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About This Manual

The TMS320C6000 Optimizing Compiler User's Guide explains how to use these compiler tools:

- Compiler
- Assembly optimizer
- Library build utility
- C++ name demangler

The compiler accepts C and C++ code conforming to the International Organization for Standardization (ISO) standards for these languages. The compiler supports the 1989 version of the C language and the 1998 version of the C++ language.

This user's guide discusses the characteristics of the C/C++ compiler. It assumes that you already know how to write C/C++ programs. The C Programming Language (second edition), by Brian W. Kernighan and Dennis M. Ritchie, describes C based on the ISO C standard. You can use the Kernighan and Ritchie (hereafter referred to as K&R) book as a supplement to this manual. References to K&R C (as opposed to ISO C) in this manual refer to the C language as defined in the first edition of Kernighan and Ritchie's The C Programming Language.

Notational Conventions

This document uses the following conventions:

- Program listings, program examples, and interactive displays are shown in a special typeface. Interactive displays use a bold version of the special typeface to distinguish commands that you enter from items that the system displays (such as prompts, command output, error messages, etc.). Here is a sample of C code:

```
#include <stdio.h>
main()
{   printf("hello, cruel world\n");
}
```

- In syntax descriptions, the instruction, command, or directive is in a bold typeface and parameters are in an italic typeface. Portions of a syntax that are in bold should be entered as shown; portions of a syntax that are in italics describe the type of information that should be entered.

- Square brackets ([ and ]) identify an optional parameter. If you use an optional parameter, you specify the information within the brackets. Unless the square brackets are in the bold typeface, do not enter the brackets themselves. The following is an example of a command that has an optional parameter:

```
cl6x [options] [filenames] [--run_linker [link_options] [object files]]
```

- Braces ({ and }) indicate that you must choose one of the parameters within the braces; you do not enter the braces themselves. This is an example of a command with braces that are not included in the actual syntax but indicate that you must specify either the --rom_model or --ram_model option:

```
cl6x --run_linker  {--rom_model | --ram_model} filenames [--output_file= name.out]
    --library= libraryname
```
In assembler syntax statements, column 1 is reserved for the first character of a label or symbol. If the label or symbol is optional, it is usually not shown. If it is a required parameter, it is shown starting against the left margin of the box, as in the example below. No instruction, command, directive, or parameter, other than a symbol or label, can begin in column 1.

```
symbol .usect "section name", size in bytes[, alignment]
```

- Some directives can have a varying number of parameters. For example, the .byte directive. This syntax is shown as [,..., parameter].
- The TMS320C6200™ core is referred to as C6200. The TMS320C6400 core is referred to as C6400. The TMS320C6700 core is referred to as C6700. TMS320C6000 and C6000 can refer to any of C6200, C6400, C6400+, C6700, C6700+, C6740, or C6600.

Related Documentation

You can use the following books to supplement this user's guide:

- **ANSI X3.159-1989, Programming Language - C (Alternate version of the 1989 C Standard)**, American National Standards Institute
- **Programming in C**, Steve G. Kochan, Hayden Book Company
You can use the following books to supplement this user's guide:

**SPRAAB5 — The Impact of DWARF on TI Object Files.** Describes the Texas Instruments extensions to the DWARF specification.

**SPRB90 — TMS320C6000 EABI Migration Guide Application Report.** Describes the changes which must be made to existing COFF ABI libraries and applications to add support for the new EABI.

**SPRU186 — TMS320C6000 Assembly Language Tools User's Guide.** Describes the assembly language tools (assembler, linker, and other tools used to develop assembly language code), assembler directives, macros, common object file format, and symbolic debugging directives for the TMS320C6000 platform of devices (including the C64x+ and C67x+ generations).

**SPRU190 — TMS320C6000 DSP Peripherals Overview Reference Guide.** Provides an overview and briefly describes the peripherals available on the TMS320C6000 family of digital signal processors (DSPs).

**SPRU198 — TMS320C6000 Programmer's Guide.** Reference for programming the TMS320C6000 digital signal processors (DSPs). Before you use this manual, you should install your code generation and debugging tools. Includes a brief description of the C6000 DSP architecture and code development flow, includes C code examples and discusses optimization methods for the C code, describes the structure of assembly code and includes examples and discusses optimizations for the assembly code, and describes programming considerations for the C64x DSP.

**SPRU197 — TMS320C6000 Technical Brief.** Provides an introduction to the TMS320C62x and TMS320C67x digital signal processors (DSPs) of the TMS320C6000 DSP family. Describes the CPU architecture, peripherals, development tools and third-party support for the C62x and C67x DSPs.

**SPRU423 — TMS320 DSP/BIOS User's Guide.** DSP/BIOS gives developers of mainstream applications on Texas Instruments TMS320 digital signal processors (DSPs) the ability to develop embedded real-time software. DSP/BIOS provides a small firmware real-time library and easy-to-use tools for real-time tracing and analysis.

**SPRU731 — TMS320C62x DSP CPU and Instruction Set Reference Guide.** Describes the CPU architecture, pipeline, instruction set, and interrupts for the TMS320C62x digital signal processors (DSPs) of the TMS320C6000 DSP family. The C62x DSP generation comprises fixed-point devices in the C6000 DSP platform.

