENDUM: Build Attributes</a> . Noted errata and omissions.
A	25 <sup>th</sup> October 2007	Document renumbered (formerly GENC-005895 v1.07).
A	13 <sup>th</sup> November 2007	Minor corrections to <a href="#">Errata and Minor Addenda</a>
B r2.07	10 <sup>th</sup> October 2008	Added architecture tags Tag_T2EE_use, Tag_Virtualization_use, and Tag_MPextension_use; clarified definitions of Tag_CPU_name and Tag_CPU_raw_name ( <a href="#">The target-related attributes</a> ); clarified tag value inheritance and Tag_Nodefaults ( <a href="#">Default values for public tags</a> , <a href="#">Inheritance of public tag values</a> , <a href="#">No defaults tag</a> ).
C r2.08	4 <sup>th</sup> November 2009	( <a href="#">The target-related attributes</a> ): added Tag_CPU_arch enum value V7E-M =13; renamed Tag_VFP_arch to Tag_FP_arch, added values for VFPv4; renamed Tag_VFP_HP_extension to Tag_FP_HP_extension; added value to Tag_Advanced_SIMD_arch for Neon with fused MAC; added values to Tag_Virtualization_use describing use of the virtualization extensions; recoded Tag_MPextension use to catch potential user-mode faults; added Tag_DIV_use to describe use of UDIV/SDIV in code for v7A. ( <a href="#">The procedure call-related attributes</a> ) clarified the role of R9 when used as a TLS (Tag_ABI_PCS_R9_use = 2). Renamed and extended Tag_ABI_align8_needed, Tag_ABI_align8_preserved to data with extended 2n-byte alignment (for n in 4-12).
D r2.09	30 <sup>th</sup> November 2012	Made section and symbol attributes deprecated and optional ( <a href="#">The kinds of compatibility modeled by build attributes</a> , <a href="#">Formal syntax of a public ("aeabi") attributes subsection</a> , <a href="#">Inheritance of public tag values</a> , <a href="#">No defaults tag</a> ). ( <a href="#">Formal syntax of a public ("aeabi") attributes subsection</a> ) clarified section and symbol numbers are ULEB128. ( <a href="#">The target-related attributes</a> ) added architecture v8 values to Tag_CPU_arch, Tag_FP_arch, Tag_Advanced_SIMD_arch; clarified use of existing Tag_Advanced_SIMD_arch and Tag_FP_HP_extension values; clarified the meaning of Tag_DIV_use; deprecated Tag_T2EE_use. ( <a href="#">The procedure call-related attributes</a> ) fixed typo in Tag_ABI_FP_exceptions; clarified use of Tag_ABI_HardFP_use values and removed pointless DP-only option; added enum value to Tag_ABI_VFP_args for code compatible with both the base and VFP variants. ( <a href="#">Secondary compatibility tag</a> clarified the format of Tag_also_compatible_with data. <a href="#">Arm CPU names recognized by Arm Compiler 5.01 (armcc)</a> ) updated list of recognised CPU names.



Issue	Date	Change
E r2.10	24 <sup>th</sup> November 2015	( <a href="#">The target-related attributes</a> ) added architecture v8.1 values to Tag_Advanced_SIMD_arch.
F 2018Q4	21 <sup>st</sup> December 2018	In <a href="#">The target-related attributes</a> , deprecated values 1 and 2 of Tag_THUMB_ISA_use, added value 3. In <a href="#">The target-related attributes</a> , deprecated Tag_CPU_arch_profile for architecture version 8 onwards. In <a href="#">The target-related attributes</a> , defined build attributes for Armv8-M, Armv8-R, Armv8.1-A, Armv8.2-A and Armv8.3-A.
G 2019Q4	30 <sup>th</sup> January 2020	Added Tag_FramePointer_use: <a href="#">The procedure call-related attributes</a> , <a href="#">Table 1</a> .
2020Q3	1 <sup>st</sup> October 2020	<ul style="list-style-type: none"> <li>• document released on Github</li> <li>• new <a href="#">Licence</a>: CC-BY-SA-4.0</li> <li>• new sections on <a href="#">Contributions</a>, <a href="#">Trademark notice</a>, and <a href="#">Copyright</a></li> <li>• <a href="#">Table 1</a>: added a missing table entry for Tag_DSP_extension</li> </ul>
2021Q1	12 <sup>th</sup> April 2021	Add definitions for PACBTI-M related build attributes: <a href="#">The target-related attributes</a> , <a href="#">The procedure call-related attributes</a> , <a href="#">Miscellaneous attributes</a> , <a href="#">Table 1</a>
2021Q3	1 <sup>st</sup> November 2021	Add Armv9-A value to Tag_CPU_arch.

## 2.2 References

This document refers to the following documents.

Ref	Status / External URL	Title
<a href="#">AAELF32</a>		ELF for the Arm Architecture
<a href="#">AAPCS32</a>		Procedure Call Standard for the Arm Architecture
<a href="#">BSABI32</a>		ABI for the Arm Architecture (Base Standard).
<a href="#">EHABI32</a>		Exception Handling ABI for the Arm Architecture
<a href="#">RTABI32</a>		Run-time ABI for the Arm Architecture
<a href="#">ARMARM</a>	<a href="#">ARM Architecture Reference Manual ARMv7-A and ARMv7-R edition</a>	Arm DDI 0406: Arm Architecture Reference Manual Arm v7-A and Arm v7-R edition
	<a href="#">ARMv7-M Architecture Reference Manual</a>	Arm DDI 0403: Armv7-M Architecture Reference Manual
<a href="#">ACLE</a>	IHI 0053A	Arm C Language Extensions

Ref	Status / External URL	Title
GDWARF	<a href="http://dwarfstd.org/Dwarf3Std.php">http://dwarfstd.org/Dwarf3Std.php</a>	DWARF 3.0, the generic debug table format.
GELF	<a href="http://www.sco.com/developers/gabi/">http://www.sco.com/developers/gabi/ ...</a>	Generic ELF, 17 <sup>th</sup> December 2003 draft.

## 2.3 Terms and abbreviations

The ABI for the Arm Architecture uses the following terms and abbreviations:

### AAPCS

Procedure Call Standard for the Arm Architecture

### ABI

Application Binary Interface:

1. The specifications to which an executable must conform in order to execute in a specific execution environment. For example, the *Linux ABI for the Arm Architecture*.
2. A particular aspect of the specifications to which independently produced relocatable files must conform in order to be statically linkable and executable. For example, the [AAELF32](#), [RTABI32](#), ...

### AEABI

(Embedded) ABI for the Arm architecture (this ABI...)

### Arm-based

... based on the Arm architecture ...

### core registers

The general purpose registers visible in the Arm architecture's programmer's model, typically r0-r12, SP, LR, PC, and CPSR.

### EABI

An ABI suited to the needs of embedded, and deeply embedded (sometimes called *free standing*), applications.

### Q-o-I

Quality of Implementation – a quality, behavior, functionality, or mechanism not required by this standard, but which might be provided by systems conforming to it. Q-o-I is often used to describe the toolchain-specific means by which a standard requirement is met.

### VFP

The Arm architecture's Floating Point architecture and instruction set. In this ABI, this abbreviation includes all floating point variants regardless of whether or not vector (V) mode is supported.

# 3 ADDENDUM: Build Attributes

## 3.1 Introduction to build attributes

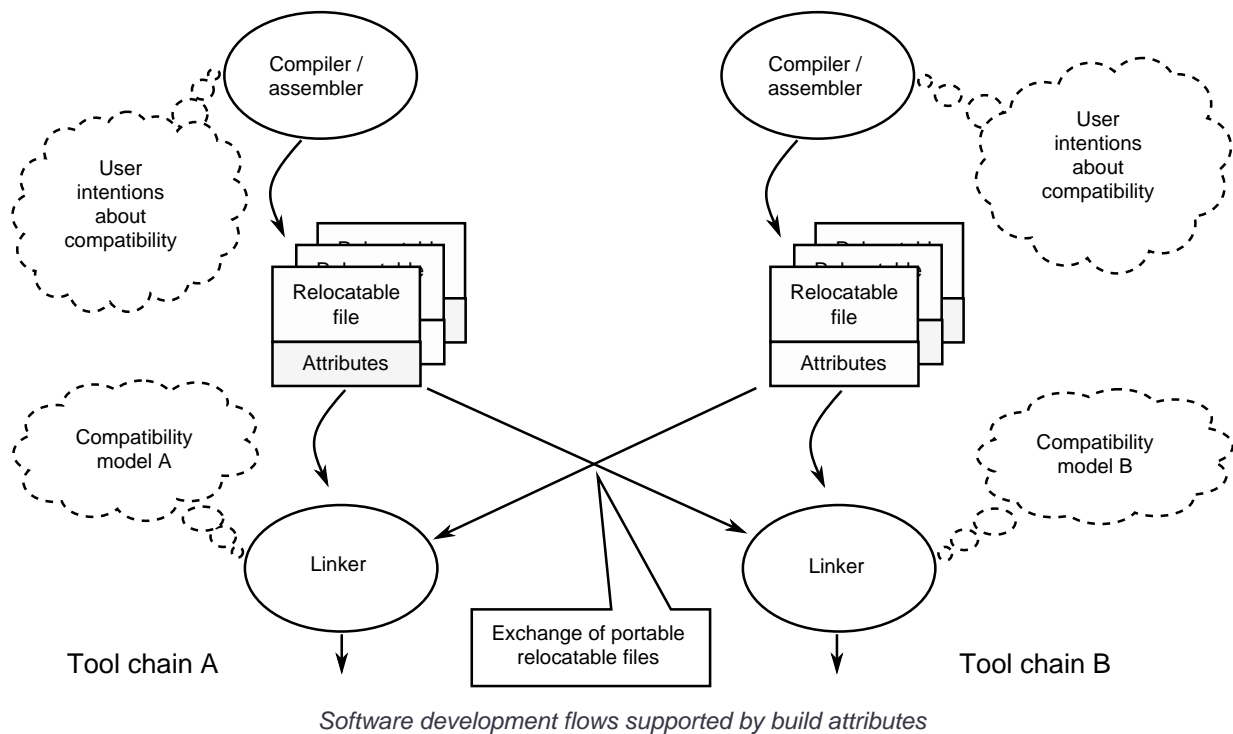
### 3.1.1 About build attributes and compatibility

Build attributes record data that a linker needs to reason mechanically about the compatibility, or incompatibility, of a set of relocatable files. Other tools that consume relocatable files may find the data useful.

Build attributes are designed to have long-term invariant meaning. They record choices to which there is long term public commitment through the Arm Architecture Reference Manual [ARMARM], the ABI for the Arm Architecture (of which this document is a component), vendor data sheets, and similar long lived publications.

Build attributes approximate the intentions the user of a compiler or assembler has for the compatibility of the relocatable file produced by the compiler or assembler (*Attribute values are based on user intentions*).

The figure below depicts the software development flows in which build attributes are important.



In this depiction there are two principal uses of build attributes.

- Within a toolchain, build attributes generate rich opportunities for a linker to diagnose incompatibility, enforce compatibility, and select library members intelligently according to its compatibility model.
- Between toolchains, build attributes describe the intended compatibility of a relocatable file and the entities it defines in terms independent of either toolchain, promoting safe exchange of portable code in binary form.

#### 3.1.1.1 Attribute values are based on user intentions

We base attribute values on user intentions to avoid the values being an unpredictable (effectively random) function of a compiler's code generation algorithms and to support using attributes with assembly language without overburdening programmers. Where attributes support exchanging portable relocatable files among toolchains, predictability is worth more than precision.

Capturing a user's compile-time intentions about compatibility is also important at link time. For example:

- A user might permit a compiler to use both the Arm ISA and the Thumb ISA.  
(The user intends the code to be usable on any processor that has both the Arm ISA and the Thumb ISA).
- The compiler might choose to use only the Thumb ISA in a specific build of a source file.

Nonetheless, the relocatable file should be tagged as having been permitted to use the Arm ISA so that a linker can later link it with Arm-state library code and generate Arm-state intra-call veneers if that gives benefit to the executable file.

On the other hand, if the user intends code to be executed by both Arm7TDMI and Cortex-M3, the compiler must be constrained to generate only Thumb v1 instructions and the relocatable file should be tagged as not permitted to use the Arm ISA.

### 3.1.1.2 Capturing user intentions about compatibility

This standard does not specify how a tool should capture and approximate the intentions of its users.

As far as possible, ABI-defined compatibility tags ([Public \("aeabi"\) attribute tags](#)) model the long-term compatibility commitments implicit in architectural specifications, product data sheets, and the ABI for the Arm Architecture.

In general, tools have invocation options – command-line options and GUI configuration options – that present choices similar to those revealed in such documentation and modeled by ABI-defined compatibility tags.

The challenge for a tool that generates relocatable files is to select the set of build attributes – giving a value to each compatibility tag – that best approximates the user's intentions implicit in its invocation options.

This part of the problem of managing compatibility does not have a perfect solution. A user's intentions are imperfectly approximated by invocation options that are then sometimes imperfectly mapped to build attributes.

### 3.1.1.3 No standard compatibility model

This specification standardizes the meaning of build attributes, not the compatibility models within which they will be interpreted.

For the majority of build attributes there is only one reasonable interpretation of compatibility among their values, and it is an obvious one.

For a minority – mostly associated with procedure-call compatibility between functions – this is not the case and it is reasonable for different toolchains to take different positions according to the markets they serve.

Thus it is entirely reasonable that a relocatable file produced by toolchain A and accepted by toolchain B's linker might be rejected by toolchain C's linker when targeting exactly the same environment as toolchain B.

Our hope and intention for attributes is that they might prevent C's linker from accepting the output of A and silently generating a non functioning executable file or failing in a mysterious and difficult to explain manner.

