

## MIPS Extensions to DWARF Version 2.0

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*Silicon Graphics Computer Systems*

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### 1. INTRODUCTION

This document describes MIPS extensions to the DWARF debugging information format. The extensions documented here are subject to change at any time.

### 2. 64 BIT DWARF

The DWARF2 spec has no provision for 64 bit offsets. SGI-IRIX/MIPS Elf64 objects contain DWARF 2 with all offsets (and addresses) as 64bit values. This non-standard extension was adopted in 1992. Nothing in the dwarf itself identifies the dwarf as 64bit. This extension 64bit-offset dwarf cannot be mixed with 32bit-offset dwarf in a single object or executable, and SGI-IRIX/MIPS compilers and tools do not mix the sizes.

In 2001 DWARF3 adopted a very different 64bit-offset format which can be mixed usefully with 32bit-offset DWARF2 or DWARF3. It is not very likely SGI-IRIX/MIPS compilers will switch to the now-standard DWARF3 64bit-offset scheme, but such a switch is theoretically possible and would be a good idea.

SGI-IRIX/MIPS Elf32 objects contain DWARF2 with all offsets (and addresses) 32 bits.

### 3. How much symbol information is emitted

The following standard DWARF V2 sections may be emitted:

1. Section `.debug_abbrev` contains abbreviations supporting the `.debug_info` section.
2. Section `.debug_info` contains Debug Information Entries (DIEs).
3. Section `.debug_frame` contains stack frame descriptions.
4. Section `.debug_line` contains line number information.
5. Section `.debug_aranges` contains address range descriptions.
6. Section `.debug_pubnames` contains names of global functions and data.

The following

are MIPS extensions. These were created to allow debuggers to know names without having to look at the `.debug_info` section.

7. Section `.debug_weaknames` is a MIPS extension containing `.debug_pubnames`-like entries describing weak symbols.
8. Section `.debug_funcnames` is a MIPS extension containing `.debug_pubnames`-like entries describing file-static functions (C static functions). The gcc extension of nested subprograms (like Pascal) adds non-global non-static functions. These should be treated like static functions and gcc should add such to this section so that IRIX `libexc(3C)` will work correctly. Similarly, Ada functions which are non-global should be here too so that `libexc(3C)` can work. Putting it another way, every function (other than inline code) belongs either in `.debug_pubnames` or in `.debug_funcnames` or else `libexc(3C)` cannot find the function name.
9. Section `.debug_varnames` is a MIPS extension containing `.debug_pubnames`-like entries describing file-static data symbols (C static variables).
10. Section `.debug_tynames` is a MIPS extension containing `.debug_pubnames`-like entries describing file-level types.

The following are not currently emitted.

11. Section `.debug_macro` Macro information is not currently emitted.
12. Section `.debug_loc` Location lists are not currently emitted.
13. Section `.debug_str` The string section is not currently emitted.

### 3.1 Overview of information emitted

We emit debug information in 3 flavors. We mention C here. The situation is essentially identical for `f77`, `f90`, and `C++`.

1. "default C" We emit line information and DIEs for each subprogram. But no local symbols and no type information. Frame information is output. The `DW_AT_producer` string has the optimization level: for example

"-O2". We put so much in the `DW_AT_producer` that the string is a significant user of space in `.debug_info` -- this is perhaps a poor use of space. When optimizing the IRIX `CC/cc` option `-DEBUG:optimize_space` eliminates such wasted space. Debuggers only currently use the lack of `-g` of `DW_AT_producer` as a hint as to how a 'step' command should be interpreted, and the rest of the string is not used for anything (unless a human looks at it for some reason), so if space-on-disk is an issue, it is quite appropriate to use `-DEBUG:optimize_space` and save disk space. Every function definition (not inline instances though) is mentioned in either `.debug_pubnames` or `.debug_funcnames`. This is crucial to allow `libexc(3C)` stack-traceback to work and show function names (for all languages).

2. "C with full symbols" All possible info is emitted. DW\_AT\_producer string has all options that might be of interest, which includes -D's, -U's, and the -g option. These options look like they came from the command line. We put so much in the DW\_AT\_producer that the string is a significant user of space in .debug\_info. this is perhaps a poor use of space. Debuggers only currently use the -g of DW\_AT\_producer as a hint as to how a 'step' command should be interpreted, and the rest of the string is not used for anything (unless a human looks at it for some reason). Every function definition (not inline instances though) is mentioned in either .debug\_pubnames or .debug\_funcnames. This is crucial to allow libexc(3C) stack-traceback to work and show function names (for all languages).
3. "Assembler (-g, non -g are the same)" Frame information is output. No type information is emitted, but DIEs are prepared for globals.

### 3.2 Detecting 'full symbols' (-g)

The debugger depends on the existence of the DW\_AT\_producer string to determine if the compilation unit has full symbols or not. It looks for -g or -g[123] and accepts these as full symbols but an absent -g or a present -g0 is taken to mean that only basic symbols are defined and there are no local symbols and no type information.

In various contexts the debugger will think the program is stripped or 'was not compiled with -g' unless the -g is in the DW\_AT\_producer string.

### 3.3 DWARF and strip(1)

The DWARF section ".debug\_frame" is marked SHF\_MIPS\_NOSTRIP and is not stripped by the strip(1) program.

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This is because the section is needed for doing stack back traces (essential for C++ and Ada exception handling).