**SPRU732 — TMS320C64x/C64x+ DSP CPU and Instruction Set Reference Guide.** Describes the CPU architecture, pipeline, instruction set, and interrupts for the TMS320C64x and TMS320C64x+ digital signal processors (DSPs) of the TMS320C6000 DSP family. The C64x/C64x+ DSP generation comprises fixed-point devices in the C6000 DSP platform. The C64x+ DSP is an enhancement of the C64x DSP with added functionality and an expanded instruction set.

**SPRU733 — TMS320C67x/C67x+ DSP CPU and Instruction Set Reference Guide.** Describes the CPU architecture, pipeline, instruction set, and interrupts for the TMS320C67x and TMS320C67x+ digital signal processors (DSPs) of the TMS320C6000 DSP platform. The C67x/C67x+ DSP generation comprises floating-point devices in the C6000 DSP platform. The C67x+ DSP is an enhancement of the C67x DSP with added functionality and an expanded instruction set.

**SPRUGH7 — TMS320C66x CPU and Instruction Set Reference Guide.** Describes the CPU architecture, pipeline, instruction set, and interrupts for the TMS320C66x digital signal processors (DSPs) of the TMS320C6000 DSP platform. The C66x DSP generation comprises floating-point devices in the C6000 DSP platform.
Introduction to the Software Development Tools

The TMS320C6000™ is supported by a set of software development tools, which includes an optimizing C/C++ compiler, an assembly optimizer, an assembler, a linker, and assorted utilities.

This chapter provides an overview of these tools and introduces the features of the optimizing C/C++ compiler. The assembly optimizer is discussed in Chapter 4. The assembler and linker are discussed in detail in the TMS320C6000 Assembly Language Tools User’s Guide.

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1.1 Software Development Tools Overview

Figure 1-1 illustrates the software development flow. The shaded portion of the figure highlights the most common path of software development for C language programs. The other portions are peripheral functions that enhance the development process.

Figure 1-1. TMS320C6000 Software Development Flow

The following list describes the tools that are shown in Figure 1-1:

- The assembly optimizer allows you to write linear assembly code without being concerned with the pipeline structure or with assigning registers. It accepts assembly code that has not been register-allocated and is unscheduled. The assembly optimizer assigns registers and uses loop optimization to turn linear assembly into highly parallel assembly that takes advantage of software pipelining. See Chapter 4.

- The compiler accepts C/C++ source code and produces C6000 assembly language source code. See Chapter 2.
• The **assembler** translates assembly language source files into machine language relocatable object files. The *TMS320C6000 Assembly Language Tools User's Guide* explains how to use the assembler.

• The **linker** combines relocatable object files into a single absolute executable object file. As it creates the executable file, it performs relocation and resolves external references. The linker accepts relocatable object files and object libraries as input. See Chapter 5. The *TMS320C6000 Assembly Language Tools User's Guide* provides a complete description of the linker.

• The **archiver** allows you to collect a group of files into a single archive file, called a library. Additionally, the archiver allows you to modify a library by deleting, replacing, extracting, or adding members. One of the most useful applications of the archiver is building a library of object files. The *TMS320C6000 Assembly Language Tools User's Guide* explains how to use the archiver.

• The **run-time-support libraries** contain the standard ISO C and C++ library functions, compiler-utility functions, floating-point arithmetic functions, and C I/O functions that are supported by the compiler. See Chapter 8. You can use the library-build utility to build your own customized run-time-support library. See Section 8.5. Source code for the standard run-time-support library functions for C and C++ are provided in the self-contained rtsrc.zip file.

• The **hex conversion utility** converts an object file into other object formats. You can download the converted file to an EPROM programmer. The *TMS320C6000 Assembly Language Tools User's Guide* explains how to use the hex conversion utility and describes all supported formats.

• The **absolute lister** accepts linked object files as input and creates .abs files as output. You can assemble these .abs files to produce a listing that contains absolute, rather than relative, addresses. Without the absolute lister, producing such a listing would be tedious and would require many manual operations. The *TMS320C6000 Assembly Language Tools User's Guide* explains how to use the absolute lister.

• The **cross-reference lister** uses object files to produce a cross-reference listing showing symbols, their definitions, and their references in the linked source files. The *TMS320C6000 Assembly Language Tools User's Guide* explains how to use the cross-reference utility.

• The **C++ name demangler** is a debugging aid that converts names mangled by the compiler back to their original names as declared in the C++ source code. As shown in Figure 1-1, you can use the C++ name demangler on the assembly file that is output by the compiler; you can also use this utility on the assembler listing file and the linker map file. See Chapter 9.

• The **disassembler** decodes object files to show the assembly instructions that they represent. The *TMS320C6000 Assembly Language Tools User's Guide* explains how to use the disassembler.

• The main product of this development process is an executable object file that can be executed in a TMS320C6000 device. You can use one of several debugging tools to refine and correct your code. Available products include:
  – An instruction-level and clock-accurate software simulator
  – An XDS emulator

### 1.2 C/C++ Compiler Overview

The following subsections describe the key features of the compiler.