## 3.1.2 The kinds of compatibility modeled by build attributes

Build attributes primarily model two kinds of compatibility.

- The compatibility of binary code with target hardware conforming to a revision of the Arm Architecture.
- The procedure-call compatibility between functions conforming to variants of this ABI.

The intuitive notion of compatibility can be given a mathematically precise definition using sets of demands placed on an execution environment.

For example, a program could be defined to be compatible with a processor if (and only if) the set of instructions the program might try to execute is a subset of the set of instructions implemented by the processor.

Target-related attributes ([Target-related attributes](#)) describe the hardware-related demands a relocatable file will place on an execution environment through being included in an executable file for that environment.

For example, target-related attributes record whether use of the Thumb ISA is permitted, and at what architectural revision use is permitted. A pair of values for these attributes describes the set of Thumb instructions that code is permitted to execute and that the target processor must implement.

Procedure call-related attributes ([Procedure call-related attributes](#)) describe features of the ABI contract that the ABI allows to vary, such as whether floating point parameters are passed in floating point registers, the size of `wchar_t`, whether enumerated values are containerized according to their size, and so on.

We can also understand procedure call-related compatibility in terms of sets of demands placed on an execution environment, but the modeling is more difficult. In this case the environment is less obvious, more abstract, and elements of it can depend on an operating system or the toolchain itself.

Mathematically, *A compatible with B* can be understood as:  $\{\text{demands made by A}\} \subseteq \{\text{demands made by B}\}$ .

Making this concrete sometimes requires combining information from several tags. Writing  $\{\text{T16@v4T}\}$  to denote the set of 16-bit Thumb instructions a processor must execute to conform to architecture version v4T, we can understand T16@v4T compatible with T16@v5TE as  $\{\text{T16@v4T}\} \subset \{\text{T16@v5TE}\}$ .

### 3.1.3 The scope of build attributes

Unless `#pragma` or other mechanisms specific to a toolchain are used, it is usual for all parts of a relocatable file to be built the same way with the same compatibility intentions. So, usually, build attributes are given file scope and apply to all entities defined in the file to which they can apply. For example:

- File-scope attributes that model the compatibility of binary instructions with processors naturally apply to each instruction in every code-containing section in the file.  
(They obviously do not apply to sections that contain no code, nor to the data – such as literal pools – embedded in code sections).
- Attributes that describe the procedure call-compatibility of functions naturally apply to every function symbol defined in the code sections contained within the file.

Build attributes can be given to individual entities defined in a relocatable file.

- To an individual ELF section.  
These attributes also apply to every (relevant) symbol defined in the section.
- To an individual function or data object identified by an ELF symbol definition.

For the public build attributes defined by this ABI ([Public \("aeabi"\) attribute tags](#)) a compiler for C/C++ can only need to use section and symbol attributes in the presence of `#pragmas`, language extensions, or other mechanisms that affect the compatibility of individual entities within a binary file.

Linkers that support relocatable file merging – termed partial linking by RealView linkers – will, in general, need to transfer the file scope attributes of an input file to the individual sections that file contributes to the output file.

This standard places no requirements on the presence or absence of build attributes in executable files.

#### Note

From the 2.09 release, section and symbol attributes are deprecated and optional. Primary object producers are discouraged from generating them and consumers are permitted to ignore them.

### 3.1.4 Build attributes and conformance to the ABI

In revision 2.05 and later revisions of this ABI specification, the presence of a build attributes section containing an “aeabi” subsection containing a conformance tag ([Conformance tag](#)) denotes an explicit claim by the producer that the relocatable file conforms to:

- The version of the ABI described by tag's string parameter.

- The variant of that version described by the public (“aeabi”) build attributes.

A claim to conform to ABI version “0” denotes that no unconditional claim to conform is being made. Generic compatibility tags ([Generic compatibility tag](#)) may then describe limited or conditional claims to conform.

In revisions of this specification before r2.05 any claim to conform to this ABI was implicit, and the version to which conformance was (possibly) claimed was implicitly “2”.

### 3.1.5 Combining attribute values

Suppose E1 and E2 are entities (for example, relocatable files) with attribute values a1 and a2 for an attribute tag T. This section discusses how to generate the correct value of T for the entity formed by combining E1 and E2 (for example, the executable file formed by linking E1 with E2)

In each case, the values of a tag can be partially ordered according to the sets of demands they represent. We shall write  $a1 \leq a2$  if an entity tagged with  $\langle T, a1 \rangle$  makes no more demands on its environment than an entity tagged with  $\langle T, a2 \rangle$ .

Writing  $\{T:a1\}$  to denote the set of demands made by an entity tagged with  $\langle T, a1 \rangle$ , we can define  $a1 \leq a2$  if  $\{T:a1\} \subseteq \{T:a2\}$ . (A set of demands might be the set of instructions a processor must execute, for example).

Informally we say that a1 is compatible with a2 or a1 is more compatible than a2 when  $a1 \leq a2$ .

Using `Tag_CPU_arch` ([The target-related attributes](#)) as an example,  $v4T \leq v5TE$ , because the set of instructions conforming to architecture v4T is a subset of the set conforming to architecture v5TE. Stated more precisely, for both the Arm ISA and the 16-bit Thumb ISA, it is the case that  $\{ISA@v4T\} \subseteq \{ISA@v5TE\}$ .

This partial order often differs from the arithmetic order of the enumerated values though in many cases it

- Is identical (as with `Tag_THUMB_ISA_use` in [The target-related attributes](#)).
- Is reversed (as with `Tag_ABI_align_preserved` in [The procedure call-related attributes](#)).
- Represents mutually incompatible choices with which only the identical choice, or no use at all, is compatible (as with `Tag_ABI_PCS_wchar_t` in [The procedure call-related attributes](#)).

Note that the appropriate partial order to use can evolve over time as the underlying specifications evolve.

#### 3.1.5.1 Combining two values of the same tag

We shall write  $a1 \ltimes a2$  if a1 and a2 are unordered in the partial order of demands/compatibility and  $a1 + a2$  to denote the combination of a1 and a2. There are the following combination rules.

- If  $a1 \leq a2$ ,  $a1 + a2 = a2$ . Similarly, if  $a2 \leq a1$ ,  $a1 + a2 = a1$ . (‘+’ behaves like the *maximum* function).
- If  $a1 \ltimes a2$  there are two mutually exclusive sub-cases.
  - There is a least a3 such that  $a1 \leq a3$  and  $a2 \leq a3$ . Then  $a1 + a2 = a3$ .  
Example: `Tag_CPU_arch` when  $a1 = v6KZ$ ,  $a2 = v6T2$ , and  $a3 = v7$ .
  - There is no such a3, so  $a1 + a2$  denotes the attempted combination of incompatible values.  
Example: `Tag_ABI_PCS_wchar_t` when  $a1 = 2$  and  $a2 = 4$ .

In this second sub-case it is a matter of notational taste whether  $a1 + a2$  is defined to have a value such as error or Top, or defined to have no value. Either way, in practice we expect an attempted combination to fail in a way specific to a toolchain’s compatibility model (for example by provoking a link-time diagnostic).

## 3.2 Representing build attributes in ELF files

### 3.2.1 Encoding

Encoding build attributes needs more than a few bits, so we encode them in an vendor-specific section of type `SHT_ARM_ATTRIBUTES` and name `.ARM.attributes` (for further details see [AAELF32]).

An attribute is encoded in a `<tag, value>` pair.

Both tags and numerical values are encoded using unsigned LEB128 encoding (ULEB128), DWARF-3 style (for details see [GDWARF]).

The public tags and values specified by this version of the ABI encode identically as ULEB128 numbers and single byte numbers (all values are in the range 0-127).

String values are encoded using NUL-terminated byte strings (NTBS).

### 3.2.2 Structure of an ELF attributes section

An attributes section contains a sequence of subsections. Each one is either

- Defined by this ABI and public to all tools that process the file.
- Private to a tool vendor's tools.

The type of each subsection is given by a short textual (NTBS) name.

This ABI requires a vendor to register a short vendor name to use as a prefix to the names of private helper functions (for details see [RTABI32] or [AAELF32]). The same vendor name identifies attribute subsections private to that vendor's tools.

A public attributes subsection is named `aeabi`. Names beginning *Anon* and *anon* are reserved to unregistered private use.

### 3.2.3 Formal syntax of an ELF attributes section

The syntactic structure of an attributes section is:

```
<format-version: 'A'>
[ <uint32: subsection-length> NTBS: vendor-name
  <bytes: vendor-data>
]*
```

*Format-version* describes the format of the following data. It is a single byte. This is version 'A' (0x41). This field exists to allow future changes in format. We do not intend that there will be many versions.

*Subsection-length* is a 4-byte integer in the byte order of the ELF file. It encodes the length of the subsection, including the length field itself, the vendor name string and its terminating NUL byte, and the following vendor data. It gives the offset from the start of this subsection to the start of the next one.

*Vendor-name* is a NUL-terminated byte string (NTBS) like a C-language literal string.

No requirements are placed on the format of private vendor data. The format of a public attributes subsection ("`aeabi`" pseudo-vendor data) is described in [Formal syntax of a public \("`aeabi`"\) attributes subsection](#).

We expect a `.ARM.attributes` section in a relocatable file will most typically contain one vendor subsection from the "`aeabi`" pseudo-vendor and possibly one from the generating toolchain (e.g. "`ARM`", "`gnu`", "`WRS`", etc).

Formally, there are no constraints on the order or number of vendor subsections. A consumer can collect the public ("`aeabi`") attributes in a single pass over the section, then all of its private data in a second pass.

### 3.2.4 Formal syntax of a public (“aeabi”) attributes subsection

The syntactic structure of a public attributes subsection is:

```
[ Tag_File      (=1) <uint32: byte-size> <attribute>*
  | Tag_Section (=2) <uint32: byte-size> <section number>* 0 <attribute>*
  | Tag_Symbol  (=3) <uint32: byte-size> <symbol number>* 0 <attribute>*
]+
```

A public subsection contains any number of sub-subsections. Each records attributes relating to:

- The whole relocatable file.

These sub-subsections contain just a list of attributes. They are identified by a leading `Tag_File` (=1) byte.

- A set of sections within the relocatable file.

These sub-subsections contain a list of ULEB128 section numbers followed by a list of attributes. They are identified by a leading `Tag_Section` (=2) byte.

- A set of (defined) symbols in the relocatable file.

These sub-subsections contain a list of ULEB128 symbol numbers followed by a list of attributes. They are identified by a leading `Tag_Symbol` (=3) byte.

In each case, `byte-size` is a 4-byte unsigned integer in the byte order of the ELF file. `byte-size` includes the initial tag byte, the size field itself, and the sub-subsection content. That is, it is the byte offset from the start of this sub-subsection to the start of the next sub-subsection.

Both section indexes and defined symbol indexes are non-zero, so a NUL byte ends a string and a list of indexes without ambiguity.

There are no constraints on the order or number of sub-subsections in a public attributes subsection (but see remarks in [Conformance tag](#) concerning `Tag_conformance` and [No defaults tag](#) concerning `Tag_nodefaults`).

A consumer that needs the data in scope nesting order can obtain the file attributes, the section-related attributes, and the symbol-related attributes, by making three passes over the subsection.

#### Note

From the 2.09 release, section and symbol attributes are deprecated and optional. Primary object producers are discouraged from generating them and consumers are permitted to ignore them.

### 3.2.5 Conformance constraints

This ABI requires the following of files that claim to conform ([Build attributes and conformance to the ABI](#)) to the ABI.

- Attributes that record data about the compatibility of this file with other files must be recorded in a public “aeabi” subsection.
- Attributes meaningful only to the producer must be recorded in a private vendor subsection. These must not affect compatibility between relocatable files.

When a producer does not explicitly claim compatibility to the ABI, it may nonetheless publicly describe the effect on compatibility of its private attributes by using generic compatibility tags ([Generic compatibility tag](#)). These must record a safe approximation. The producer can record precise information that only its own toolchain comprehends in a private vendor subsection.

- We intend that another toolchain should not mistakenly link incompatible files. The price of safety is that a toolchain might sometimes diagnose incompatibility between files that could be safely linked, because their compatibility has been approximated.



- We do not expect that a toolchain should be able to comprehend the private data of a different toolchain (other than through private agreement among toolchains).

### 3.2.6 Coding extensibility and compatibility

As a specification like this evolves, legacy binary files and the tools that process them get out of step. This will cause difficulties when a tool must consume a public attributes subsection containing tags it does not comprehend (that is, when the tool follows an earlier version of the specification than the binary file).

The attributes defined in [Public \("aeabi"\) attribute tags](#), below, carry a mix of information that consumers can safely ignore and information about incompatibility that must not be ignored. In the absence of further conventions, the only safe course for a tool to take on encountering an unknown tag would be to stop processing.

To support more graceful behavior in the face of an evolving set of public tags, we adopt these conventions.

- Tags 0-63 convey information that a consuming tool must comprehend. This includes all the tags (1-32) defined by the first release (v1.0) of this addendum. A tool encountering an unknown tag in this range should stop processing or take similar defensive action (Q-o-l).
- Tags 64-127 convey information a consumer can ignore safely (though maybe with degraded functionality).
- For  $N \geq 128$ , tag  $N$  has the same properties as tag  $N$  modulo 128.

To allow an ignored tag and its parameter value to be skipped easily, we adopt this convention.

- For  $N > 32$ , even numbered tags have a ULEB128 parameter and odd numbered ones have a null-terminated byte string (NTBS) parameter.
- A consumer must comprehend tags 1-32 individually.

## 3.3 Public ("aeabi") attribute tags

### 3.3.1 About public tags

A consumer must recognize the tags described in this section ([Public \("aeabi"\) attribute tags](#)) in vendor subsections named "aeabi".