All .debug\_\* sections are marked with elf type SHT\_MIPS\_DWARF. Applications needing to access the various DWARF sections must use the section name to discriminate between them.

### 3.4 Evaluating location expressions

When the debugger evaluates location expressions, it does so in 2 stages. In stage one it simply looks for the trivial location expressions and treats those as special cases.

If the location expression is not trivial, it enters stage two. In this case it uses a stack to evaluate the expression.

If the application is a 32-bit application, it does the operations on 32-bit values (address size values). Even though registers can be 64 bits in a 32-bit program all evaluations are done in 32-bit quantities, so an attempt to calculate a 32-bit quantity by taking the difference of 2 64-bit register values will not work. The notion is that the stack machine is, by the dwarf definition, working in address size units.

These values are then expanded to 64-bit values (addresses or offsets). This extension does not involve sign-extension.

If the application is a 64-bit application, then the stack values are all 64 bits and all operations are done on 64 bits.

### 3.4.1 The fbreg location op

Compilers shipped with IRIX 6.0 and 6.1 do not emit the fbreg location expression and never emit the DW\_AT\_frame\_base attribute that it depends on. However, this changes with release 6.2 and these are now emitted routinely.

## 4. Frame Information

### 4.1 Initial Instructions

The DWARF V2 spec provides for "initial instructions" in each CIE (page 61, section 6.4.1). However, it does not say whether there are default values for each column (register).

Rather than force every CIE to have a long list of bytes to initialize all 32 integer registers, we define that the default values of all registers (as returned by libdwarf in the frame interface) are 'same value'. This is a good choice for many non-register-windows implementations.

### 4.2 Augmentation string in debug\_frame

The augmentation string we use in shipped compilers (up thru irix6.2) is the empty string.

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IRIX6.2 and later has an augmentation string the empty string ("") or "z" or "mti v1" where the "v1" is a version number (version 1).

We do not believe that "mti v1" was emitted as the augmentation string in any shipped compiler.

#### 4.2.1 CIE processing based on augmentation string:

If the augmentation string begins with 'z', then it is followed immediately by a `unsigned_leb_128` number giving the code alignment factor. Next is a `signed_leb_128` number giving the data alignment factor. Next is a `unsigned byte` giving the number of the return address register. Next is an `unsigned_leb_128` number giving the length of the 'augmentation' fields (the length of augmentation bytes, not including the `unsigned_leb_128` length itself). As of release 6.2, the length of the CIE augmentation fields is 0. What this means is that it is possible to add new augmentations, z1, z2, etc and yet an old consumer to understand the entire CIE as it can bypass the augmentation it does not understand because the length of the augmentation fields is present. Presuming of course that all augmentation fields are simply additional information, not some 'changing of the meaning of an existing field'. Currently there is no CIE data in the augmentation for things beginning with 'z'.

If the augmentation string is "mti v1" or "" then it is followed immediately by a `unsigned_leb_128` number giving the code alignment factor. Next is a `signed_leb_128` number giving the data alignment factor. Next is a `unsigned byte` giving the number of the return address register.

If the augmentation string is something else, then the code alignment factor is assumed to be 4 and the data alignment factor is assumed to be -1 and the return address register is assumed to be 31. Arbitrarily. The library (libdwarf) assumes it does not understand the rest of the CIE.

## 4.2.2 FDE processing based on augmentation

If the CIE augmentation string for an fde begins with 'z' then the next FDE field after the address\_range field is an unsigned\_leb\_128 number giving the length of the 'augmentation' fields, and those fields follow immediately.

### 4.2.2.1 FDE augmentation fields

If the CIE augmentation string is "mti v1" or "" then the FDE is exactly as described in the Dwarf Document section 6.4.1.

Else, if the CIE augmentation string begins with "z" then the next field after the FDE augmentation length field is a Dwarf\_Sword size offset into

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exception tables. If the CIE augmentation string does not begin with "z" (and is neither "mti v1" nor "") the FDE augmentation fields are skipped (not understood). Note that libdwarf actually (as of MIPSpro7.3 and earlier) only tests that the initial character of the augmentation string is 'z', and ignores the rest of the string, if any. So in reality the test is for a `_prefix_` of 'z'.

If the CIE augmentation string neither starts with 'z' nor is "" nor is "mti v1" then libdwarf (incorrectly) assumes that the table defining instructions start next. Processing (in libdwarf) will be incorrect.

## 4.3 Stack Pointer recovery from debug\_frame

There is no identifiable means in DWARF2 to say that the stack register is recovered by any particular operation. A 'register rule' works if the caller's stack pointer was copied to another register. An 'offset(N)' rule works if the caller's stack pointer was stored on the stack. However if the stack pointer is some register value plus/minus some offset, there is no means to say this in an FDE. For MIPS/IRIX, the recovered stack pointer of the next frame up the stack (towards main()) is simply the CFA value of the current frame, and the CFA value is precisely a register (value of a register) or a register plus offset (value of a register plus offset). This is a software convention.

## 5. egcs dwarf extensions (egcs-1.1.2 extensions)

This and following egcs sections describe the extensions currently shown in egcs dwarf2. Note that egcs has chosen to adopt tag and attribute naming as if their choices were standard dwarf, not as if they were extensions. However, they are properly numbered as extensions.

### 5.1 DW\_TAG\_format\_label      0x4101

For FORTRAN 77, Fortran 90. Details of use not defined in egcs source, so unclear if used.