#### 1.2.1 ANSI/ISO Standard

The C and C++ language features in the compiler are implemented in conformance with these ISO standards:

**ISO-standard C**

The C/C++ compiler conforms to the C Standard ISO/IEC 9899:1990. The ISO standard supercedes and is the same as the ANSI C standard. There is also a 1999 version of the ISO standard, but the TI compiler conforms to the 1990 standard, not the 1999 standard. The language is also described in the second edition of Kernighan and Ritchie's *The C Programming Language* (K&R).

**ISO-standard C++**

The C/C++ compiler conforms to the C++ Standard ISO/IEC 14882:1998. The language is also described in Ellis and Stroustrup's *The Annotated C++ Reference Manual* (ARM), but this is not the
The compiler also supports embedded C++. For a description of unsupported C++ features, see Section 6.2.

- **ISO-standard run-time support**
  The compiler tools come with an extensive run-time library. All library functions conform to the ISO C/C++ library standard. The library includes functions for standard input and output, string manipulation, dynamic memory allocation, data conversion, timekeeping, trigonometry, and exponential and hyperbolic functions. Functions for signal handling are not included, because these are target-system specific. For more information, see Chapter 8.

### 1.2.2 Output Files

These types of output files are created by the compiler:

- **COFF object files**
  Common object file format (COFF) allows you to define your system's memory map at link time. This maximizes performance by enabling you to link C/C++ code and data objects into specific memory areas. COFF also supports source-level debugging.

- **ELF object files**
  Executable and linking format (ELF) enables supporting modern language features like early template instantiation and exporting inline functions.

### 1.2.3 Compiler Interface

These features enable interfacing with the compiler:

- **Compiler program**
  The compiler tools include a compiler program (cl6x) that you use to compile, optimize, assemble, and link programs in a single step. For more information, see Section 2.1

- **Flexible assembly language interface**
  The compiler has straightforward calling conventions, so you can write assembly and C functions that call each other. For more information, see Chapter 7.

### 1.2.4 Utilities

These features are compiler utilities:

- **Library-build utility**
  The library-build utility lets you custom-build object libraries from source for any combination of run-time models. For more information, see Section 8.5.

- **C++ name demangler**
  The C++ name demangler (dem6x) is a debugging aid that translates each mangled name it detects in compiler-generated assembly code, disassembly output, or compiler diagnostic messages to its original name found in the C++ source code. For more information, see Chapter 9.

- **Hex conversion utility**
  For stand-alone embedded applications, the compiler has the ability to place all code and initialization data into ROM, allowing C/C++ code to run from reset. The COFF or ELF files output by the compiler can be converted to EPROM programmer data files by using the hex conversion utility, as described in the TMS320C6000 Assembly Language Tools User's Guide.
Chapter 2

Using the C/C++ Compiler

The compiler translates your source program into machine language object code that the TMS320C6000 can execute. Source code must be compiled, assembled, and linked to create an executable object file. All of these steps are executed at once by using the compiler.

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</table>
2.1 About the Compiler

The compiler lets you compile, assemble, and optionally link in one step. The compiler performs the following steps on one or more source modules:

- **The compiler** accepts C/C++ source code and assembly code, and produces object code. You can compile C, C++, and assembly files in a single command. The compiler uses the filename extensions to distinguish between different file types. See Section 2.3.9 for more information.

- **The linker** combines object files to create a static executable or dynamic object file. The linker is optional, so you can compile and assemble many modules independently and link them later. See Chapter 5 for information about linking the files.

---

**Invoking the Linker**

**NOTE:** By default, the compiler does not invoke the linker. You can invoke the linker by using the `--run_linker` compiler option.

---

For a complete description of the assembler and the linker, see the *TMS320C6000 Assembly Language Tools User’s Guide*.

2.2 Invoking the C/C++ Compiler

To invoke the compiler, enter:

```
cl6x [options] [filenames] [--run_linker [link_options] object files]
```

- **cl6x** Command that runs the compiler and the assembler.
- **options** Options that affect the way the compiler processes input files. The options are listed in Table 2-5 through Table 2-32.
- **filenames** One or more C/C++ source files, assembly language source files, linear assembly files, or object files.
- **--run_linker** Option that invokes the linker. The `--run_linker` option's short form is `-z`. See Chapter 5 for more information.
- **link_options** Options that control the linking process.
- **object files** Name of the additional object files for the linking process.

The arguments to the compiler are of three types:

- Compiler options
- Link options
- Filenames

The `--run_linker` option indicates linking is to be performed. If the `--run_linker` option is used, any compiler options must precede the `--run_linker` option, and all link options must follow the `--run_linker` option.

Source code filenames must be placed before the `--run_linker` option. Additional object file filenames can be placed after the `--run_linker` option.

For example, if you want to compile two files named symtab.c and file.c, assemble a third file named seek.asm, and link to create an executable program called myprogram.out, you will enter:

```
cl6x symtab.c file.c seek.asm --run_linker --library=lnk.cmd --library=rts6200.lib --output_file=myprogram.out
```
2.3 Changing the Compiler's Behavior With Options

Options control the operation of the compiler. This section provides a description of option conventions and an option summary table. It also provides detailed descriptions of the most frequently used options, including options used for type-checking and assembling.