Other vendor sections may re-use these tags, define their own tags, or use a completely different encoding of their private attribute data. In each case the meaning of the data is private to the defining vendor.

While public tags and their numerical parameters are specified as ULEB128-encoded, the values defined by this version, and all earlier versions, of the ABI encode identically as ULEB128 numbers and single byte numbers.

### 3.3.2 Default values for public tags

The effect of omitting a public tag in file scope is identical to including it with a value of 0 or "", depending on its parameter type.

A producer must consider what value it intends to give to each public tag. In the absence of `Tag_nodefaults` ([No defaults tag](#)) a consumer should conclude that the producer intended to give the value 0 to each omitted public tag.

### 3.3.3 Inheritance of public tag values

An attribute can be given to a symbol, a section, or a relocatable file. Normally, each section in a file inherits the attributes defined at file level and each symbol defined in a section inherits the attributes of that section.

A tag value given explicitly in a scope overrides a value that would otherwise be inherited. If `Tag_nodefaults` ([No defaults tag](#)) appears in a scope, enclosed empty scopes have undefined attribute values value rather than default zero values.

Semi formally we define the value of a public tag T in a scope S (one of Symbol, Section, or File) as follows.

```
value(T, S) ≡ S.empty() & S.parent.has(Tag_nodfaults) ? undefined :
    S.has(T) ? T.value :
    value(T, S.parent)
value(T, File.parent) ≡ 0
```

```
Where S.empty() ≡ not (S.has(T) for some T ≠ Tag_nodfaults)
    S.has(T) ≡ T and its value are given explicitly in scope S
    Symbol.parent ≡ Section; Section.parent ≡ File
```

In any scope it is erroneous to give two different values to the same attribute, though the same value may be given more than once.

#### Note

From the 2.09 release, section and symbol attributes are deprecated and optional. Primary object producers are discouraged from generating them and consumers are permitted to ignore them.

### 3.3.4 How this specification describes public attributes

In the following sections we describe each attribute in a uniform style, as follows.

```
Tag_tag_name (=tag value), parameter type (=uleb128 or NTBS)
  value Comment
  value Comment
  ...
```

Block commentary about the tag and its possible values.

*Tag value* gives the numerical representation of the tag. It is a small integer less than 128.

*Parameter type* gives the type of the parameter that immediately follows the tag in the attributes section. It is either a ULEB128-encoded integer or a NUL-terminated byte string (NTBS).

Following lines enumerate the currently defined parameter values, giving a short comment about each one.

A block of explanatory text follows in some cases.

### 3.3.5 Target-related attributes

#### 3.3.5.1 About target-related attributes

Target-related attributes describe the demands a user permitted a producer to place on the target system ([Capturing user intentions about compatibility](#)).

These attributes summarize the target features and facilities needed to execute the instructions contained in the code sections of this relocatable file. A file may make fewer demands than its attributes describe, but not more.

#### 3.3.5.2 The target-related attributes

```
Tag_CPU_raw_name, (=4), NTBS
```

The raw name is the name a user gave to a tool or selected from a menu. It can be:

- The name of a specific manufacturer's part (such as ML692000).
- The name of a generic part (such as Arm946E-S) or architecture (such as v5TE).
- Any other name acceptable to the toolchain.

The value "" denotes that the raw name is identical to the CPU name (described immediately below) and records that the user built for a generic implementation (such as Arm946E-S) rather than any manufacturer-specific part (such as ML692000) based on it.

It is always safe to use "" as a dummy value for this tag, or to omit this tag.

```
Tag_CPU_name, (=5), NTBS
```

A CPU name is defined by Arm or the architecture licensee responsible for designing the part. It is the official product name, with no extension and no abbreviation.

An Arm-defined architecture name may be used instead of a CPU name, and denotes that the user had more generic intentions. Arm-defined names of CPUs and architectures recognized by Arm Compiler 5.01 are listed in [Arm CPU names recognized by Arm Compiler 5.01 \(armcc\)](#).

The following tags describe the processor architecture version and architecture profile for which the user intended the producer to produce code.

```
Tag_CPU_arch, (=6), uleb128
 0 Pre-v4
 1 Arm v4 // e.g. SA110
 2 Arm v4T // e.g. Arm7TDMI
 3 Arm v5T // e.g. Arm9TDMI
 4 Arm v5TE // e.g. Arm946E-S
 5 Arm v5TEJ // e.g. Arm926EJ-S
 6 Arm v6 // e.g. Arm1136J-S
 7 Arm v6KZ // e.g. Arm1176JZ-S
 8 Arm v6T2 // e.g. Arm1156T2F-S
 9 Arm v6K // e.g. Arm1136J-S
10 Arm v7 // e.g. Cortex-A8, Cortex-M3
11 Arm v6-M // e.g. Cortex-M1
12 Arm v6S-M // v6-M with the System extensions
13 Arm v7E-M // v7-M with DSP extensions
14 Arm v8-A
15 Arm v8-R
16 Arm v8-M.baseline
17 Arm v8-M.mainline
18 Arm v8.1-A
19 Arm v8.2-A
20 Arm v8.3-A
21 Arm v8.1-M.mainline
22 Arm v9-A

Tag_CPU_arch_profile (=7), uleb128
 0 Architecture profile is not applicable (e.g. pre v7, or cross-profile code),
   or is indicated by Tag_CPU_arch
 'A' (0x41) The application profile (e.g. for Cortex-A8)
 'R' (0x52) The real-time profile (e.g. for Cortex-R4)
 'M' (0x4D) The microcontroller profile (e.g. for Cortex-M3)
 'S' (0x53) Application or real-time profile (i.e. the 'classic' programmer's model)
```

Tag\_CPU\_arch\_profile states that the attributed entity requires the noted architecture profile.

The value 0 states that there is no requirement for any specific architecture profile. The value 'S' denotes that the attributed entity requires the classic programmer's model rather than the microcontroller programmer's model.

Starting with architecture versions v8-A, v8-R and v8-M, the profile is represented by Tag\_CPU\_arch. For these architecture versions and any later versions, a value of 0 should be used for Tag\_CPU\_arch\_profile.

The following tags track the permitted use of instruction sets. The architecture revision (Tag\_CPU\_arch) implies the permitted subset of instructions from the permitted ISA.

```
Tag_ARM_ISA_use, (=8), uleb128
  0 The user did not permit this entity to use Arm instructions
  1 The user intended that this entity could use Arm instructions

Tag_THUMB_ISA_use, (=9), uleb128
  0 The user did not permit this entity to use Thumb instructions
  1 (deprecated) The user permitted this entity to use 16-bit Thumb instructions (including BL)
  2 (deprecated) 32-bit Thumb instructions were permitted (implies 16-bit instructions permitted)
  3 The user permitted this entity to use Thumb code. The set of permitted instructions can be
    determined by the setting of Tag_CPU_arch and Tag_CPU_arch_profile

Note: The historical use of values 1 and 2 date to a time when there was
a clear separation between implementations using 16-bit only Thumb
instructions and those using the extended set of instructions. The
introduction of Armv8-M.baseline has blurred this distinction to the
point where it is no-longer useful. Arm recommends that in future all
toolchains emit a value of 3 when use of Thumb was intended by the user
and 0 (or omitting the tag entirely) when use of Thumb was not intended.

Tag_FP_arch, (=10), uleb128 (formerly Tag_VFP_arch = 10)
  0 The user did not permit this entity to use instructions requiring FP hardware
  1 The user permitted use of instructions from v1 of the floating point (FP) ISA
  2 Use of the v2 FP ISA was permitted (implies use of the v1 FP ISA)
  3 Use of the v3 FP ISA was permitted (implies use of the v2 FP ISA)
  4 Use of the v3 FP ISA was permitted, but only citing registers D0-D15, S0-S31
  5 Use of the v4 FP ISA was permitted (implies use of the non-vector v3 FP ISA)
  6 Use of the v4 FP ISA was permitted, but only citing registers D0-D15, S0-S31
  7 Use of the Arm v8-A FP ISA was permitted
  8 Use of the Arm v8-A FP ISA was permitted, but only citing registers D0-D15, S0-S31

Tag_WMMX_arch, (=11), uleb128
  0 The user did not permit this entity to use WMMX
  1 The user permitted this entity to use WMMX v1
  2 The user permitted this entity to use WMMX v2

Tag_Advanced_SIMD_arch, (=12), uleb128
  0 The user did not permit this entity to use the Advanced SIMD Architecture (Neon)
  1 Use of the Advanced SIMDv1 Architecture (Neon) was permitted
  2 Use of Advanced SIMDv2 Architecture (Neon) (with half-precision floating-point and
    fused MAC operations) was permitted
  3 Use of the Arm v8-A Advanced SIMD Architecture (Neon) was permitted
  4 Use of the Arm v8.1-A Advanced SIMD Architecture (Neon) was permitted

Tag_MVE_arch, (=48), uleb128
  0 The user did not permit this entity to use the M-profile Vector Extension
  1 Use of the Integer M-profile Vector Extension was permitted
  2 Use of the Integer and Floating Point M-profile Vector Extension was
    permitted

Tag_FP_HP_extension (=36), uleb128 (formerly Tag_VFP_HP_extension = 36)
  0 The user intended half-precision floating point instructions may be used if they
    exist in the available FP and ASIMD instruction sets as indicated by Tag_FP_arch
    and Tag_ASIMD_arch
  1 Use of the half-precision instructions first added as an optional extension to
    VFPv3/Advanced SIMDv1 was permitted, in addition to those indicated by Tag_FP_arch
    and Tag_ASIMD_arch
  2 Use of the half-precision instructions first added as an optional extension to
    Armv8.2-A Floating-Point and Advanced SIMD was permitted, in addition to those
    indicated by Tag_FP_arch and Tag_ASIMD_arch
```

The following tag describes the unaligned data accesses the user permitted the producer to make.

```
Tag_CPU_unaligned_access, (=34), uleb128
  0 The user did not intend this entity to make unaligned data accesses
  1 The user intended that this entity might make v6-style unaligned data accesses
```

The following tags describe intended use of optional architectural extensions.

```
Tag_T2EE_use, (=66), uleb128
  0 No use of T2EE extension was permitted, or no information is available
  1 Use of the T2EE extension was permitted
```

In effect, Tag\_T2EE\_use describes the intended use of ENTERX and LEAVEX instructions. Tag\_T2EE\_use is deprecated from r2.09.

```
Tag_Virtualization_use, (=68), uleb128
  0 No use of any virtualization extension was permitted, or no information available
  1 Use of the TrustZone extension was permitted
  2 Use of the virtualization extensions (HVC, ERET) were permitted
  3 Use of TrustZone and virtualization extensions were permitted
```

In effect, Tag\_Virtualization\_use describes the intended use of the SMC instruction in bit 0 of the tag value and the intended use of HVC and ERET instructions in bit 1.

```
Tag_MPextension_use, (=42), uleb128
  0 No use of Arm v7 MP extension was permitted, or no information available.
  1 Use of the Arm v7 MP extension was permitted.
```

In effect, Tag\_MPextension\_use describes the intended use of the PLDW (preload write hint) instruction.

```
Tag_DIV_use, (=44), uleb128
  0 The user intended divide instructions may be used if they exist, or no explicit
    information recorded. This code was permitted to use SDIV and UDIV if the
    instructions are guaranteed present in the architecture,
    as indicated by Tag_CPU_arch and Tag_CPU_arch_profile.
  1 This code was explicitly not permitted to use SDIV or UDIV.
  2 This code was permitted to use SDIV and UDIV in the Arm and Thumb ISAs; the
    instructions are present as an optional architectural extension above the base
    architecture implied by Tag_CPU_arch and Tag_CPU_arch_profile.
```

#### Note

Value 1 records an explicit intention to not use divide instructions in this code, on targets where they would otherwise be permitted. This intention could be conveyed to the object producer by citing a "no divide" command-line option, or by other means. How a linker interprets this intention is QoI.

#### Note

Producers must emit value 2 if and only if the permission to use SDIV and UDIV cannot be conveyed using values 0 and 1.

```
Tag_DSP_extension, (=46), uleb128
  0 The user intended DSP instructions may be used if they exist. This
    entity is permitted to use DSP instructions if they are guaranteed
```

present in the architecture as indicated by Tag\_CPU\_arch.

- 1 This code was permitted to use Thumb DSP functions as an optional architecture extension above the base architecture as indicated by Tag\_CPU\_arch.

Tag\_PAC\_extension (=50), uleb128

- 0 The user did not permit this entity to use PAC/AUT instructions
- 1 The user permitted this entity to use PAC/AUT instructions in the NOP space
- 2 The user permitted this entity to use PAC/AUT instructions in the NOP and in the non-NOP space

Tag\_BTI\_extension (=52), uleb128

- 0 The user did not permit this entity to use BTI instructions
- 1 The user permitted this entity to use BTI instructions in the NOP space
- 2 The user permitted this entity to use BTI instructions in the NOP and in the non-NOP space

### 3.3.6 Procedure call-related attributes

#### 3.3.6.1 About procedure call-related attributes

Procedure call-related attributes describe compatibility with the ABI. They summarize the features and facilities that must be agreed in an interface contract between functions defined in this relocatable file and elsewhere. We call the functions subject to such interface contracts *public functions*.

#### Aside

In C/C++ terminology, all public functions have extern linkage but not all extern functions are public. In ELF terminology, all public symbols are global, but not all global symbols are public.

For a public function defined in this relocatable file, attributes describe what the user intended the producer to guarantee about the function.

For a public function used by code in this relocatable file, attributes describe what the user intended the producer to assume about the function.