### 5.2 DW\_TAG\_function\_template      0x4102

For C++. Details of use not defined in egcs source, so unclear if used.

### **5.3 DW\_TAG\_class\_template      0x4103**

For C++. Details of use not defined in egcs source, so unclear if used.

### **5.4 DW\_AT\_sf\_names              0x2101**

Apparently only output in DWARF1, not DWARF2.

### **5.5 DW\_AT\_src\_info              0x2102**

Apparently only output in DWARF1, not DWARF2.

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### **5.6 DW\_AT\_mac\_info              0x2103**

Apparently only output in DWARF1, not DWARF2.

### **5.7 DW\_AT\_src\_coords          0x2104**

Apparently only output in DWARF1, not DWARF2.

### **5.8 DW\_AT\_body\_begin          0x2105**

Apparently only output in DWARF1, not DWARF2.

### **5.9 DW\_AT\_body\_end             0x2106**

Apparently only output in DWARF1, not DWARF2.

## **6. egcs .eh\_frame (non-sgi) (egcs-1.1.2 extensions)**

egcs-1.1.2 (and earlier egcs) emits by default a section named `.eh_frame` for ia32 (and possibly other platforms) which is nearly identical to `.debug_frame` in format and content. This section is used for helping handle C++ exceptions.

Because after linking there are sometimes zero-ed out bytes at the end of the `eh_frame` section, the reader code in `dwarf_frame.c` considers a zero `cie/fde` length as an indication that it is the end of the section.

### **6.1 CIE\_id 0**

The section is an `ALLOCATED` section in an executable, and is therefore mapped into memory at run time. The `CIE_pointer` (aka `CIE_id`, section 6.4.1 of the DWARF2 document) is the field that distinguishes a CIE from an FDE. The designers of the egcs `.eh_frame` section decided to make the `CIE_id` be 0 as the `CIE_pointer` definition is

the number of bytes from the `CIE_pointer` in the FDE back to the applicable CIE.

In a dwarf `.debug_frame` section, the `CIE_pointer` is the offset in `.debug_frame` of the CIE for this `fde`, and since an offset can be zero of some CIE, the `CIE_id` cannot be 0, but must be all 1 bits. Note that the dwarf2.0 spec does specify the value of `CIE_id` as `0xffffffff` (see section 7.23 of v2.0.0), though earlier versions of this extensions document incorrectly said it was not specified in the dwarf document.

## 6.2 augmentation eh

The augmentation string in each CIE is "eh" which, with its following NUL character, aligns the following word to a 32bit boundary. Following the augmentation string is a 32bit word with the address of the `__EXCEPTION_TABLE__`, part of the exception handling data for egcs.

## 6.3 DW\_CFA\_GNU\_window\_save 0x2d

This is effectively a flag for architectures with register windows, and tells the unwinder code that it must look to a previous frame for the correct register window set.

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As of this writing, egcs gcc/frame.c indicates this is for SPARC register windows.

## 6.4 DW\_CFA\_GNU\_args\_size 0x2e

DW\_CFA\_GNU\_args\_size has a single uleb128 argument which is the size, in bytes, of the function's stack at that point in the function.

## 6.5 `__EXCEPTION_TABLE__`

A series of 3 32bit word entries by default: 0 word: low pc address 1 word: high pc address 2 word: pointer to exception handler code The end of the table is signaled by 2 words of -1 (not 3 words!).

# 7. Interpretations of the DWARF V2 spec

## 7.1 template TAG spellings

The DWARF V2 spec spells two attributes in two ways. DW\_TAG\_template\_type\_param (listed in Figure 1, page 7) is spelled DW\_TAG\_template\_type\_parameter in the body of the document (section 3.3.7, page 28). We have adopted the spelling DW\_TAG\_template\_type\_param.

DW\_TAG\_template\_value\_param (listed in Figure 1, page 7) is spelled DW\_TAG\_template\_value\_parameter in the body of the document (section 3.3.7, page 28). We have adopted the spelling DW\_TAG\_template\_value\_parameter.

We recognize that the choices adopted are neither consistently the longer nor the shorter name. This inconsistency was an accident.

## 7.2 DW\_FORM\_ref\_addrconfusing

Section 7.5.4, Attribute Encodings, describes DW\_FORM\_ref\_addr. The description says the reference is the size of an address on the target architecture. This is surely a mistake, because on a 16bit-pointer-architecture it would mean that the reference could not exceed 16 bits, which makes only a limited amount of sense as the reference is from one part of the dwarf to another, and could (in theory) be \*on the disk\* and not limited to what fits in memory. Since MIPS is 32 bit pointers (at the smallest) the restriction is not a problem for MIPS/SGI. The 32bit pointer ABIs are limited to 32 bit section sizes anyway (as a result of implementation details). And the 64bit pointer ABIs currently have the same limit as a result of how the compilers and tools are built (this has not proven to be a limit in practice, so far).

This has been clarified in the DWARF3 spec and the IRIX use of DW\_FORM\_ref\_addr being an offset is

correct.

### **7.3 Section .debug\_macinfo in a debugger**

It seems quite difficult, in general, to

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tie specific text(code) addresses to points in the stream of macro information for a particular compilation unit. So it's been difficult to see how to design a consumer interface to libdwarf for macro information.

The best (simple to implement, easy for a debugger user to understand) candidate seems to be that the debugger asks for macros of a given name in a compilation unit, and the debugger responds with \*all\* the macros of that name.