For a help screen summary of the options, enter `cl6x` with no parameters on the command line.

The following apply to the compiler options:

- Options are preceded by one or two hyphens.
- Options are case sensitive.
- Options are either single letters or sequences of characters.
- Individual options cannot be combined.
- An option with a required parameter should be specified with an equal sign before the parameter to clearly associate the parameter with the option. For example, the option to undefine a constant can be expressed as `--undefine=name`. Although not recommended, you can separate the option and the parameter with or without a space, as in `--undefine name` or `-undefine name`.
- An option with an optional parameter should be specified with an equal sign before the parameter to clearly associate the parameter with the option. For example, the option to specify the maximum amount of optimization can be expressed as `-O=3`. Although not recommended, you can specify the parameter directly after the option, as in `-O3`. No space is allowed between the option and the optional parameter, so `-O 3` is not accepted.
- Files and options except the `--run_linker` option can occur in any order. The `--run_linker` option must follow all other compile options and precede any link options.

You can define default options for the compiler by using the `C6X_C_OPTION` environment variable. For a detailed description of the environment variable, see Section 2.4.1.

Table 2-5 through Table 2-32 summarize all options (including link options). Use the references in the tables for more complete descriptions of the options.

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<tr>
<th>Option</th>
<th>Alias</th>
<th>Effect</th>
<th>Section</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>--silicon_version=id</code></td>
<td>-mv</td>
<td>Selects target version. Defaults to 6200.</td>
<td>Section 2.3.4</td>
</tr>
<tr>
<td><code>--big_endian</code></td>
<td>-me</td>
<td>Produces object code in big-endian format</td>
<td>Section 2.13</td>
</tr>
<tr>
<td>`--abi={coffabi</td>
<td>eabi}`</td>
<td></td>
<td>Selects application binary interface. Default is coffabi.</td>
</tr>
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</table>

Table 2-2. Optimization Options

<table>
<thead>
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<th>Option</th>
<th>Alias</th>
<th>Effect</th>
<th>Section</th>
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</thead>
<tbody>
<tr>
<td><code>--opt_level=0</code></td>
<td>-O0</td>
<td>Optimizes register usage</td>
<td>Section 3.1</td>
</tr>
<tr>
<td><code>--opt_level=1</code></td>
<td>-O1</td>
<td>Uses -O0 optimizations and optimizes locally</td>
<td>Section 3.1</td>
</tr>
<tr>
<td><code>--opt_level=2</code></td>
<td>-O2 or -O</td>
<td>Uses -O1 optimizations and optimizes globally (default)</td>
<td>Section 3.1</td>
</tr>
<tr>
<td><code>--opt_level=3</code></td>
<td>-O3</td>
<td>Uses -O2 optimizations and optimizes the file</td>
<td>Section 3.6</td>
</tr>
<tr>
<td><code>--opt_for_space=n</code></td>
<td>-ms</td>
<td>Controls code size on four levels (0, 1, 2, and 3)</td>
<td>Section 3.5</td>
</tr>
</tbody>
</table>

(1) Note: Machine-specific options (see Table 2-11) can also affect optimization.

Table 2-3. Debug Options

<table>
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<th>Option</th>
<th>Alias</th>
<th>Effect</th>
<th>Section</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>--symdebug:dwarf</code></td>
<td>-g</td>
<td>Enables symbolic debugging</td>
<td>Section 2.3.5</td>
</tr>
<tr>
<td><code>--symdebug:coff</code></td>
<td></td>
<td>Enables symbolic debugging using the alternate STABS debugging format. STABS format is not supported for C6400+ or C674x, or when using ELF.</td>
<td>Section 2.3.5</td>
</tr>
<tr>
<td><code>--symdebug:none</code></td>
<td></td>
<td>Disables all symbolic debugging</td>
<td>Section 2.3.5</td>
</tr>
</tbody>
</table>
### Table 2-3. Debug Options (continued)

<table>
<thead>
<tr>
<th>Option</th>
<th>Alias</th>
<th>Effect</th>
<th>Section</th>
</tr>
</thead>
<tbody>
<tr>
<td>--symdebug:profile_coff</td>
<td></td>
<td>Enables profiling using the alternate STABS debugging format. STABS format is not supported for C6400+ or C674x, or when using ELF.</td>
<td>Section 2.3.5</td>
</tr>
<tr>
<td>--symdebug:skeletal</td>
<td></td>
<td>Enables minimal symbolic debugging that does not hinder optimizations (default behavior)</td>
<td>Section 2.3.5</td>
</tr>
<tr>
<td>--disable_push_pop</td>
<td></td>
<td>Disables push-pop optimization</td>
<td></td>
</tr>
<tr>
<td>--optimize_with_debug</td>
<td>-mn</td>
<td>Reenables optimizations disabled with --symdebug:dwarf</td>
<td>Section 3.14.3.1</td>
</tr>
<tr>
<td>--symdebug:dwarf_version=2</td>
<td>3</td>
<td>Specifies the DWARF format version</td>
<td>Section 2.3.5</td>
</tr>
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</table>