#### 3.3.6.2 The procedure call-related attributes

Tag\_PCS\_config, (=13), uleb128

- 0 No standard configuration used, or no information recorded
- 1 Bare platform configuration
- 2 Linux application configuration
- 3 Linux DSO configuration
- 4 Palm OS 2004 configuration
- 5 Reserved to future Palm OS configuration
- 6 Symbian OS 2004 configuration
- 7 Reserved to future Symbian OS configuration

Tag\_PCS\_config summarizes the user intention behind the procedure-call standard configuration used. Its value must be consistent with the values given to the tags below, and must not be used as a macro in place of them.

The following four tags summarize how the user intended the attributed entity to address static data.

```
Tag_ABI_PCS_R9_use, (=14), uleb128
  0 R9 used as V6 (just another callee-saved register, implied by omitting the tag)
  1 R9 used as SB, a global Static Base register
  2 R9 used as a Thread Local Storage (TLS) pointer
  3 R9 not used at all by code associated with the attributed entity
```

R9 has a role in some variants of the PCS. Tag\_ABI\_PCS\_R9\_use describes the user's chosen PCS variant.

When R9 is used as a Thread Local Storage (TLS) pointer (Tag\_ABI\_PCS\_R9\_use = 2), R9 plays the role that would otherwise be played by one of the three Software Thread ID Registers TPIDRURW, TPIDRURO, TPIDRPRW defined in section B3.12.46, CP15 c13 Software Thread ID registers, of the Arm Architecture Reference Manual Arm v7-A and Arm v7-R edition [Arm DDI 0406].

The role played by that TPID\* register is defined by the software platform's ABI.

```
Tag_ABI_PCS_RW_data, (=15), uleb128
  0 RW static data was permitted to be addressed absolutely
  1 RW static data was only permitted to be addressed PC-relative
  2 RW static data was only permitted to be addressed SB-relative
  3 The user did not permit this entity to use RW static data

Tag_ABI_PCS_RO_data, (=16), uleb128
  0 RO static data was permitted to be addressed absolutely
  1 RO static data was only permitted to be addressed PC-relative
  2 The user did not permit this entity to use RO static data

Tag_ABI_PCS_GOT_use, (=17), uleb128
  0 The user did not permit this entity to import static data
  1 The user permitted this entity to address imported data directly
  2 The user permitted this entity to address imported data indirectly (e.g. via a GOT)
```

Compatibility among shared objects and their clients is affected by whether imported data are addressed directly or indirectly. Linux imported data must be addressed indirectly (via the Global Object Table, or GOT). Symbian OS (2004) imported data must be addressed directly.

The following two tags describe the permitted sizes of a wide character and an enumerated data item.

```
Tag_ABI_PCS_wchar_t, (=18), uleb128
  0 The user prohibited the use of wchar_t when building this entity
  2 The user intended the size of wchar_t to be 2
  4 The user intended the size of wchar_t to be 4

Tag_ABI_enum_size, (=26), uleb128
  0 The user prohibited the use of enums when building this entity
  1 Enum values occupy the smallest container big enough to hold all their values
  2 The user intended Enum containers to be 32-bit
  3 The user intended that every enumeration visible across an ABI-complying interface
    contains a value needing 32 bits to encode it; other enums can be containerized
```

The following pair of tags summarizes the alignment contract across an interface.

```
Tag_ABI_align_needed, (=24), uleb128
  0 The user did not permit code to depend the alignment of 8-byte data or data with
    extended (> 8-byte) alignment
  1 Code was permitted to depend on the 8-byte alignment of 8-byte data items
  2 Code was permitted to depend on the 4-byte alignment of 8-byte data items
```

- 3 Reserved
- n (in 4..12) Code was permitted to depend on the 8-byte alignment of 8-byte data items and the alignment of data items having up to 2n-byte extended alignment

Tag\_ABI\_align\_preserved, (=25), uleb128

- 0 The user did not require code to preserve 8-byte alignment of 8-byte data objects
- 1 Code was required to preserve 8-byte alignment of 8-byte data objects
- 2 Code was required to preserve 8-byte alignment of 8-byte data objects and to ensure (SP MOD 8) = 0 at all instruction boundaries (not just at function calls)
- 3 Reserved
- n (in 4..12) Code was required to preserve the alignments of case 2 and the alignment of data items having up to 2n-byte extended alignment.

The following five tags summarize the requirements code associated with this attributed entity was permitted to place on floating-point arithmetic.

Tag\_ABI\_FP\_rounding, (=19), uleb128

- 0 The user intended this code to use the IEEE 754 round to nearest rounding mode
- 1 The user permitted this code to choose the IEEE 754 rounding mode at run time

Tag\_ABI\_FP\_denormal, (=20), uleb128

- 0 The user built this code knowing that denormal numbers might be flushed to (+) zero
- 1 The user permitted this code to depend on IEEE 754 denormal numbers
- 2 The user permitted this code to depend on the sign of a flushed-to-zero number being preserved in the sign of 0

Tag\_ABI\_FP\_exceptions, (=21), uleb128

- 0 The user intended that this code should not check for inexact results
- 1 The user permitted this code to check the IEEE 754 inexact exception

Tag\_ABI\_FP\_user\_exceptions, (=22), uleb128

- 0 The user intended that this code should not enable or use IEEE user exceptions
- 1 The user permitted this code to enables and use IEEE 754 user exceptions

Tag\_ABI\_FP\_number\_model, (=23), uleb128

- 0 The user intended that this code should not use floating point numbers
- 1 The user permitted this code to use IEEE 754 format normal numbers only
- 2 The user permitted numbers, infinities, and one quiet NaN (see [RTABI32\_])
- 3 The user permitted this code to use all the IEEE 754-defined FP encodings

FP model hierarchies are difficult to specify. In practice, there is a large lattice of potentially useful models, depending on whether FP arithmetic is done by software or by hardware, and on the properties of that hardware. The tags above allow requirements to be specified using independent features. For example, code following the Java numerical model should record Tag\_ABI\_FP\_denormal = 1 and Tag\_ABI\_FP\_number\_model = 2, while graphics code concerned with speed above all other considerations might record Tag\_ABI\_FP\_number\_model = 1 and Tag\_ABI\_FP\_optimization\_goals = 2 (see below).

The following tag summarizes use of 16-bit floating point numbers by the attributed entities.

Tag\_ABI\_FP\_16bit\_format (=38), uleb128

- 0 The user intended that this entity should not use 16-bit floating point numbers
- 1 Use of IEEE 754 (draft, November 2006) format 16-bit FP numbers was permitted
- 2 Use of VFPv3/Advanced SIMD "alternative format" 16-bit FP numbers was permitted

Options 1 and 2 are mutually incompatible.

The next three tags record permitted use of the VFP extension and WMMX co-processor. Note that:

- Under the base variant of the procedure call standard [AAPCS32], FP parameters and results are passed the soft FP way, in core registers or on the stack. WMMX parameters and results are passed the same way.
- The VFP variant of [AAPCS32] uses VFP registers D0-D7 (s0-s15) to pass parameters and results.



- The Intel WMMX convention is to use wR0-wR9 to pass parameters and results.

```

Tag_ABI_HardFP_use, (=27), uleb128
 0 The user intended that FP use should be implied by Tag_FP_arch
 1 The user intended this code to execute on the single-precision variant
   derived from Tag_FP_arch
 2 Reserved
 3 The user intended that FP use should be implied by Tag_FP_arch
   (Note: This is a deprecated duplicate of the default encoded by 0)

Tag_ABI_VFP_args, (=28), uleb128
 0 The user intended FP parameter/result passing to conform to AAPCS, base variant
 1 The user intended FP parameter/result passing to conform to AAPCS, VFP variant
 2 The user intended FP parameter/result passing to conform to toolchain-specific
   conventions
 3 Code is compatible with both the base and VFP variants; the user did not permit
   non-variadic functions to pass FP parameters/results

Tag_ABI_WMMX_args, (=29), uleb128
 0 The user intended WMMX parameter/result passing conform to the AAPCS, base variant
 1 The user intended WMMX parameter/result passing conform to Intel's WMMX conventions
 2 The user intended WMMX parameter/result passing conforms to toolchain-specific
   conventions

```

The following tag summarizes the level of conformance to the rules for creating and maintaining a chain of frame records on the stack.

```

Tag_FramePointer_use, (=72), uleb128
 0 This code makes no claims to conformance with the rules for use of a frame pointer
 1 This code creates a frame record for all functions that may modify the value stored
   in the link register (LR)
 2 This code does not create frame records, but preserves the value stored in the
   frame pointer register (FP)

```

It is recommended that code that uses a private convention for maintaining a frame chain should leave this tag unset (=0) and then use a vendor-specific attribute to record this property.

Generally this tag can be ignored for the purposes of diagnosing object file compatibility, unless a program explicitly needs to depend on being able to walk the frame chain.

The following tag describes a producer use of branch target identification instructions.

```

Tag_BTI_use (=74), uleb128
 0 This code is compiled without branch target enforcement
 1 This code is compiled with branch target enforcement

```

### 3.3.7 Miscellaneous attributes

The following tag describes a producer use of pointer authentication instructions.

```

Tag_PACRET_use (=76), uleb128
 0 This code is compiled without return address signing and authentication
 1 This code is compiled with return address signing and authentication

```

#### 3.3.7.1 Optimization attributes

The final pair of ABI-related tags record optimization goals. These are not required for reasoning about incompatibility, but assist with selecting appropriate variants of library members.

```

Tag_ABI_optimization_goals, (=30), uleb128
 0 No particular optimization goals, or no information recorded
 1 Optimized for speed, but small size and good debug illusion preserved
 2 Optimized aggressively for speed, small size and debug illusion sacrificed
 3 Optimized for small size, but speed and debugging illusion preserved
 4 Optimized aggressively for small size, speed and debug illusion sacrificed
 5 Optimized for good debugging, but speed and small size preserved
 6 Optimized for best debugging illusion, speed and small size sacrificed

```

With `Tag_ABI_optimization_goals` we capture one of three potentially conflicting intentions – high performance, small size, and easy debugging – at one of two levels.

At the first level the goal is unambiguous, but pursuit of it is constrained. The conflicting goals still matter, but less than the primary goal.

At the second level, the conflicting goals are insignificant in comparison to the primary goal. It is difficult to capture optimization intentions precisely, but to a significant degree what matters to a toolchain is the user's goal (speed, small size, or debug-ability), and whether or not the user is willing to sacrifice all other considerations to achieving that goal.

```

Tag_ABI_FP_optimization_goals, (=31), uleb128
 0 No particular FP optimization goals, or no information recorded
 1 Optimized for speed, but small size and good accuracy preserved
 2 Optimized aggressively for speed, small size and accuracy sacrificed
 3 Optimized for small size, but speed and accuracy preserved
 4 Optimized aggressively for small size, speed and accuracy sacrificed
 5 Optimized for accuracy, but speed and small size preserved
 6 Optimized for best accuracy, speed and small size sacrificed

```

With `Tag_ABI_FP_optimization_goals` we also capture one of three potentially conflicting goals at one of the same two levels as `Tag_ABI_optimization_goals` captures.

Some accuracy sacrificed is intended to allow, for example, re-association of expressions in generated code. In library code it is intended to permit the assumption that value ranges will be reasonable. In particular, binary to decimal and decimal to binary conversion may meet only the minimum standards specified by IEEE 754, and range reduction for trigonometric functions should be assumed to be naive.

### 3.3.7.2 Generic compatibility tag

The generic compatibility tag describes the limited compatibility this file might offer when no strong claim to conform to the ABI ([Build attributes and conformance to the ABI](#)) has been made using `Tag_conformance` ([Conformance tag](#)).

```

Tag_compatibility (=32), uleb128: flag, NTBS: vendor-name

```

An omitted tag implies `flag = 0`, `vendor-name = ""`. An explicit `flag` value is not 0 and can be considered to be the first byte(s) of the vendor name for the purpose of skipping the entry. The default value of 0 describes the implicit claim made by files generated prior to v1.06 of this specification.

The defined `flag` values and their meanings are as follows.

```

0 The tagged entity has no toolchain-specific requirements
  (and no vendor tag hides an ABI incompatibility)
1 This entity can conform to the ABI if processed by the named toolchain.
  The ABI variant to which it conforms is described solely by public "aeabi" tags
>1 The tagged entity does not conform to the ABI but it can be processed by other
  tools under a private arrangement described by flag and vendor-name

```

A `flag` value >1 identifies an arrangement, beyond the scope of the ABI, defined by the named vendor. A toolchain that recognizes the arrangement might successfully process this file. Note that a producer must use the name of the vendor defining the arrangement, not the name of the producing toolchain.

(Versions of this specification through v1.05 stated:

```
>1 The tagged entity is compatible only with identically tagged entities,  
and entities not tagged by this toolchain
```

The underlined part of that definition was a mistake that makes the definition useless. With the underlined part removed, the old definition is effectively compatible with, but more restrictive than, the new one).

### 3.3.7.3 Secondary compatibility tag

Tag\_CPU\_arch conceals a difficulty in relation to the 16-bit Thumb ISA: there is no way to tag an entity as compatible with both Arm7TDMI (architecture v4T) and Cortex-M1 (architecture v6-M variant). The set of instructions compatible with both targets excludes the 16-bit Thumb SVC (formerly SWI) instruction. In effect we need a pseudo architecture v4T-no-SVC to describe such code, but no such architecture exists so it cannot simply be added to the Tag\_CPU\_arch enumeration.

We have chosen to deal with this problem describing such code as v4T also compatible with v6-M (or as v6-M also compatible with v4T) using the following safely ignorable ([Coding extensibility and compatibility](#)) tag.

```
Tag_also_compatible_with (=65), NTBS: data
```

The data string must be further interpreted as a ULEB128-encoded tag followed by a value of that tag. If that value is numerical (i.e. ULEB128), there is an additional NUL byte following it. Thus, the data string value of the Tag\_also\_compatible\_with tag must be in one of the following two formats:

- ULEB128: tag, ULEB128: value, 0.
- ULEB128: tag, NTBS: data.