#### **7.3.1 only a single choice exists**

If there is exactly one, that is usable in expressions, if the debugger is able to evaluate such.

#### **7.3.2 multiple macros with same name.**

If there are multiple macros with the same name in a compilation unit, the debugger (and the debugger user and the application programmer) have a problem: confusion is quite possible. If the macros are simple the debugger user can simply substitute by hand in an expression. If the macros are complicated hand substitution will be impractical, and the debugger will have to identify the choices and let the debugger user choose an interpretation.

### **7.4 Section 6.1.2 Lookup by address problem**

Each entry is a beginning-address followed by a length. And the distinguished entry 0,0 is used to denote the end of a range of entries.

This means that one must be careful not to emit a zero length, as in a .o (object file) the beginning address of a normal entry might be 0 (it is a section offset after all), and the resulting 0,0 would be taken as end-of-range, not as a valid entry. A dwarf dumper would have trouble with such data in an object file.

In an a.out or shared object (dynamic shared object, DSO) no text will be at address zero so in such this problem does not arise.

### **7.5 Section 5.10 Subrange Type Entries problem**

It is specified that DW\_AT\_upper\_bound (and lower bound) must be signed entries if there is no object type info to specify the bound type (Sec 5.10, end of section). One cannot tell (with some dwarf constant types) what the signedness is from the form itself (like DW\_FORM\_data1), so it is necessary to determine the object and type according to the rules in 5.10 and then if all that fails, the type is signed. It's a bit complicated and earlier versions of mips\_extensions incorrectly said signedness was not defined.

### **7.6 Section 5.5.6 Class Template Instantiations problem**

Lots of room for implementor to canonicalize template declarations. Ie various folks won't agree. This is not serious since a given compiler will be consistent with itself and debuggers will have to cope!

### **7.7 Section 2.4.3.4 # 11. operator spelling**

DW\_OP\_add should be DW\_OP\_plus (page 14) (this mistake just one place on the page).

### **7.8 No clear specification of C++ static funcs**

There is no clear way to tell if a C++ member function is a static member or a non-static member function. (dwarf2read.c in gdb 4.18, for example, has this observation)

### **7.9 Misspelling of DW\_AT\_const\_value**

Twice in appendix 1, DW\_AT\_const\_value is misspelled as DW\_AT\_constant\_value.

### **7.10 Mistake in Attribute Encodings**

Section 7.5.4, "Attribute Encodings" has a brief discussion of "constant" which says there are 6 forms of constants. It is incorrect in that it fails to mention (or count) the block forms, which are clearly allowed by section 4.1 "Data Object Entries" (see entry number 9 in the numbered list, on constants).

### **7.11 DW\_OP\_bregx**

The description of DW\_OP\_bregx in 2.4.3.2 (Register Based Addressing) is slightly misleading, in that it lists the offset first. As section 7.7.1 (Location Expression) makes clear, in the encoding the register number comes first.

## **8. MIPS attributes**

### **8.1 DW\_AT\_MIPS\_fde**

This extension to Dwarf appears only on subprogram TAGs and has as its value the offset, in the .debug\_frame section, of the fde which describes the frame of this function. It is an optimization of sorts to have this present.

### **8.2 DW\_CFA\_MIPS\_advance\_loc8 0x1d**

This obvious extension to dwarf line tables enables encoding of 8 byte advance\_loc values (for cases when such must be relocatable, and thus must be full length). Applicable only to 64-bit objects.

### **8.3 DW\_TAG\_MIPS\_loop 0x4081**

For future use. Not currently emitted. Places to be emitted and attributes that this might own not finalized.

### **8.4 DW\_AT\_MIPS\_loop\_begin 0x2002**

For future use. Not currently emitted. Attribute form and content not finalized.

### **8.5 DW\_AT\_MIPS\_tail\_loop\_begin 0x2003**

For future use. Not currently emitted. Attribute form and content not finalized.

## **8.6 DW\_AT\_MIPS\_epilog\_begin 0x2004**

For future use. Not currently emitted. Attribute form and content not finalized.

## **8.7 DW\_AT\_MIPS\_loop\_unroll\_factor 0x2005**

For future use. Not currently emitted.

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Attribute form and content not finalized.

## **8.8 DW\_AT\_MIPS\_software\_pipeline\_depth 0x2006**

For future use. Not currently emitted. Attribute form and content not finalized.

## **8.9 DW\_AT\_MIPS\_linkage\_name 0x2007**

The rules for mangling C++ names are not part of the C++ standard and are different for different versions of C++. With this extension, the compiler emits both the DW\_AT\_name for things with mangled names (recall that DW\_AT\_name is NOT the mangled form) and also emits DW\_AT\_MIPS\_linkage\_name whose value is the mangled name.

This makes looking for the mangled name in other linker information straightforward. It also is passed (by the debugger) to the libmangle routines to generate names to present to the debugger user.

## **8.10 DW\_AT\_MIPS\_stride 0x2008**

F90 allows assumed shape arguments and pointers to describe non-contiguous memory. A (runtime) descriptor contains address, bounds and stride information - rank and element size is known during compilation. The extent in each dimension is given by the bounds in a DW\_TAG\_subrange\_type, but the stride cannot be represented in conventional dwarf. DW\_AT\_MIPS\_stride was added as an attribute of a DW\_TAG\_subrange\_type to describe the location of the stride. Used in the MIPSpro 7.2 (7.2.1 etc) compilers.

If the stride is constant (ie: can be inferred from the type in the usual manner) DW\_AT\_MIPS\_stride is absent.