### Table 2-4. Include Options

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<th>Option</th>
<th>Alias</th>
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</tr>
</thead>
<tbody>
<tr>
<td>--include_path=directory</td>
<td>-I</td>
<td>Defines #include search path</td>
<td>Section 2.6.2.1</td>
</tr>
<tr>
<td>--preinclude=filename</td>
<td></td>
<td>Includes filename at the beginning of compilation</td>
<td>Section 2.3.2</td>
</tr>
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</table>

### Table 2-5. Control Options

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<tr>
<th>Option</th>
<th>Alias</th>
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<tbody>
<tr>
<td>--compile_only</td>
<td>-c</td>
<td>Disables linking (negates --run_linker)</td>
<td>Section 5.1.3</td>
</tr>
<tr>
<td>--help</td>
<td>-h</td>
<td>Prints (on the standard output device) a description of the options understood by the compiler.</td>
<td>Section 2.3.1</td>
</tr>
<tr>
<td>--run_linker</td>
<td>-z</td>
<td>Enables linking</td>
<td>Section 2.3.1</td>
</tr>
<tr>
<td>--skip_assembler</td>
<td>-n</td>
<td>Compiles or assembly optimizes only</td>
<td>Section 2.3.1</td>
</tr>
</tbody>
</table>

### Table 2-6. Advanced Debug Options

<table>
<thead>
<tr>
<th>Option</th>
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<th>Effect</th>
<th>Section</th>
</tr>
</thead>
<tbody>
<tr>
<td>--machine_regs</td>
<td></td>
<td>Displays reg operands as machine registers in assembly code</td>
<td>Section 2.3.11</td>
</tr>
<tr>
<td>--symdebug:keep_all_types</td>
<td></td>
<td>Keep unreferenced type information (default for ELF with debug)</td>
<td>Section 2.3.5</td>
</tr>
</tbody>
</table>

### Table 2-7. Language Options

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<th>Option</th>
<th>Alias</th>
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<th>Section</th>
</tr>
</thead>
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<tr>
<td>--cpp_default</td>
<td>-fg</td>
<td>Processes all source files with a C extension as C++ source files.</td>
<td>Section 2.3.7</td>
</tr>
<tr>
<td>--create_pch=filename</td>
<td></td>
<td>Creates a precompiled header file with the name specified</td>
<td>Section 2.5</td>
</tr>
<tr>
<td>--embedded_cpp</td>
<td>-pe</td>
<td>Enables embedded C++ mode</td>
<td>Section 6.14.3</td>
</tr>
<tr>
<td>--exceptions</td>
<td></td>
<td>Enables C++ exception handling</td>
<td>Section 6.6</td>
</tr>
<tr>
<td>--extern_c_can_throw</td>
<td></td>
<td>Allow extern C functions to propagate exceptions (EABI only)</td>
<td>--</td>
</tr>
<tr>
<td>--gcc</td>
<td></td>
<td>Enables support for GCC extensions</td>
<td>Section 6.15</td>
</tr>
<tr>
<td>--gen_acp_raw</td>
<td>-pl</td>
<td>Generates a raw listing file</td>
<td>Section 2.10</td>
</tr>
<tr>
<td>--gen_acp_xref</td>
<td>-px</td>
<td>Generates a cross-reference listing file</td>
<td>Section 2.9</td>
</tr>
<tr>
<td>--keep_unneeded_statics</td>
<td></td>
<td>Keeps unreferenced static variables.</td>
<td>Section 2.3.2</td>
</tr>
<tr>
<td>--kr_compatible</td>
<td>-pk</td>
<td>Allows K&amp;R compatibility</td>
<td>Section 6.14.1</td>
</tr>
<tr>
<td>--multibyte_chars</td>
<td>-pc</td>
<td>Enables support for multibyte character sequences in comments, string literals and character constants.</td>
<td>--</td>
</tr>
<tr>
<td>--no_inlining</td>
<td>-pi</td>
<td>Disables definition-controlled inlining (but --opt_level=3 (or -O3) optimizations still perform automatic inlining)</td>
<td>Section 2.11</td>
</tr>
<tr>
<td>--no_intrinsics</td>
<td>-pn</td>
<td>Disables intrinsic functions. No predefinition of compiler-supplied intrinsic functions.</td>
<td>--</td>
</tr>
<tr>
<td>--pch</td>
<td></td>
<td>Creates or uses precompiled header files</td>
<td>Section 2.5</td>
</tr>
</tbody>
</table>
Table 2-7. Language Options (continued)

<table>
<thead>
<tr>
<th>Option</th>
<th>Alias</th>
<th>Effect</th>
<th>Section</th>
</tr>
</thead>
<tbody>
<tr>
<td>--pch_dir=directory</td>
<td></td>
<td>Specifies the path where the precompiled header file resides</td>
<td>Section 2.5.2</td>
</tr>
<tr>
<td>--pchVerbose</td>
<td></td>
<td>Displays a message for each precompiled header file that is</td>
<td>Section 2.5.3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>considered but not used</td>
<td></td>
</tr>
<tr>
<td>--program_level_compile</td>
<td>-pm</td>
<td>Combines source files to perform program-level optimization</td>
<td>Section 3.7</td>
</tr>
<tr>
<td>--relaxed_ansi</td>
<td>-pr</td>
<td>Enables relaxed mode; ignores strict ISO violations</td>
<td>Section 6.14.2</td>
</tr>
<tr>
<td>--rtti</td>
<td>-rtti</td>
<td>Enables run time type information (RTTI)</td>
<td>—</td>
</tr>
<tr>
<td>--static_template_instantiation</td>
<td></td>
<td>Instantiates all template entities with internal linkage</td>
<td>—</td>
</tr>
<tr>
<td>--strict_ansi</td>
<td>-ps</td>
<td>Enables strict ISO mode (for C/C++, not K&amp;R C)</td>
<td>Section 6.14.2</td>
</tr>
<tr>
<td>--use_pch=filename</td>
<td></td>
<td>Specifies the precompiled header file to use for this compilation</td>
<td>Section 2.5.2</td>
</tr>
</tbody>
</table>