The following byte sequence records the intention to also be compatible with architecture version v6-M.

```
Tag_also_compatible_with (=65) Tag_CPU_arch (=6) v6-M (=11) 0
```

At this release of the ABI (2023Q3) there are only two defined uses of Tag\_also\_compatible\_with:

- To express v4T also compatible with v6-M and v6-M also compatible with v4T.
- To express v8-A also compatible with v8-R and v8-R also compatible with v8-A.

All other uses are RESERVED to the ABI. Future releases of the ABI may relax this constraint.

### 3.3.7.4 Conformance tag

The conformance tag describes the version of the ABI to which conformity is claimed by an entity.

```
Tag_conformance (=67), string: ABI-version
```

This version of the ABI is “2023Q3”. The minor version (dot-xy) is for information and does not affect the claim. Version “0” denotes no claim to conform and is the default if the tag is omitted.

To simplify recognition by consumers in the common case of claiming conformity for the whole file, this tag should be emitted first in a file-scope sub-subsection of the first public subsection of the attributes section.

In this case, the dot-ARM-dot-attributes section would begin “A~~~~aeabi01~~~~C2023Q3”, where ‘~’ denotes an unknown byte value.

### 3.3.7.5 No defaults tag

The occurrence of a no defaults tag in an attributes sub-subsection indicates that the tag values inherited ([Default values for public tags](#), [Inheritance of public tag values](#)) by entities in enclosed scopes with no explicitly given tags are UNDEFINED rather than 0.

```
Tag_nodefaults (=64), uleb128: ignored (write as 0)
```

A consuming tool may take IMPLEMENTATION DEFINED action if any tag has an UNDEFINED value after a dot-ARM-dot-attributes section has been fully processed.

Consumers that do not recognize this tag will default UNDEFINED values to 0.

To make processing easy for consumers, this tag should be emitted before any other tag in an attributes sub-subsection other than the conformance tag ([Conformance tag](#)).

We expect the no defaults tag to be used only by linkers that merge attributed and un-attributed (legacy) relocatable files.

#### Note

From the 2.09 release, section and symbol attributes are deprecated and optional. Primary object producers are discouraged from generating them and consumers are permitted to ignore them. Hence from the 2.09 release use of this tag is deprecated.

### 3.4 Arm CPU names recognized by Arm Compiler 5.01 (armcc)

Arm Compiler 5.01 armcc recognizes the following Arm processor product names:

ARM7EJ-S	ARM9TDMI	ARM1020E	Cortex-M0	Cortex-R7
ARM7TM	ARM920T	ARM1022E	Cortex-M0plus	Cortex-A5
ARM7TDM	ARM922T	ARM1026EJ-S	Cortex-M1	Cortex-A7
ARM7TDMI	ARM940T	ARM1136J-S	Cortex-M3	Cortex-A8
ARM710T	ARM9E-S	ARM1136JF-S	Cortex-M4	Cortex-A9
ARM720T	ARM9EJ-S	ARM1156T2-S	SC000	Cortex-A15
ARM740T	ARM926EJ-S	ARM1156T2F-S	SC300	
ARM7TM-S	ARM946E-S	ARM1176JZ-S	Cortex-R4	
ARM7TDMI-S	ARM966E-S	ARM1176JZF-S	Cortex-R4F	
ARM810	ARM968E-S	MPCore	Cortex-R5	

(Many of these names are trademarks of Arm Limited. For details see <http://www.arm.com/legal.html>).

The following pseudo processor names are recognized as architecture version names:

4	5T	6	7
4T	5TE	6K	7-A
	5TEJ	6T2	7-R
		6Z	7-M
		6-M	7E-M
		6S-M	

(Other Arm product version names and non-Arm product names are also recognized).

### 3.5 Attributes summary and history

Table 1 lists the public attribute tag names and for each tag its numerical value, its parameter type, the ABI revision in which it was introduced, and the revisions in which its parameter values or meaning were amended.

A program claiming conformance to revision r2.x of this ABI must comprehend tags with values less than 64 ([Coding extensibility and compatibility](#)) defined in revisions r2.x and earlier, and all parameter values defined for those tags by those revisions.

Table 2 summarizes amendments to the specification of build attributes ABI revision by ABI revision.

**Table 1, Summary and history of individual attributes**

Tag	Value	Parameter type	ABI revision	Amendments
Tag_File	1	uint32	r2.0	
Tag_Section	2	uint32	r2.0	r2.09: Use deprecated.
Tag_Symbol	3	uint32	r2.0	r2.09: Use deprecated.
Tag_CPU_raw_name	4	NTBS	r2.0	

Tag	Value	Parameter type	ABI revision	Amendments
Tag_CPU_name	5	NTBS	r2.0	
Tag_CPU_arch	6	uleb128	r2.0	r2.06: Added enum values for v6-M, v6S-M;
				r2.08: Added enum value for v7E-M.
				r2.09: Added enum value for v8.
Tag_CPU_arch_profile	7	uleb128	r2.0	r2.05: Added 'S' denoting 'A' or 'R' (don't care)
Tag_ARM_ISA_use	8	uleb128	r2.0	
Tag_THUMB_ISA_use	9	uleb128	r2.0	
Tag_FP_arch (formerly Tag_VFP_arch)	10	uleb128	r2.0	r2.04: Added enum value for VFPv3
				r2.06: Added enum value for VFPv3 restricted to D0-D15
				r2.08: Renamed; added enum value for VFPv4 (adds fused MAC + 16-bit FP data in memory).
				r2.09: Added enum value for v8-A FP
Tag_WMMX_arch	11	uleb128	r2.0	r2.02: Added enum value for wireless MMX v2.
Tag_Advanced_SIMD_arch	12	uleb128	r2.0	r2.08: Added enum value for Neon with fused MAC
				r2.09: Clarified existing usages and added enum value for v8-A ASIMD
Tag_PCS_config	13	uleb128	r2.0	
Tag_ABI_PCS_R9_use	14	uleb128	r2.0	r2.08: Clarified that value = 2 denotes using R9 to emulate one of the architecturally defined thread ID registers in CP15 c13.
Tag_ABI_PCS_RW_data	15	uleb128	r2.0	
Tag_ABI_PCS_RO_data	16	uleb128	r2.0	
Tag_ABI_PCS_GOT_use	17	uleb128	r2.0	
Tag_ABI_PCS_wchar_t	18	uleb128	r2.0	
Tag_ABI_FP_rounding	19	uleb128	r2.0	
Tag_ABI_FP_denormal	20	uleb128	r2.0	
Tag_ABI_FP_exceptions	21	uleb128	r2.0	r2.09: fixed typo (missing 'permitted')
Tag_ABI_FP_user_exceptions	22	uleb128	r2.0	

Tag	Value	Parameter type	ABI revision	Amendments
Tag_ABI_FP_number_model	23	uleb128	r2.0	
Tag_ABI_align_needed (formerly ..._align8_needed)	24	uleb128	r2.0	r2.08: Generalized to extended alignment of 2 <sup>n</sup> bytes for n in 4..12
Tag_ABI_align8_preserved (formerly ..align8_preserved)	25	uleb128	r2.0	r2.08: Generalized to extended alignment of 2 <sup>n</sup> bytes for n in 4..12
Tag_ABI_enum_size	26	uleb128	r2.0	
Tag_ABI_HardFP_use	27	uleb128	r2.0	r2.09: Clarified use of existing values and removed DP-only option
Tag_ABI_VFP_args	28	uleb128	r2.0	r2.09: Added enum value for code compatible with both the base and VFP variants
Tag_ABI_WMMX_args	29	uleb128	r2.0	
Tag_ABI_optimization_goals	30	uleb128	r2.0	
Tag_ABI_FP_optimization_goals	31	uleb128	r2.0	
Tag_compatibility	32	NTBS	r2.0	r2.05: Revised the ineffective definition. The new one is compatible with the old one if a nonsensical clause in the old one is ignored.
Tag_CPU_unaligned_access	34	uleb128	r2.02	
Tag_FP_HP_extension (was Tag_VFP_HP_extension)	36	uleb128	r2.06	r2.08: Renamed (VFP → FP) r2.09: Clarified use of existing values.
Tag_ABI_FP_16bit_format	38	uleb128	r2.06	
Tag_MPextension_use	42	uleb128	r2.08	
Tag_DIV_use	44	uleb128	r2.08	r2.09: Changed wording to clarify meaning.
Tag_DSP_extension	46	uleb128	2018q4	
Tag_MVE_arch	48	uleb128	2019q4	
Tag_PAC_extension	50	uleb128	2021q1	
Tag_BTI_extension	52	uleb128	2021q1	
Tag_nodfaults	64	uleb128	r2.06	r2.07: Re-specified tag value inheritance more precisely ( <a href="#">Inheritance of public tag values</a> and <a href="#">No defaults tag</a> ). In the absence of Tag_nodfaults the specification reduces to that used before its introduction. We believe that only Arm tools are affected. r2.09: Use deprecated as Tag_Section and Tag_Symbol are deprecated.

Tag	Value	Parameter type	ABI revision	Amendments
Tag_also_compatible_with	65	NTBS	r2.05	r2.06: Restricted usage as noted in <a href="#">Secondary compatibility tag</a> .
				r2.09: Clarified data format.
Tag_conformance	67	NTBS	r2.05	
Tag_T2EE_use	66	uleb128	r2.07	r2.09: Deprecated as not useful
Tag_Virtualization_use	68	uleb128	r2.07	r2.08: Added two enumeration values to support the 2009 virtualization extensions.
Tag_MPextension_use	70	uleb128	r2.07	r2.08: Recoded to 42 (must be recognized by toolchains). PLDW is a user-mode instruction, undefined in architecture v7 w/o MP extensions.
Tag_FramePointer_use	72	uleb128	2019q2	
Tag_BTI_use	74	uleb128	2021q1	
Tag_PACRET_use	76	uleb128	2021q1	

**Table 2, History of attributes in ABI revisions and ABI-Addenda document versions**

ABI Revision	Doc vsn	Date	Amendments
r2.0	v1.0	March 2005	Initial release of the build attributes specification.
r2.01	v1.01	5 <sup>th</sup> July 2005	Added extensibility and compatibility rules (now <a href="#">Coding extensibility and compatibility</a> ).
r2.02	v1.03	13 <sup>th</sup> October 2005	Added wMMX v2 to Tag_WMMX_arch enumeration. Added Tag_CPU_unaligned_access.
r2.03	v1.04	6 <sup>th</sup> January 2006	No changes to the specification of build attributes.
r2.04	v1.05	8 <sup>th</sup> May 2006	Added VFPv3 to Tag_FP_arch enumeration.
r2.05	v1.06	25 <sup>th</sup> January 2007	Added introductory <a href="#">Introduction to build attributes</a> . Clarified that all current uleb128 values are also plain byte values. Clarified inheritance of default values through nested scopes. Clarified the definition of conformance. Added 'S' to the Tag_CPU_arch_profile enumeration. Corrected the previously useless definition of Tag_compatibility. Added Tag_also_compatible_with and Tag_conformance. Added <a href="#">Procedure call-related attributes</a> about combining attribute values. Many minor editorial improvements.



ABI Revision	Doc vsn	Date	Amendments
r2.06	A	October 2007	Major re-write of material with emphasis on clear presentation. Added v6-M and v6S-M to Tag_CPU_arch enumeration. Added VFPv3 restricted to D0-D15 to Tag_FP_arch enumeration. Added Tag_FP_HP_extension, Tag_ABI_FP_16bit_format, and Tag_nofaults. Restricted the use of Tag_also_compatible_with in the face of persistent difficulties with its formal definition.
r2.07	B	October 2008	Added Tag_T2EE_use, Tag_Virtualization_use and Tag_MPextension_use. Clarified tag value inheritance and the use of Tag_Nofaults; clarified the meaning of Tag_CPU_name and Tag_CPU_raw_name.
r2.08	C	October 2009	Added Tag_CPU_arch enum value V7E-M=13; renamed Tag_VFP_arch to Tag_FP_arch, added values for VFPv4; renamed Tag_VFP_HP_extension to Tag_FP_HP_extension; added value to Tag_Advanced_SIMD_arch for Neon with fused MAC; added values to Tag_Virtualization_use describing use of the virtualization extensions; recoded Tag_MPextension use to catch potential user-mode faults; added Tag_DIV_use to describe use of UDIV/SDIV in code for v7A. Clarified the role of R9 when used as a TLS (Tag_ABI_PCS_R9_use = 2). Renamed Tag_ABI_align8_needed, Tag_ABI_align8_preserved and extended them to extended 2 <sup>n</sup> -byte alignment (for n in 4-12).
r2.09	D	November 2012	Changed Tag_DIV_use wording to clarify meaning. Clarified Tag_also_compatible_with data format. Deprecated Tag_Section, Tag_Symbol and Tag_nofaults. Added architecture v8 values to Tag_CPU_arch, Tag_FP_arch, Tag_Advanced_SIMD_arch. Clarified use of existing Tag_Advanced_SIMD_arch and Tag_FP_HP_extension values. Deprecated Tag_T2EE_use. Clarified use of Tag_ABI_HardFP_use values and removed DP-only option. Fixed typo (missing 'permitted') in Tag_ABI_FP_exceptions. Added enum value to Tag_ABI_VFP_args for code compatible with both the base and VFP variants.

# 4 ADDENDUM: Thread Local Storage

## 4.1 Introduction to thread local storage

Thread Local Storage (TLS) is a class of own data (static storage) that – like the stack – is instanced once for each thread of execution. It fits into the abstract storage hierarchy as follows.