If DW\_AT\_MIPS\_stride is present, the attribute contains a reference to a DIE which describes the location holding the stride, and the DW\_AT\_stride\_size field of DW\_TAG\_array\_type is ignored if present. The value of the stride is the number of 4 byte words between elements along that axis.

This applies to

- a) Intrinsic types whose size is greater or equal to 4bytes ie: real\*4,integer\*8 complex etc, but not character types.
- b) Derived types (ie: structs) of any size, unless all components are of type character.

## 8.11 DW\_AT\_MIPS\_abstract\_name 0x2009

This attribute only appears in a DA\_TAG\_inlined\_subroutine DIE. The value of this attribute is a string. When IPA inlines a routine and the abstract origin is in another compilation unit, there is a problem with putting in a reference, since the ordering and timing of the

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creation of references is unpredictable with reference to the DIE and compilation unit the reference refers to.

Since there may be NO ordering of the compilation units that allows a correct reference to be done without some kind of patching, and since even getting the information from one place to another is a problem, the compiler simply passes the problem on to the debugger.

The debugger must match the DW\_AT\_MIPS\_abstract\_name in the concrete inlined instance DIE with the DW\_AT\_MIPS\_abstract\_name in the abstract inlined subroutine DIE.

A dwarf-consumer-centric view of this and other inline issues could be expressed as follows:

If DW\_TAG\_subprogram

If has DW\_AT\_inline is abstract instance root

If has DW\_AT\_abstract\_origin, is out-of-line instance of function (need abstract origin for some data)

(abstract root in same CU (conceptually anywhere a ref can reach, but reaching outside of CU is

a problem for ipa: see DW\_AT\_MIPS\_abstract\_name))

If has DW\_AT\_MIPS\_abstract\_name is abstract instance root( must have DW\_AT\_inline) and this name is used to match with the abstract root

If DW\_TAG\_inline\_subroutine

Is concrete inlined subprogram instance.

If has DW\_AT\_abstract\_origin, it is a CU-local inline.

If it has DW\_AT\_MIPS\_abstract\_name it is an inline whose abstract root is in another file (CU).

## 8.12 DW\_AT\_MIPS\_clone\_origin 0x200a

This attribute appears only in a cloned subroutine. The procedure is cloned from the same compilation unit. The value of this attribute is a reference to the original routine in this compilation unit.

The 'original' routine means the routine which has all the original code. The cloned routines will always have been 'specialized' by IPA. A routine with DW\_AT\_MIPS\_clone\_origin will also have the DW\_CC\_nocall value of the DW\_AT\_calling\_convention attribute.

## 8.13 DW\_AT\_MIPS\_has\_inlines 0x200b

This attribute may appear in a DW\_TAG\_subprogram DIE. If present and it has the value True, then the subprogram has inlined functions somewhere in the body.

By default, at startup, the debugger may not look for inlined functions in scopes inside the outer function.

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This is a hint to the debugger to look for the inlined functions so the debugger can set breakpoints on these in case the user requests 'stop in foo' and foo is inlined.

#### **8.14 DW\_AT\_MIPS\_stride\_byte 0x200c**

Created for f90 pointer and assumed shape arrays. Used in the MIPSpro 7.2 (7.2.1 etc) compilers. A variant of DW\_AT\_MIPS\_stride. This stride is interpreted as a byte count. Used for integer\*1 and character arrays and arrays of derived type whose components are all character.

#### **8.15 DW\_AT\_MIPS\_stride\_elem 0x200d**

Created for f90 pointer and assumed shape arrays. Used in the MIPSpro 7.2 (7.2.1 etc) compilers. A variant of DW\_AT\_MIPS\_stride. This stride is interpreted as a byte-pair (2 byte) count. Used for integer\*2 arrays.

#### **8.16 DW\_AT\_MIPS\_ptr\_dopetype 0x200e**

See following.

#### **8.17 DW\_AT\_MIPS\_allocatable\_dopetype 0x200f**

See following.

#### **8.18 DW\_AT\_MIPS\_assumed\_shape\_dopetype 0x2010**

DW\_AT\_MIPS\_assumed\_shape\_dopetype, DW\_AT\_MIPS\_allocatable\_dopetype, and DW\_AT\_MIPS\_ptr\_dopetype have an attribute value which is a reference to a Fortran 90 Dope Vector. These attributes are introduced in MIPSpro7.3. They only apply to f90 arrays (where they are needed to describe arrays never properly described before in debug information). C, C++, f77, and most f90 arrays continue to be described in standard dwarf.

The distinction between these three attributes is the f90 syntax distinction: keywords 'pointer' and 'allocatable' with the absence of these keywords on an assumed shape array being the third case.

A "Dope Vector" is a struct (C struct) which describes a dynamically-allocatable array. In objects with full debugging the C struct will be in the dwarf information (of the f90 object, represented like C). A debugger will use the link to find the main struct DopeVector and will use that information to decode the dope vector. At the outer allocatable/assumed-shape/pointer the DW\_AT\_location points at the dope vector (so debugger calculations use that as a base).

### **8.19 Overview of debugger use of dope vectors**

Fundamentally, we build two distinct representations of the arrays and pointers. One, in dwarf, represents the statically-representable information (the types and variable/type-names, without type size information). The other, using dope vectors in memory, represents the run-time data of sizes. A debugger must process the two representations

in parallel (and merge them) to deal with user expressions in a debugger.