Table 2-8. Parser Preprocessing Options

<table>
<thead>
<tr>
<th>Option</th>
<th>Alias</th>
<th>Effect</th>
<th>Section</th>
</tr>
</thead>
<tbody>
<tr>
<td>--preproc_dependency[]=</td>
<td>-ppd</td>
<td>Performs preprocessing only, but instead of writing preprocessed</td>
<td>Section 2.6.7</td>
</tr>
<tr>
<td></td>
<td></td>
<td>output, writes a list of dependency lines suitable for input to a</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>standard make utility</td>
<td></td>
</tr>
<tr>
<td>--preproc_includes[]=</td>
<td>-ppi</td>
<td>Performs preprocessing only, but instead of writing preprocessed</td>
<td>Section 2.6.8</td>
</tr>
<tr>
<td></td>
<td></td>
<td>output, writes a list of files included with the #include directive</td>
<td></td>
</tr>
<tr>
<td>--preproc_macros[]=</td>
<td>-ppm</td>
<td>Performs preprocessing only. Writes list of predefined and user-</td>
<td>Section 2.6.9</td>
</tr>
<tr>
<td></td>
<td></td>
<td>defined macros to a file with the same name as the input but with a .pp</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>extension.</td>
<td></td>
</tr>
<tr>
<td>--preproc_only</td>
<td>-ppo</td>
<td>Performs preprocessing only. Writes preprocessed output to a file</td>
<td>Section 2.6.3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>with the same name as the input but with a .pp extension</td>
<td></td>
</tr>
<tr>
<td>--preproc_with_comment</td>
<td>-ppc</td>
<td>Performs preprocessing only. Writes preprocessed output, keeping</td>
<td>Section 2.6.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>the comments, to a file with the same name as the input but with a .pp</td>
<td></td>
</tr>
<tr>
<td>--preproc_with_compile</td>
<td>-ppa</td>
<td>Continues compilation after preprocessing</td>
<td>Section 2.6.4</td>
</tr>
<tr>
<td>--preproc_with_line</td>
<td>-ppl</td>
<td>Performs preprocessing only. Writes preprocessed output with line-</td>
<td>Section 2.6.6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>control information (#line directives) to a file with the same name</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>as the input but with a .pp extension</td>
<td></td>
</tr>
</tbody>
</table>

Table 2-9. Predefined Symbols Options

<table>
<thead>
<tr>
<th>Option</th>
<th>Alias</th>
<th>Effect</th>
<th>Section</th>
</tr>
</thead>
<tbody>
<tr>
<td>--define=name[]=</td>
<td>-D</td>
<td>Predefines</td>
<td>Section 2.3.1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>name</td>
<td></td>
</tr>
<tr>
<td>--undefine=name</td>
<td>-U</td>
<td>Undefines</td>
<td>Section 2.3.1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>name</td>
<td></td>
</tr>
</tbody>
</table>

Table 2-10. Diagnostics Options

<table>
<thead>
<tr>
<th>Option</th>
<th>Alias</th>
<th>Effect</th>
<th>Section</th>
</tr>
</thead>
<tbody>
<tr>
<td>--compiler_revision</td>
<td></td>
<td>Prints out the compiler release revision and exits</td>
<td>--</td>
</tr>
<tr>
<td>--diag_error=num</td>
<td>-pdse</td>
<td>Categorizes the diagnostic identified by num as an error</td>
<td>Section 2.7.1</td>
</tr>
<tr>
<td>--diag_remark=num</td>
<td>-pdsr</td>
<td>Categorizes the diagnostic identified by num as a remark</td>
<td>Section 2.7.1</td>
</tr>
<tr>
<td>--diag_suppress=num</td>
<td>-pds</td>
<td>Suppresses the diagnostic identified by num</td>
<td>Section 2.7.1</td>
</tr>
<tr>
<td>--diag_warning=num</td>
<td>-pdsw</td>
<td>Categorizes the diagnostic identified by num as a warning</td>
<td>Section 2.7.1</td>
</tr>
<tr>
<td>--display_error_number</td>
<td>-pden</td>
<td>Displays a diagnostic's identifiers along with its text</td>
<td>Section 2.7.1</td>
</tr>
<tr>
<td>--emit_warnings_as_errors</td>
<td>-pdew</td>
<td>Treat warnings as errors</td>
<td>Section 2.7.1</td>
</tr>
<tr>
<td>--issueRemarks</td>
<td>-pdr</td>
<td>Issues remarks (nonserious warnings)</td>
<td>Section 2.7.1</td>
</tr>
<tr>
<td>--no_warnings</td>
<td>-pdw</td>
<td>Suppresses warning diagnostics (errors are still issued)</td>
<td>Section 2.7.1</td>
</tr>
<tr>
<td>--quiet</td>
<td>-q</td>
<td>Suppresses progress messages (quiet)</td>
<td>--</td>
</tr>
<tr>
<td>--set_error_limit=num</td>
<td>-pdel</td>
<td>Sets the error limit to num. The compiler abandons compiling after this number of errors. (The default is 100.)</td>
<td>Section 2.7.1</td>
</tr>
</tbody>
</table>
## Table 2-10. Diagnostics Options (continued)