- (Most global) Program-own data (static and extern variables, instanced once per program/process).
- Thread local storage (variables instanced once per thread, shared between all accessing function activations).
- (Most local) Automatic data (stack variables, instanced once per function activation, per thread).

Thread local storage generates a number of issues at a number of levels, not all of which affect an ABI.

- How to denote TLS in source programs.

Gcc uses `__tls T t...`; Microsoft use `__declspec(thread) T t...`; this is Q-o-I.

- How to represent the initializing images of TLS in object files, and how to define symbols in TLS.

The rules for ELF are well established (see `SHF_TLS`, `STT_TLS` in [\[GELF\]](#))

- How a loader or run-time system creates instances of TLS per-thread at execution time.

This is part of ABI for the platform or execution environment.

- How to relocate, statically and dynamically, with respect to symbols defined in TLS (for details of relocations relevant to Arm Linux see [\[AAELF32\]](#)).
- How code must address variables allocated in TLS (the subject of the notes below).

It is the last two bullet points that are the subject of this ABI.

## 4.2 Introduction to TLS addressing

In the most general form supported by Linux, Windows, and similar platforms, a program is constructed dynamically from an application and a number of shared libraries (called, respectively, DSOs or DLLs). Each component (application or shared library) can be mapped into multiple processes. Additionally, a DSO or DLL can be loaded dynamically by a program, rather than being part of the initial process image constructed when the program is first loaded.

For the purpose of addressing TLS, both Linux and Windows identify the components of an application using indexes. On both platforms, indexes are allocated dynamically when a process is created, or when a DSO or DLL is loaded dynamically. The details of how indexes are allocated are specific to a platform and differ significantly between Linux and Windows.

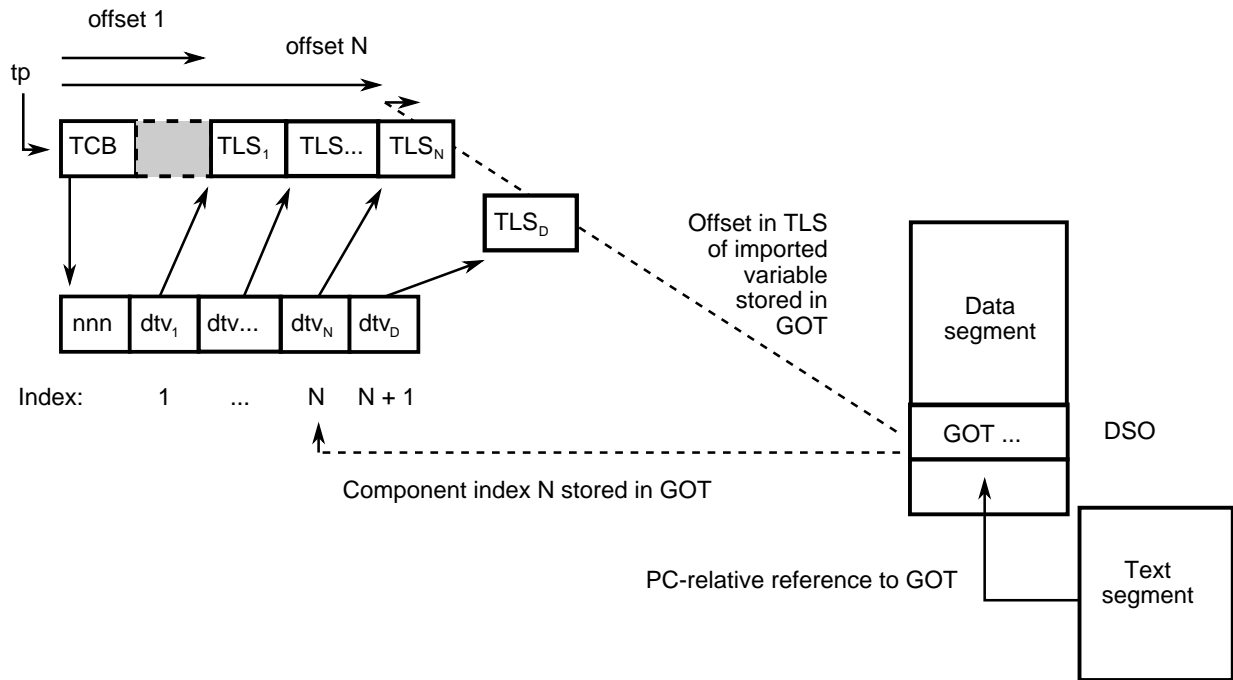
A component can have a different TLS index in two different processes, so its thread index must be part of its program-own state (or be queried dynamically). The run-time system is responsible for maintaining a per-thread vector of pointers to allocated TLS regions indexed by these component indexes. Under both Linux and the Win32 API, access to the vector is hidden behind run-time functions.

There is a system resource (such as a dedicated register) called the *thread pointer* that, typically, points to a control block for the currently executing thread which, in turn, points to the TLS vector for that thread.

At this stage, the details of TLS addressing become quite platform specific. In the next subsection we describe the concepts appropriate to Linux for Arm, which is all that this revision of the ABI supports.

## 4.3 Linux for Arm TLS addressing

The below figure depicts the fundamental components of the TLS addressing architecture used by Linux for Arm.



Linux for Arm TLS addressing architecture

In the most general case, the location of an imported thread local datum – or an exported datum that might be pre-empted – is represented by a pair of GOT entries that give:

- The index in the dynamic thread vector of the pointer to the TLS block containing the datum (the application itself has index 1 and index 0 is reserved to the run-time system).
- The offset of the datum in the pointed-to TLS block.

In the most general case the expression to address a thread local symbol S is:

$$(tp[0])[GOT_S[0]] + GOT_S[1]$$

### 4.3.1 Linux for Arm general dynamic model

In the *general dynamic model*, the addressing expression is packaged by a call to `__tls_get_addr` that takes a single parameter, the address of `GOT_S`. The code sequence and required relocations are shown in [Table 3](#).

A space-optimized version of the general dynamic model that calls `___tls_get_addr` (triple-underscore) is shown in [Table 4](#). The parameter passed to `___tls_get_addr` is the offset of `GOT_S` from `lr`.

The Linux for Arm TLS model has two local dynamic variants. These are used to address component-local thread-local variables more efficiently, but it can still be used in a dynamically loaded DSO. (A variable is local if symbol S has `STB_LOCAL` binding or non-`STV_DEFAULT` visibility). In these variants the offset of variable in the component's TLS segment is known at link time and only the component index must be loaded from the GOT. Specimen code sequences and relocations are given in [Table 5](#). This model is advantageous whenever a function accesses more than one variable (the address of the TLS block can be a common sub-expression).

**Table 3, General dynamic model (time optimized)**

Location	General dynamic model code sequence
.text	<pre> ldr r0, .Lt0 .L1 add r0, pc, r0 bl  __tls_get_addr           ; R_ARM_CALL(__tls_get_addr) ldr rS, [r0]                ; Load S... </pre>
literal_pool	<pre> .Lt0 .word S(tlsgd) + [. - .L1 - 8] ; R_ARM_TLS_GD32(S) </pre>
GOT[S]	<pre> .word           ; R_ARM_TLS_DTPMOD32(S) .word           ; R_ARM_TLS_DTPOFF32(S) </pre>

**Table 4, General dynamic model (space optimized)**

Location	General dynamic model (space optimized)
.text	<pre> ldr r0, .Lt0 .L1 bl  __tls_get_addr           ; R_ARM_CALL(__tls_get_addr) ldr rS, [r0]                ; Load S... </pre>
literal_pool	<pre> .Lt0 .word S(tlsgd) + [. - .L1 - 4] ; R_ARM_TLS_GD32(S) </pre>
GOT[S]	<pre> .word           ; R_ARM_TLS_DTPMOD32(S) .word           ; R_ARM_TLS_DTPOFF32(S) </pre>

**Table 5, Local dynamic models**

Location	Local dynamic model Relocation Symbol
.text	<pre> ldr r0, .Lt0 .L1 add r0, pc, r0 bl  __tls_get_addr           ; R_ARM_CALL(__tls_get_addr)  ... r0 points to my TLS, a CSE ...  ldr r1, .Lt1 ldr rX, [r0, r1] ; long offset to X  ...           ; but a short offset to Y  ldr rY, [r0, #Y(tlslldo)]   ; R_ARM_TLS_LDO12(Y) </pre>
literal_pool	<pre> .Lt0 .word X(tlslldm) + [. - .L1 - 8] ; R_ARM_TLS_LDM32(X) .Lt1 .word Y(tlslldo)                ; R_ARM_TLS_LDO32(Y) </pre>
GOT[X]	<pre> .word           ; R_ARM_TLS_DTPMOD32(X) .word 0 </pre>

`R_ARM_TLS_LDM32` sets the first element of the GOT pair to the symbol's dynamic TLS vector index, as does `R_ARM_TLS_GD32`, but sets the second element to 0 (as shown in [Table 5](#)).

TLS-related relocations for Linux for Arm are described further in [\[AAELF32\]](#).

### 4.3.2 Linux for Arm static (initial exec) model

If DSOs need not be loaded dynamically, more efficient addressing modes can be constructed if the run-time system allocates TLS at process creation time. As depicted in [Linux for Arm TLS addressing architecture](#), the offset from the thread pointer `tp` to a component's TLS is then known at process creation time (dynamic link time), so a component can address its thread local variables relative to `tp`, without indexing the dynamic thread vector.

Below, `$tp` denotes a general purpose register containing the result of reading `tp`.

[Table 6](#) shows the general model. It works for DSOs and the root application, in Arm and Thumb state.

[Table 7](#) shows an optimized model for DSOs. If the compiler uses a GOT pointer (denoted by `$gp`) and small PIC (12-bit PC-relative) addressing. This model works only in Arm state.

Finally, [Table 8](#) shows the code to access an application's local thread-local variables. Because an application's TLS is allocated first in the initial TLS vector for the process, the offsets of its variables from `tp` are known at static link time and do not need to be read from the GOT. The 12-bit model works only in Arm state.

**Table 6, General initial exec model**

Location	Initial exec model code sequence
.text	<pre>ldr r0, .Lt0 .L1 ldr r0, [pc, r0] ... ldr rS, [\$tp, r0] ; Load S...</pre>
literal pool	<code>.Lt0 .word S(tpoff) + [. - .L1 - 8] ; R_ARM_TLS_IE32(S)</code>
GOT[S]	<code>.word ; R_ARM_TLS_TPOFF32(S)</code>

**Table 7, Initial exec model, DSO with GOT pointer and small FPIC addressing (DSO only)**

Location	Initial exec model code sequence
.text	<pre>ldr r0, [\$gp, #S(gottpoff)] ; R_ARM_TLS_IE12GP(S) ... ldr rS, [\$tp, r0] ; Load S...</pre>
GOT[S]	<code>.word ; R_ARM_TLS_TPOFF32(S)</code>

**Table 8, Initial exec model, access to an application’s local thread-local variables**

Location	Initial exec model code sequence
<pre data-bbox="183 383 383 443">.text</pre>	<pre data-bbox="414 383 1407 546">ldr r0, .Lt0 ... ldr rX, [\$tp, r0] ; Load X ... ldr rY, [\$tp, #Y(tpoff)] ; Load Y ; R_ARM_TLS_LE12(Y)</pre>
<pre data-bbox="183 591 383 629">literal pool</pre>	<pre data-bbox="414 591 1407 629">.Lt0 .word S(tpoff) ; R_ARM_TLS_LE32(X)</pre>

TLS-related relocations for Linux for Arm are described further in [\[AAELF32\]](#).

# 5 Reserved Names

For external symbols defined/required by the C++ ABI there are already agreed names – either the standard mangling of C++ names or names like `__cxa_acquire_guard`.

The ABI for the Arm Architecture also needs a space of global symbol names private to each compiler vendor – external names guaranteed not to clash with other vendors – and a C++ name space private to each vendor.

Many of these names have C or assembly language linkage, so we propose to reserve names of the form `__vendor-name_name`, for example:

```
__ARM_foo
__gnu_foobar
__cxa_foobaz
```

In each case, namespace `__vendor-name[vn]` is also reserved in C++, for example:

```
namespace __ARM { ... }           namespace __ARMv2 { ... }
namespace __gnuv1 { ... }         namespace __aeabi { ... }
```

We also reserve the corresponding upper case vendor name with a single leading underscore to use by the vendor for C macro names, for example:

```
#if _AEABI_... != 0
#if _ARM_... == 2
```

Prefix names themselves must not contain underscore ('\_') or dollar ('\$'). The following prefixes are registered.

## Registered Vendors

Name	Vendor
ADI	Analog Devices
acle	Reserved for use by Arm C Language Extensions.
aeabi	Reserved to the ABI for the Arm Architecture (EABI pseudo-vendor)
AnonXyz anonXyz	Reserved to private experiments by the Xyz vendor. Guaranteed not to clash with any registered vendor name.
ARM	Arm Ltd (Note: the company, not the processor).
cxa	C++ ABI pseudo-vendor
dig	Dignus, LLC
FSL	Freescale Semiconductor Inc.
GHS	Green Hills Systems
gnu	GNU compilers and tools (Free Software Foundation)
iar	IAR Systems
icc	ImageCraft Creations Inc ( <i>ImageCraft C Compiler</i> )

Name	Vendor
intel	Intel Corporation
ixs	Intel Xscale
llvm	The LLVM/Clang projects
PSI	PalmSource Inc.
RAL	Rowley Associates Ltd
SEGGER	SEGGER Microcontroller GmbH
somm	SOMNIUM Technologies Limited.
TASKING	Altium Ltd.
TI	TI Inc.
tls	Reserved for use in thread-local storage routines.
WRS	Wind River Systems.