### 8.20 Example f90 code for use in explanation

[Note We want dwarf output with \*exactly\* this little (arbitrary) example. Not yet available. end Note]  
Consider the following code.

```

type array_ptr
  real :: myvar
  real, dimension (:), pointer :: ap
end type array_ptr

type (array_ptr), allocatable, dimension (:) :: arrays

allocate (arrays(20))
do i = 1,20
  allocate (arrays(i)%ap(i))
end do

```

arrays is an allocatable array (1 dimension) whose size is not known at compile time (it has a Dope Vector). At run time, the allocate statement creates 20 array\_ptr dope vectors and marks the base arrays dope vector as allocated. The myvar variable is just there to add complexity to the example :-)

- In the loop, arrays(1)%ap(1) is allocated as a single element array of reals.
- In the loop, arrays(2)%ap(2) is allocated as an array of two reals.
- In the loop, arrays(20)%ap(20) is allocated as an array of twenty reals.

### 8.21 the problem with standard dwarf and this example

In dwarf, there is no way to find the array bounds of arrays(3)%ap, for example, (which are 1:3 in f90 syntax) since any location expression in an ap array lower bound attribute cannot involve the 3 (the 3 is known at debug time and does not appear in the running binary, so no way for the location expression to get to it). And of course the 3 must actually index across the array of dope vectors in 'arrays' in our implementation, but that is less of a problem than the problem with the '3'.

Plus dwarf has no way to find the 'allocated' flag in the dope vector (so the debugger can know when the allocate is done for a particular arrays(j)%ap).

Consequently, the calculation of array bounds and indices for these dynamically created f90 arrays

is now pushed of into the debugger, which must know the field names and usages of the dope vector C structure and use the field offsets etc to find data arrays. C, C++, f77, and most f90 arrays continue to be described in standard dwarf. At the outer allocatable/assumed-shape/pointer the DW\_AT\_location points at

the dope vector (so debugger calculations use that as a base).

It would have been nice to design a dwarf extension to handle the above problems, but the methods considered to date were not any more consistent with standard dwarf than this dope vector centric approach: essentially just as much work in the debugger appeared necessary either way. A better (more dwarf-ish) design would be welcome information.

## 8.22 A simplified sketch of the dwarf information

[Note: Needs to be written. end Note]

## 8.23 A simplified sketch of the dope vector information

[Note: This one is simplified. Details left out that should be here. Amplify. end Note] This is an overly simplified version of a dope vector, presented as an initial hint. Full details presented later.

```
struct simplified{
  void *base; // pointer to the data this describes
  long el_len;
  int  assoc:1
  int  ptr_alloc:1
  int  num_dims:3;
  struct dims_s {
    long lb;
    long ext;
    long str_m;
  } dims[7];
};
Only 'num_dims' elements of dims[] are actually used.
```

## 8.24 The dwarf information

Here is dwarf information from the compiler for the example above, as printed by dwarfdump(1)

[Note:

The following may not be the test.

Having field names with '.' in the name is not such a good idea, as it conflicts with the

use of '.' in dbx extended naming.

Something else, like \_\$, would be much easier to work with in dbx (customers won't care about this, for the most part, but folks working on dbx will, and in those rare circumstances when a customer cares, the '.' will be a real problem in dbx.).

Note that to print something about .base., in dbx one would have to do

```
whatis '.base.'
```

where that is the grave accent, or back-quote I am using.

With extended naming one do

```
whatis '.dope.'.base.'
```

which is hard to type and hard to read.

end Note]

```
<2><x 388> DW_TAG_array_type
    DW_AT_name      .base.
    DW_AT_type      <815>
    DW_AT_declaration yes(1)
<3><x 401> DW_TAG_subrange_type
    DW_AT_lower_bound 0
    DW_AT_upper_bound 0
<2><x 405> DW_TAG_pointer_type
    DW_AT_type      <388>
    DW_AT_byte_size 4
    DW_AT_address_class 0
<2><x 412> DW_TAG_structure_type
    DW_AT_name      .flds.
    DW_AT_byte_size 28
<3><x 421> DW_TAG_member
    DW_AT_name      el_len
    DW_AT_type      <815>
    DW_AT_data_member_location DW_OP_consts 0
<3><x 436> DW_TAG_member
    DW_AT_name      assoc
    DW_AT_type      <841>
    DW_AT_byte_size 0
    DW_AT_bit_offset 0
    DW_AT_bit_size 1
    DW_AT_data_member_location DW_OP_consts 4
<3><x 453> DW_TAG_member
    DW_AT_name      ptr_alloc
    DW_AT_type      <841>
    DW_AT_byte_size 0
    DW_AT_bit_offset 1
    DW_AT_bit_size 1
    DW_AT_data_member_location DW_OP_consts 4
<3><x 474> DW_TAG_member
    DW_AT_name      p_or_a
    DW_AT_type      <841>
    DW_AT_byte_size 0
    DW_AT_bit_offset 2
    DW_AT_bit_size 2
    DW_AT_data_member_location DW_OP_consts 4
<3><x 492> DW_TAG_member
```

```
DW_AT_name      a_contig
DW_AT_type      <841>
DW_AT_byte_size 0
DW_AT_bit_offset 4
DW_AT_bit_size  1
DW_AT_data_member_location DW_OP_consts 4
<3><x 532> DW_TAG_member
  DW_AT_name      num_dims
  DW_AT_type      <841>
  DW_AT_byte_size 0
  DW_AT_bit_offset 29
  DW_AT_bit_size  3
  DW_AT_data_member_location DW_OP_consts 8
<3><x 572> DW_TAG_member
  DW_AT_name      type_code
  DW_AT_type      <841>
  DW_AT_byte_size 0
  DW_AT_bit_offset 0
  DW_AT_bit_size  32
  DW_AT_data_member_location DW_OP_consts 16
<3><x 593> DW_TAG_member
  DW_AT_name      orig_base
  DW_AT_type      <841>
  DW_AT_data_member_location DW_OP_consts 20
<3><x 611> DW_TAG_member
  DW_AT_name      orig_size
  DW_AT_type      <815>
  DW_AT_data_member_location DW_OP_consts 24
<2><x 630> DW_TAG_structure_type
  DW_AT_name      .dope_bnd.
  DW_AT_byte_size 12
<3><x 643> DW_TAG_member
  DW_AT_name      lb
  DW_AT_type      <815>
  DW_AT_data_member_location DW_OP_consts 0
<3><x 654> DW_TAG_member
  DW_AT_name      ext
  DW_AT_type      <815>
  DW_AT_data_member_location DW_OP_consts 4
<3><x 666> DW_TAG_member
  DW_AT_name      str_m
  DW_AT_type      <815>
  DW_AT_data_member_location DW_OP_consts 8
<2><x 681> DW_TAG_array_type
  DW_AT_name      .dims.
  DW_AT_type      <630>
  DW_AT_declaration yes(1)
<3><x 694> DW_TAG_subrange_type
  DW_AT_lower_bound 0
  DW_AT_upper_bound 0
<2><x 698> DW_TAG_structure_type
```

```
DW_AT_name      .dope.  
DW_AT_byte_size 44  
<3>< 707> DW_TAG_member  
DW_AT_name      base  
DW_AT_type      <405>
```