<table>
<thead>
<tr>
<th>Option</th>
<th>Alias</th>
<th>Effect</th>
<th>Section</th>
</tr>
</thead>
<tbody>
<tr>
<td>--super_quiet</td>
<td>-qq</td>
<td>Super quiet mode</td>
<td>--</td>
</tr>
<tr>
<td>--tool_version</td>
<td>-version</td>
<td>Displays version number for each tool</td>
<td>--</td>
</tr>
<tr>
<td>--verbose</td>
<td></td>
<td>Display banner and function progress information</td>
<td>--</td>
</tr>
<tr>
<td>--verbose_diagnostics</td>
<td>-pdv</td>
<td>Provides verbose diagnostics that display the original source with line-wrap</td>
<td>Section 2.7.1</td>
</tr>
<tr>
<td>--write_diagnostics_file</td>
<td>-pdf</td>
<td>Generates a diagnostics information file. Compiler only option.</td>
<td>Section 2.7.1</td>
</tr>
</tbody>
</table>

## Table 2-11. Run-Time Model Options

<table>
<thead>
<tr>
<th>Option</th>
<th>Alias</th>
<th>Effect</th>
<th>Section</th>
</tr>
</thead>
<tbody>
<tr>
<td>--debug_software_pipeline</td>
<td>-mw</td>
<td>Produce verbose software pipelining report</td>
<td>Section 3.2.2</td>
</tr>
<tr>
<td>--disable_software_pipelining</td>
<td>-mu</td>
<td>Turns off software pipelining</td>
<td>Section 3.2.1</td>
</tr>
<tr>
<td>--dprel</td>
<td></td>
<td>Specifies that all non-const data is addressed using DP-relative addressing</td>
<td>Section 7.1.5.2</td>
</tr>
<tr>
<td>--fp_not_associative</td>
<td>-mc</td>
<td>Prevents reordering of associative floating-point operations</td>
<td>Section 3.11</td>
</tr>
<tr>
<td>--fp_reassoc=(on</td>
<td>off)</td>
<td></td>
<td>Enables or disables the reassociation of floating-point arithmetic</td>
</tr>
<tr>
<td>--gen_func_subsections=(on</td>
<td>off)</td>
<td>-mo</td>
<td>Puts each function in a separate subsection in the object file</td>
</tr>
<tr>
<td>--interrupt_threshold=[num]</td>
<td>-mi</td>
<td>Specifies an interrupt threshold value</td>
<td>Section 2.12</td>
</tr>
<tr>
<td>--mem_model:const=[far_aggregates</td>
<td>far</td>
<td>data]</td>
<td></td>
</tr>
<tr>
<td>--mem_model:data=[far_aggregates</td>
<td>near</td>
<td>far]</td>
<td></td>
</tr>
<tr>
<td>--no_bad_aliases</td>
<td>-mt</td>
<td>Allows certain assumptions about aliasing and loops</td>
<td>Section 3.10.2, 4.6.2</td>
</tr>
<tr>
<td>--no_compress</td>
<td></td>
<td>Prevents compression on C6400+, C6740, and C6600</td>
<td>-</td>
</tr>
<tr>
<td>--no_reload_errors</td>
<td></td>
<td>Turns off all reload-related loop buffer error messages for C6400+, C6740, and C6600</td>
<td>-</td>
</tr>
<tr>
<td>--profile:breakpt</td>
<td></td>
<td>Enables breakpoint-based profiling</td>
<td>Section 2.3.5, 3.14.3.2</td>
</tr>
<tr>
<td>--profile:power</td>
<td></td>
<td>Enables power profiling</td>
<td>Section 2.3.5, 3.14.3.2</td>
</tr>
<tr>
<td>--sat_reassoc=(on</td>
<td>off)</td>
<td></td>
<td>Enables or disables the reassociation of saturating arithmetic. Default is --sat_reassoc=off.</td>
</tr>
<tr>
<td>--small_enum</td>
<td>--small_enum</td>
<td>Uses the smallest possible size for the enumeration type</td>
<td>Section 2.3.3</td>
</tr>
<tr>
<td>--speculate_loads=n</td>
<td>-mh</td>
<td>Specifies speculative load byte count threshold. Allows speculative execution of loads with bounded address ranges.</td>
<td>Section 2.3.3.1</td>
</tr>
<tr>
<td>--speculate_unknown_loads</td>
<td></td>
<td>Allows speculative execution of loads with unbounded addresses</td>
<td>Section 2.3.3</td>
</tr>
<tr>
<td>--target_compatibility_6200</td>
<td>-mb</td>
<td>Enables C62xx compatibility with C6400 code</td>
<td>Section 2.13</td>
</tr>
<tr>
<td>--use_const_for_alias_analysis</td>
<td>-ox</td>
<td>Uses const to disambiguate pointers</td>
<td>Section 2.3.3</td>
</tr>
<tr>
<td>--wchar_t=(32</td>
<td>16)</td>
<td></td>
<td>Sets the size of the C/C++ type wchar_t. Default is 16 bits.</td>
</tr>
</tbody>
</table>
### Table 2-12. Advanced Optimization Options