To register a vendor prefix with Arm, please E-mail your request to [arm.eabi@arm.com](mailto:arm.eabi@arm.com).



# 6 Errata and Minor Addenda

This section details errors found in the ABI for the Arm Architecture after publication of version 2.0 and minor additions made since then.

## 6.1 DWARF for the Arm Architecture

### 6.1.1 Clarifications

(v2.01, r2.02) The ABI-v2.0 DWARF register numbering scheme for VFP registers (S0-S31 → 64-95) has been declared obsolescent. It will become obsolete in the next major release of the ABI for the Arm Architecture.

(B, r2.09) aadwarf32-section3-5: Clarify CIE descriptions of registers that are unused by intention of the user, for example as a consequence of the chosen procedure call standard.

### 6.1.2 Errors fixed

(v2.02, r2.04) aadwarf32-section3-3, suggested that DW\_AT\_endianness, coded as 0x5b, might be approved by the DWARF3.0 standardization committee. In fact, 0x5b was used for another purpose and DW\_AT\_endianity, coded as 0x65, has been approved. The parametric values of this attribute have also changed their names and encodings.

### 6.1.3 Additions and omissions fixed

(v2.01, r2.02) aadwarf32-section3-1-1, specifies how to describe the VFP-v3/Neon SIMD register file. There is a new range of DWARF register numbers allocated to D0-D31 and new schemes for describing Neon Q registers and VFP S registers. The new numbering should also be used for VFP-v2.

## 6.2 ELF for the Arm Architecture

### 6.2.1 Clarifications

(v1.02, r2.03) aael32-section4-2: Corrected the wording of the description of e\_entry.

(v1.03, r2.04) aael32-section4-2: Clarified that bit[0] of [e\_entry] controls the instruction set selection on entry.

(v1.02, r2.03) aael32-section4-5-4: Clarified the necessary restrictions on local symbol removal in relocatable files.

(v1.04, r2.05) aael32-section4-6-1-2: Clarified that 'Pa' is the adjusted address of the place being relocated, with the Thumb-bit stripped (defined as P & 0xFFFFFFF), for Thumb state LDR- and ADR-type relocations.

(v1.04, r2.05) aael32-section4-6-1-4: Clarified that R\_ARM\_LDR\_PC\_G0 applies equally to LDRB, STRB.

(v1.04, r2.05) aael32-section4-6-1-6: Added this section explicitly tabulating the relocations specific to 32-bit Thumb instructions.

(v1.05, r2.06) aael32-section4-1-1: Inserted the complete table of registered vendor names, now shared among AAELF, CLIBABI, and RTABI.

(vC, r2.07) aael32-section5-1, aael32-section5-3: Added small remarks to previously empty sections to remove any doubt that the sections might be accidentally empty.

(vC, r2.07) aael32-section4-6-1-4, subsection Call and Jump relocations: Listed R\_ARM\_PC24, R\_ARM\_CALL, R\_ARM\_JUMP24, R\_ARM\_THM\_CALL, R\_ARM\_THM\_JUMP24, and R\_ARM\_THM\_JUMP19 as the only relocations that might cause an intra procedure call veneer to be generated.

(vC, r2.07) aael32-section4-6-1-7: Clarified the definition of the R\_ARM\_V4BX relocation and use of the null symbol (index 0) by it.

(vC, r2.07) aelf32-section4-6-1-10: Added additional text to table 4-16 for R\_ARM\_TLS\_DTPMOD32 and R\_ARM\_TLS\_TPOFF32 clarifying the meaning of relocating with respect to the null symbol (index = 0).

(vD, r2.08) aelf32-section1-2: Updated references to the Arm ARM to refer to the latest version published on <http://infocenter.arm.com>.

(vD, r2.08) aelf32-section4-6-1-6: Referenced the text in aelf32-section4-6-1-4 (under the subheading Call and Jump relocations) that describes the conditions under which a relocation is permitted to generate an ip-corrupting intra-call or long jump veneer.

(vE, r2.09) aelf32-section4-6-1-6: Clarified/extended note on what the aelf32-section4-6-1-4 text deals with.

(vE, r2.09) aelf32-section4-6: Standardized instruction descriptions to use Arm ARM terminology.

(vE, r2.09) aelf32-section4-6-1-1: Clarified initial addend formulation for MOVW/MOVT and R\_ARM\_THM\_PC8.

(vE, r2.09) aelf32-section4-6-1-10: In aelf32-table4-16, clarified the wording for R\_ARM\_RELATIVE.

(vF, r2.10) aelf32-section4-6-1-2: Clarified relocation expression values are computed mod  $2^{32}$ .

## 6.2.2 Errors fixed

(v1.01, r2.01) aelf32-section4-3-2, aelf32-table4-4: The definition of SHT\_ARM\_ATTRIBUTES was given the value 0x70000002, already allocated to SHT\_ARM\_PREEMPTMAP (used by RVCT 2.2 and others). The correct value of SHT\_ARM\_ATTRIBUTES is 0x70000003.

(v1.04, r2.05) aelf32-section4-6-1-2: Corrected the relocation formulae for the R\_ARM\_ALU\_{PC|SB}\_GN\_NC relocations so that they uniformly include the obligation to set the T bit when this is required.

(v1.05, r2.06) aelf32-section4-6-1-2: Corrected the definition of Pa (introduced in r2.05) which had the wrong mask.

(v1.05, r2.06) aelf32-section4-6-1-9: Corrected the text following aelf32-table4-15, which misspelled R\_ARM\_TLS\_LE32 (relocation #108) and R\_ARM\_TLS\_LE12 (relocation #110).

(vB, r2.06) aelf32-section4-6-1-6: Corrected an error in aelf32-table4-13 where the instructions to which R\_ARM\_THM\_PC12 and R\_ARM\_THM\_ALU\_PREL\_11\_0 apply had been transposed.

(vE, r2.09) aelf32-section4-6-1-4: Changed the behaviour of jump relocations to unresolved weak references to be implementation-defined rather than undefined.

(vE, r2.09) aelf32-section4-6-1-6, aelf32-table4-13: Corrected Result Mask for R\_ARM\_THM\_PC12.

(vE, r2.09) aelf32-section5-2-1-1: Corrected off-by-one error in size of array.

(vF, r2.10) aelf32-section4-6-1-2: aelf32-table4-9: Renumbered R\_ARM\_IRELATIVE from 140 to 160 (the number agreed with stakeholders; publication as 140 was incorrect). aelf32-table4-11: Removed incorrect overflow check on R\_ARM\_MOVT\_ABS, R\_ARM\_MOVT\_PREL and R\_ARM\_MOVT\_BREL.

## 6.2.3 Additions and omissions fixed

(v1.01, r2.01) aelf32-section4-3-2, aelf32-table4-4: The definition of SHT\_ARM\_PREEMPTMAP was omitted. The correct value is 0x70000002.

(v1.03, r2.04) aelf32-section4-3-3-1, Merging of objects in sections with SHF\_MERGE: Rules governing SHF\_MERGE optimizations are needed to support inter-operation between toolchains (omitted from release 1.02 and earlier).

(v1.01, r2.01) aelf32-section4-3-4, aelf32-table4-5: The definition and explanation of .ARM.preemptmap were omitted.

(v1.03, r2.04) aelf32-section4-6-1-1, Addends and PC-bias compensation: Release 1.03 makes explicit the rules describing the required initial addends for REL-type relocations.

(v1.04, r2.05) aelf32-section4-6-1-2: Added additional relocations to support a new, experimental Linux TLS addressing model described in aelf32-section4-6-1-9, Relocations for thread-local storage.

(v1.02, r2.03) aelf32-section4-6-1-9: Added a definition of R\_ARM\_RELATIVE when S = 0; described the new, experimental, Linux TLS addressing model.

(v1.02, r2.03) aelf32-section5-2-1: Added a specification of architecture compatibility information for executable files.

(vC, r2.07) aelf32-section4-3-2: Added SHT\_ARM\_DEBUGOVERLAY and SHT\_ARM\_OVERLAYSECTION to aelf32-table4-4. These are new section types to support debugging overlaid programs.

(vC, r2.07) aelf32-section4-3-4: Added .ARM.debug\_overlay and .ARM.overlay\_table to aelf32-table4-5. These are new special section names to support debugging overlaid programs.

(vD, r2.08) aelf32-section4-6-1-5, aelf32-table4-12: extended the range of R\_ARM\_THM\_PC8 to ADR as well as LDR(literal) instructions.

(vD, r2.08) aelf32-section5-2-1: Updated and tidied the text and added aelf32-section5-2-1-1, as an informative proposal for recording executable file attributes.

(vE, r2.09) aelf32-section4-3: Added e\_flags EF\_ARM\_ABI\_FLOAT\_HARD and EF\_ARM\_ABI\_FLOAT\_SOFT to indicate floating point PCS conformance, and EF\_ARM\_GCCMASK as a mask for legacy bits.

(vE, r2.09) aelf32-section4-6-1-2, aelf32-section4-6-1-6, aelf32-section4-6-1-8: added R\_ARM\_THM\_GOT\_BREL12.

(vE, r2.09) aelf32-section4-6-1-2, aelf32-table4-9: Reserved relocation 140 for a specific future use.

(vE, r2.09) aelf32-section4-6-1-4, aelf32-table4-12: Added entries for MOVW and MOVT.

(vE, r2.09) aelf32-section4-6-1-5, aelf32-table4-13: Added Overflow column.

(vE, r2.09) aelf32-section4-6-1-6: Added aelf32-table4-15.

(vF, r2.10) aelf32-section4-6-1-2, aelf32-table4-9: Changed the subdivisions within the reserved/unallocated relocation space.

(vF, r2.10) aelf32-section4-6, aelf32-table4-9, aelf32-table4-13, aelf32-table4-15: Added R\_ARM\_THM\_ALU\_ABS\_Gn[\_NC] relocations.

(vF, r2.10) aelf32-section4-3-3, aelf32-table4-5: Added SHF\_ARM\_NOREAD processor specific section attribute flag.

## 6.3 Procedure Call Standard for the Arm Architecture

### 6.3.1 Clarifications

(v2.05, r2.04) Added aapcs32-section5-1, clarifying the roles of core registers and co-processor registers in the AAPCS.

(v2.03, r2.02) aapcs32-section5-5, clarified that a callee may overwrite an incoming parameter area on the stack.

(v2.03, r2.02) aapcs32-section5-1-1-1, described how VFP-v3 d16-d31 are used.

(v2.04, r2.04) aapcs32-section5-3-1-1, clarified when linking may insert intra-call veneers that may corrupt r12 and the condition flags.

(v2.01, r2.01) aapcs32-section7-1-3, following aapcs32-table5: Clarified that if a platform chooses that all container types should be word sized, the type of the container is int unless the upper bound of the enumerator exceeds 2147483647.

(vB, r2.07) aapcs32-section6-1-2-1: Simplified duplicated text and clarified that homogeneous aggregates of containerized vectors are limited to four members.

(vC, r2.07) aapcs32-section4-3-5: Minor clarifications and improvements to the terminology. Added a remark that source language access control does not affect the test for homogeneity.

(vC, r2.07) aapcs32-section6-1-2-3: Added a remark clarifying the requirement to 'back fill' unused coprocessor register candidates when passing floating-point parameters using the VFP variant of AAPCS.

(vD, r2.08) aapcs32-section7-1-3: Re-wrote the specification to better reflect the intentions for enumerated types in ABI-complying interfaces.

(vE, r2.09) aapcs32-appendix: Re-written to clarify requirements on Advanced SIMD types.

## 6.3.2 Errors fixed

(v2.03, r2.02) aapcs32-section7-1-7, retracted the requirement that the type of a plain bit-field be unsigned by default.

(vF, r2.10) aapcs32-appendixa-2, corrected the element counts of `poly16x4_t` and `poly16x8_t`.

## 6.3.3 Additions and omissions fixed

(v2.05, r2.05) aapcs32-section5-1-1-1, added in support of the Advanced SIMD Architecture.

(v2.05, r2.05) aapcs32-section5-1-2-1, extended in support of the Advanced SIMD Architecture.

(v2.05, r2.05) aapcs32-section5-4, extended in support of the Advanced SIMD Architecture.

(v2.05, r2.05) aapcs32-section6-1-1, added in support of the Advanced SIMD Architecture.

(v2.05, r2.05) aapcs32-section6-1-2-1 and aapcs32-section6-1-2-2, extended in support of the Advanced SIMD Architecture.

(v2.05, r2.05) aapcs32-appendixa, added in support of the Advanced SIMD Architecture.

(v2.06, r2.06) aapcs32-section4-1: Added half-precision floating point to the data type table.

(v2.06, r2.06) Added aapcs32-section4-1-1.

(v2.06, r2.06) aapcs32-section5-4, aapcs32-section6-1-2-1: Extended the rules to half-precision floating point.

(v2.06, r2.06) Added aapcs32-section6-4-4.

(v2.06, r2.06) aapcs32-section7-1-1: Added `__f16` (as an Arm extension) to aapcs32-table3.

(v2.06, r2.06) aapcs32-appendixa-2: Added `float16x4_t` to aapcs32-table7.

(vC, r2.07) aapcs32-section7-1-1: Specified in aapcs32-table3 that the only values of `_Bool/bool` are 0 and 1.

(vC, r2.07) aapcs32-section7-1-3: Specified container types for enumerated values larger than 32 bits.

(vC, r2.07) aapcs32-section7-1-4: Clarified that in C++ `__va_list` is in namespace `std`.

(vE, r2.09) aapcs32-section5-4: Clarified that memory passed for a function result may be modified at any point during the function call.