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```
          DW_AT_data_member_location DW_OP_consts 0  
<3>< 720> DW_TAG_member  
          DW_AT_name      .flds  
          DW_AT_type      <412>  
          DW_AT_data_member_location DW_OP_consts 4  
<3>< 734> DW_TAG_member  
          DW_AT_name      .dims.  
          DW_AT_type      <681>  
          DW_AT_data_member_location DW_OP_consts 32  
<2>< 750> DW_TAG_variable  
          DW_AT_type      <815>  
          DW_AT_location  DW_OP_fbreg -32  
          DW_AT_artificial yes(1)  
<2>< 759> DW_TAG_variable  
          DW_AT_type      <815>  
          DW_AT_location  DW_OP_fbreg -28  
          DW_AT_artificial yes(1)  
<2>< 768> DW_TAG_variable  
          DW_AT_type      <815>  
          DW_AT_location  DW_OP_fbreg -24  
          DW_AT_artificial yes(1)  
<2>< 777> DW_TAG_array_type  
          DW_AT_type      <815>  
          DW_AT_declaration yes(1)  
<3>< 783> DW_TAG_subrange_type  
          DW_AT_lower_bound <750>  
          DW_AT_count      <759>  
          DW_AT_MIPS_stride <768>  
<2>< 797> DW_TAG_variable  
          DW_AT_decl_file  1  
          DW_AT_decl_line  1  
          DW_AT_name      ARRAY  
          DW_AT_type      <698>  
          DW_AT_location  DW_OP_fbreg -64 DW_OP_deref  
<1>< 815> DW_TAG_base_type  
          DW_AT_name      INTEGER_4  
          DW_AT_encoding  DW_ATE_signed  
          DW_AT_byte_size  4  
<1>< 828> DW_TAG_base_type
```

```

        DW_AT_name           INTEGER_8
        DW_AT_encoding       DW_ATE_signed
        DW_AT_byte_size     8
<1><< 841>   DW_TAG_base_type
        DW_AT_name           INTEGER*4
        DW_AT_encoding       DW_ATE_unsigned
        DW_AT_byte_size     4
<1><< 854>   DW_TAG_base_type
        DW_AT_name           INTEGER*8
        DW_AT_encoding       DW_ATE_unsigned
        DW_AT_byte_size     8

```

### 8.25 The dope vector structure details

A dope vector is the following C struct, "dopevec.h". Not all the fields are of use to a debugger. It may be that not all fields will show up

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in the f90 dwarf (since not all are of interest to debuggers).

[Note:

Need details on the use of each field.

And need to know which are really 32 bits and which are 32 or 64.

end Note]

The following

struct

is a representation of all the dope vector fields.

It suppresses irrelevant detail and may not exactly match the layout in memory (a debugger must examine the dwarf to find the fields, not compile this structure into the debugger!).