(vE, r2.09) aapcs32-section7-1-1: Changed the illustrative source name of the half-precision float type from `__f16` to `__fp16` to match [\[ACLE\]](#).

(vF, r2.10) aapcs32-appendixa-2, added `[u]int64x1_t`, `[u]int64x2_t`, `poly64x2_t`. aapcs32-section5-4, aapcs32-section5-5, aapcs32-section6-1-1, aapcs32-section6-1-2-1: Allow half-precision floating point types as function parameter and return types, by specifying how half-precision floating point types are passed and returned in registers.

(vF, r2.10) aapcs32-section4-3: Added definitions of member alignment and natural alignment.

(vF, r2.10) aapcs32-section5-5: Added parameter passing rules for over-aligned types.

## 6.4 Base Platform ABI for the Arm Architecture

### 6.4.1 Clarifications

(vC, r2.09) bpabi32-section2-6-2-4: Clarify `STB_WEAK` definitions are treated as equivalent to `STB_GLOBAL` when generating a Windows-style export table.

(vC, r2.09) bpabi32-section5-2: Give more details on export rules.

## 6.4.2 Errors fixed

(vB, r2.07) bpabi32-section2-4-3-7: Made a minor correction to the dllimport example (does not affect the specification).

(vB, r2.07) bpabi32-section3-6-2: (In the final bullet point of the section) Changed depth-first traversal to the intended breadth-first traversal.

## 6.5 C Library ABI for the Arm Architecture

### 6.5.1 Clarifications

(v2.01, r2.01) General: When a library function is added to a header (e.g. following additions to the C standard), any inline (e.g. macro-implemented) version should be hidden when `_AEABI_PORTABILITY_LEVEL != 0`.

(v2.01, r2.01) clibabi32-section5-3-1-1: Names of macros (`__A`, `__X`, etc) are for illustration only and are not mandated by the specification.

(v2.04, r2.06) clibabi32-section3-4: Inserted the complete table of registered vendor names, now shared among AAELF, CLIBABI, and RTABI.

(v2.04, r2.06) clibabi32-section4-2-4: Added clibabi32-section4-2-4-2, explaining why, when generating portable binary from C++, standard library functions should be used via extern "C" linkage.

(vC, r2.09) clibabi32-section5-2: Clarified the intended method of customizing `assert()`.

### 6.5.2 Errors fixed

(v2.01, r2.01) clibabi32-section5-9, clibabi32-table6: `struct lconv` should be `struct __aeabi_lconv`.

(v2.01, r2.01) clibabi32-section5-11, clibabi32-table10: The text "`((__aeabi_JMP_BUF_SIZE))`" at the end of the table is left over from a previous version and should be deleted.

(v2.02, r2.02) clibabi32-section5-3-1-1: The C99 `isblank()` function cannot be implemented as a macro within this framework because `__B` is required to exclude tab when used by the C89 function `isprint()` and to include it when used by `isblank()`. To fix this, we define `isblank()` out of line, but allow compilers to inline the obvious implementation that is excluded from being a macro because it evaluates its parameter twice.

(v2.03, r2.04) clibabi32-section5-12: Corrected misinformation suggesting that it might be possible to access 8-byte types using `LDRD/STRD` and `LDM/STM`.

(vC, r2.09) clibabi32-section5-11: Corrected calculation of minimum `jmp_buf` size (previously given as 24 double-words).

### 6.5.3 Additions and omissions fixed

(v2.01, r2.01) clibabi32-section4-1, clibabi32-table1: The C99 header `stdbool.h` is missing. There are no portability implications of providing it. A new §5.14, describes `stdbool.h`, and Table 19, Summary of conformance requirements when `_AEABI_PORTABILITY_LEVEL != 0` in §6 has a new entry for `stdbool.h`.

(v2.01, r2.01) clibabi32-section5-3-1: The same character translations and locale bindings should be used for the implementations of the `toxxxx` macros and functions as are used for the `isxxxx` macros and functions.

(vD, r2.10) clibabi32-section5-21: Permit `wint_t` to be unsigned int.

## 6.6 C++ ABI for the Arm Architecture

### 6.6.1 Clarifications

(v2.02, r2.03) cppabi32-section3-2-5-5: Clarify that entities defined in unnamed namespaces must not be exported (because unnamed namespaces do not have globally defined names).

(v2.03, r2.04) In cppabi32-section3-2-2-3, cppabi32-section3-2-2-5, cppabi32-section3-2-4-2: Clarified the use of `__aeabi_atexit` for registering atexit functions.

(v2.04, r2.06) In cppabi32-section1-2, Updated the base standard for C++ to ISO/IEC 14882:2003.

(vD, r2.09) cppabi32-section3-1: Clarified handling of empty classes.

(vE, r2.10) cppabi32-section3-1: Again clarified handling of empty classes.

### 6.6.2 Errors fixed

(v2.01, r2.01) cppabi32-section3-2-4: The global constructor vector section (`.init_array`) of ELF type `SHT_INITARRAY`, was erroneously specified to be read-only. The generic ELF specification requires these sections to have the `SHF_WRITE` flag set. The C++ ABI for the Arm Architecture requires producers to generate these sections as if they were read-only. (Some execution environments require `.init_array` sections to be read-only and linkers targeting these environments may drop the `SHF_WRITE` flag. Doing so must not cause run-time failures).

(vB, r2.07) In cppabi32-section3-1, removed the Arm-specified mangling of the 16-bit FP type name added in r2.06 (Dh has been specified by the generic C++ ABI). Noted the mangling of `std::va_list` now that [AAPCS32] affirms that `__va_list` is in namespace `std`.

(vC, r2.08) In cppabi32-section3-2-2-3: corrected typos in and the wording of the justification for defining `__aeabi_vec_delete3` but not `__aeabi_vec_delete2`.

(vC, r2.08) cppabi32-section3-2-2-3: In the definition of `__aeabi_vec_ctor_nocookie_nodtor`, corrected the order of size and count parameters to `__aeabi_vec_ctor_cookie_nodtor()`.

(vC, r2.08) In cppabi32-section3-2-5-5: corrected broken class export syntax and corrected comments about entities declared in unnamed namespaces and those derived from them.

### 6.6.3 Additions and omissions fixed

(v2.04, r2.06) In cppabi32-section3-1, specified the name mangling (GC++ABI § 5.1.5) for the 16-bit FP type added to [AAPCS32].

(v2.04, r2.06) In cppabi32-section3-2-6, added an Arm-specific rule for the ELF binding of guard variable symbols.

## 6.7 Exception Handling ABI for the Arm Architecture

### 6.7.1 Clarifications

(v2.04, r2.05) In paragraph 5 in ehabi32-section7-4, clarified that an unwinder must in general restore all the machine registers listed in the VRS.

(v2.02, r2.02) In ehabi32-section7-7, and ehabi32-section8-4-1, we clarify that `_Unwind_Complete` may overwrite UCB fields specific to the exception propagation that has just completed, and make clear the consequences of this. In ehabi32-section8-4-1 we are less prescriptive about which of `__cxa_allocate_exception` and `__cxa_throw` initialize the UCB and LEO fields.

(vB, r2.10) Throughout, use UAL instruction mnemonics where possible.

## 6.7.2 Errors fixed

(v2.02, r2.02) In ehabi32-section8-4-1, we have added the specification of `__cxa_get_exception_ptr`. Adding this function and having compilers generate calls to it, corrects a non-conformance with the C++ Standard. This function was recently added to the Itanium ABI, from which the Arm EHABI is derived. There are consequential changes to ehabi32-section8-2, bullet 1 to mandate that `barrier_cache.bitpattern[0]` is valid on catch handler entry and to ehabi32-section8-4-1 in the definition of `__cxa_begin_catch`, regarding initialisation of `barrier_cache.bitpattern[0]`. ehabi32-section8-5-4 adds an example of using `__cxa_get_exception_ptr` in a handler entry sequence.

Detailed rationale: The C++ Standard states that `std::uncaught_exception()` should return true after completing evaluation of the object to be thrown until completing the initialization of the exception-declaration in the matching catch handler. Thus for example:

```
try {
    // .....
    throw S();
    // .....
} catch (S s) {
    // .....
}
```

`uncaught_exception()` should return true between the end of the `S()` call and the end of the initialization of `s`. This has not been the case in several implementations, such as `g++` and `RVCT 2.2`, where `uncaught_exception()` was incorrectly false during any copy construction of `s`. Version 2.0 of the EHABI cannot handle this case correctly.

The original Itanium spec declared `void __cxa_begin_catch(void *exceptionObject)` and required it be called on entry to a catch handler, and in some other circumstances, to perform some housekeeping including updating the `uncaught_exception` count. The `void *exceptionObject` is really intended to be a pointer to (IA\_64 terminology) an `_Unwind_Exception` object, the language-independent sub-object within a propagated exception object. The handler code itself (as Arm understands it) was supposed to obtain a pointer to the matched C++ object by being passed such a pointer in a machine register, or by some other unspecified means. In EHABI terminology, `_Unwind_Exception` is `_Unwind_Control_Block`.

The `g++` community, HP, and Arm all changed `__cxa_begin_catch` to return the pointer to the matched C++ object, thus avoiding the need to save the register containing the matched object pointer over the call to `__cxa_begin_catch`. On return from `__cxa_begin_catch`, initialization of the catch parameter then proceeds. In other words, the code sequence is BL `__cxa_begin_catch`, initialize catch parameter if there is one.

Unfortunately, because `__cxa_begin_catch` has updated the `uncaught_exception` count, `uncaught_exception()` will return the wrong value if it is called during the initialization – as is possible if the catch parameter is a class type with non-trivial copy constructor. This is corrected by using the new routine, when the code sequence for catches with a parameter of class type with a non-trivial copy constructor becomes:

```
save r0 somewhere
BL __cxa_get_exception_ptr
initialize catch parameter
recover r0
BL __cxa_begin_catch
```

The wording change in ehabi32-section8-4-1 precludes the unlikely (and undesirable) possibility that handler code received the matched object pointer in some other place, then copied it to `barrier_cache.bitpattern[0]`, without overly constraining the implementation.

## 6.7.3 Additions and omissions fixed

(v2.02, r2.02) In ehabi32-section7-2, we have added `_Unwind_DeleteException` whose behaviour is described in ehabi32-section7-6. This function is present in the Itanium ABI and is a convenience function with no cost if not used by an implementation. Some vendors have requested Arm add this to remove a need for conditional compilation when targeting the Arm ABI verses other ABIs. The Arm definition is compatible with the Itanium requirements.

(v2.02, r2.02) In ehabi32-section7-5-2, ehabi32-section7-5-3, ehabi32-section7-5-4, and ehabi32-section9-3, we have added support for VFPv3. The Arm VFP v3 adds 16 double precision registers, D16-D31. It should be possible to restore these during unwinding but because the registers are intended for scratch use, this is expected to be uncommon. Specifically:

- In ehabi32-section7-5-2, we extend the register range for `_UVRSC_VFP/_UVRSD_DOUBLE` to 0-31.
- In ehabi32-section7-5-3, we extend the register range for `_UVRSC_VFP/_UVRSD_DOUBLE` to 0-31.
- In ehabi32-section7-5-4, we clarify that `_UVRSC_VFP/_UVRSD_DOUBLE` undoes the effect of one or more FSTMD instructions.
- In ehabi32-section9-3 we allocate unwinding instruction "11001000 ssscccc" to popping `D[16+ssss]-D[16+ssss+cccc]`, to permit recovery of a range of the new registers (including any range containing just one register).
- In ehabi32-section9-3 Update the remarks (split remark d and add extra words) to clarify the limitations of VFP unwinding instructions (No incompatible change)

## 6.8 Run-time ABI for the Arm Architecture

### 6.8.1 Clarifications

(v2.03, r2.06) rtabi32-section3-8: Inserted the complete table of registered vendor names, now shared among AAELF, CLIBABI, and RTABI.

(v2.03, r2.06) rtabi32-section4-3-1: Clarified the meaning of signed integer division when the result cannot be represented (`MIN_INT/-1`).

(vB, r2.07) rtabi32-section4-4-3-2: Add return value comments to each of the `__aeabi_*` helper functions.

(vC, r2.08) rtabi32-section3: added rtabi32-section3-10, to explain legacy, deprecated `__hardfp_` name mangling implemented by some compilers, notably `armcc`.

(vC, r2.08) rtabi32-section4-1-2: improved text specifying the registers maybe affected by a call to an FP helper.

### 6.8.2 Errors fixed and features withdrawn or deprecated

(v2.02, r2.05) rtabi32-section4-1-2, deprecated use of `fneg` and `dneg` because inlining these functions is always more efficient, even with the Thumb-1 ISA. Conforming library implementations must still provide implementations.

(vC, r2.08) rtabi32-section4-1-2: declared `fneg/dneg` obsolete (withdrawn).

### 6.8.3 Additions and omissions fixed

(v2.01, r2.02) In (new) rtabi32-section4-3-5, we define `__aeabi_read_tp()` that returns the thread pointer denoted by `$tp` in [Linux for Arm static \(initial exec\) model](#), of this specification.

(v2.01, r2.02) In rtabi32-section4-4-7, brought the list of `__cxa_` functions up to date and in line with [\[EHABI32\]](#).

(vC, r2.08) rtabi32-section4-1-2: added to rtabi32-table7, conversion helpers between VFPv3 half-precision memory format and float.

(vD, r2.09) rtabi32-section4-1-2: added to rtabi32-table7, conversion helpers from double to VFPv3 half-precision memory format.



## 6.9 ABI for the Arm Architecture - The Base Standard

### 6.9.1 Clarifications

(vB, r2.07) bsabi32-section3-9, A note about ar format: Fixed one minor typographical error and added a newly found Wikipedia reference to ar format.