```

struct .dope. {
    void *base; // pointer to data
    struct .flds. {
        long el_len; // length of element in bytes?
        unsigned int assoc:1; //means?
        unsigned int ptr_alloc:1; //means?
        unsigned int p_or_a:2; //means?
        unsigned int a_contig:1; // means?
        unsigned int num_dims: 3; // 0 thru 7
        unsigned int type_code:32; //values?
        unsigned int orig_base; //void *? means?
        long orig_size; // means?
    } .flds;

```

struct .dope\_bnd. {

```
long lb ; // lower bound
long ext ; // means?
long str_m; // means?
} .dims[7];
}
```

## 8.26 DW\_AT\_MIPS\_assumed\_size 0x2011

This flag was invented to deal with f90 arrays. For example:

```
pointer (rptr, axx(1))
pointer (iptr, ita(*))
rptr = malloc (100*8)
iptr = malloc (100*4)
```

This flag attribute has the value 'yes' (true, on) if and only if the size is unbounded, as iptr is. Both may show an explicit upper bound of 1 in the dwarf, but this flag notifies the debugger that there is explicitly no user-provided size.

So if a user asks for a printout of the rptr allocated array, the default will be of a single entry (as

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there is a user slice bound in the source). In contrast, there is no explicit upper bound on the iptr (ita) array so the default slice will use the current bound (a value calculated from the malloc size, see the dope vector).

Given explicit requests, more of rptr(axx) can be shown than the default.

## 9. Line information and Source Position

DWARF does not define the meaning of the term 'source statement'. Nor does it define any way to find the first user-written executable code in a function.

It does define that a source statement has a file name, a line number, and a column position (see Sec 6.2, Line Number Information of the Dwarf Version 2 document). We will call those 3 source coordinates a 'source position' in this document. We'll try not to accidentally call the source position a 'line number' since that is ambiguous as to what it means.

### 9.1 Definition of Statement

A function prolog is a statement.

A C, C++, Pascal, or Fortran statement is a statement.

Each initialized local variable in C,C++ is a statement in that its initialization generates a source position. This means that

```
x =3, y=4; is two statements.
```

For C, C++: The 3 parts a,b,c in for(a;b;c) {d;} are individual statements. The condition portion of a while() and do {} while() is a statement. (of course d; can be any number of statements)

For Fortran, the controlling expression of a DO loop is a statement. Is a 'continue' statement in Fortran a DWARF statement?

Each function return, whether user coded or generated by the compiler, is a statement. This is so one can step over (in a debugger) the final user-coded statement (exclusive of the return statement if any) in a function while not leaving the function scope.

## 9.2 Finding The First User Code in a Function

Consider:

```
int func(int a)
{
    /* source position 1 */
    float b = a; /* source position 2 */
    int x;
```

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```
    x = b + 2; /* source position 3 */
} /* source position 4 */
```

The DIE for a function gives the address range of the function, including function prolog(s) and epilog(s)

Since there is no scope block for the outer user scope of a function (and thus no beginning address range for the outer user scope: the DWARF committee explicitly rejected the idea of having a user scope block) it is necessary to use the source position information to find the first user-executable statement.

This means that the user code for a function must be presumed to begin at the code location of the second source position in the function address range.

If a function has exactly one source position, the function presumably consists solely of a return.

If a function has exactly two source positions, the function may consist of a function prolog and a return or a single user statement and a return (there may be no prolog code needed in a leaf function). In this case, there is no way to be sure which is the first source position of user code, so the rule is to presume that the first address is user code.

If a function consists of 3 or more source positions, one should assume that the first source position is function prolog and the second is the first user executable code.

## 9.3 Using debug\_frame Information to find first user statement

In addition to the line information, the debug\_frame information can be useful in determining the first user source line.

Given that a function has more than 1 source position, Find the code location of the second source position, then examine the debug\_frame information to determine if the Canonical Frame Address (cfa) is updated before the second source position code location. If the cfa is updated, then one can be pretty sure that the

code for the first source position is function prolog code.

Similarly, if the cfa is restored in the code for a source position, the source position is likely to represent a function exit block.

## 9.4 Debugger Use Of Source Position

Command line debuggers, such as dbx and gdb, will ordinarily want to consider multiple statements on one line to be a single statement: doing otherwise is distressing to users since it causes a 'step' command to appear to have no effect.

An exception for command line debuggers is in determining the

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first user statement: as detailed above, there one wants to consider the full source position and will want to consider the function return a separate statement. It is difficult to make the function return a separate statement 'step' reliably however if a function is coded all on one line or if the last line of user code before the return is on the same line as the return.

A graphical debugger has none of these problems if it simply highlights the portion of the line being executed. In that case, stepping will appear natural even stepping within a line.

## 10. Known Bugs

Up through at least MIPSpro7.2.1 the compiler has been emitting form DW\_FORM\_DATA1,2, or 4 for DW\_AT\_const\_value in DW\_TAG\_enumerator. And dwarfdump and debuggers have read this with dwarf\_formudata() or form\_sdata() and gotten some values incorrect. For example, a value of 128 was printed by debuggers as a negative value. Since dwarfdump and the compilers were not written to use the value the same way, their output differed. For negative enumerator values the compiler has been emitting 32bit values in a DW\_FORM\_DATA4. The compiler should probably be emitting a DW\_FORM\_sdata for enumerator values. And consumers of enumerator values should then call form\_sdata(). However, right now, debuggers should call form\_udata() and only if it fails, call form\_sdata(). Anything else will break backward compatibility with the objects produced earlier.



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# **MIPS Extensions to DWARF Version 2.0**

*Silicon Graphics Computer Systems*

## *ABSTRACT*

This document describes the MIPS/Silicon Graphics extensions to the "DWARF Information Format" (version 2.0.0 dated July 27, 1993). DWARF3 draft 8 (or draft 9) is out as of 2005, and is mentioned below where applicable. MIPS/IRIX compilers emit DWARF2 (with extensions).

Rather than alter the base documents to describe the extensions we provide this separate document.

The extensions documented here are subject to change.

It also describes known bugs resulting in incorrect dwarf usage.

rev 1.18, 31 March 2005