<table>
<thead>
<tr>
<th>Option</th>
<th>Alias</th>
<th>Effect</th>
<th>Section</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>--auto_inline=[size]</code></td>
<td>-oi</td>
<td>Sets automatic inlining size (--opt_level=3 only). If size is not specified, the default is 1.</td>
<td>Section 3.13</td>
</tr>
<tr>
<td><code>--call_assumptions=0</code></td>
<td>-op0</td>
<td>Specifies that the module contains functions and variables that are called or modified from outside the source code provided to the compiler</td>
<td>Section 3.7.1</td>
</tr>
<tr>
<td><code>--call_assumptions=1</code></td>
<td>-op1</td>
<td>Specifies that the module contains variables modified from outside the source code provided to the compiler but does not use functions called from outside the source code</td>
<td>Section 3.7.1</td>
</tr>
<tr>
<td><code>--call_assumptions=2</code></td>
<td>-op2</td>
<td>Specifies that the module contains no functions or variables that are called or modified from outside the source code provided to the compiler (default)</td>
<td>Section 3.7.1</td>
</tr>
<tr>
<td><code>--call_assumptions=3</code></td>
<td>-op3</td>
<td>Specifies that the module contains functions that are called from outside the source code provided to the compiler but does not use variables modified from outside the source code</td>
<td>Section 3.7.1</td>
</tr>
<tr>
<td><code>--gen_opt_info=0</code></td>
<td>-on0</td>
<td>Disables the optimization information file</td>
<td>Section 3.6.2</td>
</tr>
<tr>
<td><code>--gen_opt_info=1</code></td>
<td>-on1</td>
<td>Produces an optimization information file</td>
<td>Section 3.6.2</td>
</tr>
<tr>
<td><code>--gen_opt_info=2</code></td>
<td>-on2</td>
<td>Produces a verbose optimization information file</td>
<td>Section 3.6.2</td>
</tr>
<tr>
<td><code>--openmp</code></td>
<td>-omp</td>
<td>Enables support for OpenMP 3.0</td>
<td>Section 7.9.1</td>
</tr>
<tr>
<td><code>--opt_for_speed=[n]</code></td>
<td>-mf</td>
<td>Controls speed over space (0-5 range) (Default is 4.)</td>
<td>Section 3.14.4</td>
</tr>
<tr>
<td><code>--optimizer_interlist</code></td>
<td>-os</td>
<td>Interlists optimizer comments with assembly statements</td>
<td>Section 3.14.2</td>
</tr>
<tr>
<td><code>--remove_hooks_when_inlining</code></td>
<td></td>
<td>Removes entry/exit hooks for auto-inlined functions</td>
<td>Section 2.17</td>
</tr>
<tr>
<td><code>--single_inline</code></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><code>--aliased_variables</code></td>
<td>-ma</td>
<td>Assumes called functions create hidden aliases (rare)</td>
<td>Section 3.10.1</td>
</tr>
</tbody>
</table>

(1) **Note:** Machine-specific options (see Table 2-11) can also affect optimization.

### Table 2-13. Entry/Exit Hook Options

<table>
<thead>
<tr>
<th>Option</th>
<th>Alias</th>
<th>Effect</th>
<th>Section</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>--entry_hook=[name]</code></td>
<td></td>
<td>Enables entry hooks</td>
<td>Section 2.17</td>
</tr>
<tr>
<td>`--entry_parm={none</td>
<td>name</td>
<td>address}`</td>
<td></td>
</tr>
<tr>
<td><code>--exit_hook=[name]</code></td>
<td></td>
<td>Enables exit hooks</td>
<td>Section 2.17</td>
</tr>
<tr>
<td>`--exit_parm={none</td>
<td>name</td>
<td>address}`</td>
<td></td>
</tr>
</tbody>
</table>

### Table 2-14. Feedback Options

<table>
<thead>
<tr>
<th>Option</th>
<th>Alias</th>
<th>Effect</th>
<th>Section</th>
</tr>
</thead>
<tbody>
<tr>
<td>`--analyze={codecov</td>
<td>callgraph}`</td>
<td></td>
<td>Generate analysis info from profile data</td>
</tr>
<tr>
<td><code>--analyze_only</code></td>
<td></td>
<td>Only generate analysis</td>
<td>Section 3.9.4.2</td>
</tr>
<tr>
<td><code>--gen_profile_info</code></td>
<td></td>
<td>Generates instrumentation code to collect profile information</td>
<td>Section 3.8.1.3</td>
</tr>
<tr>
<td><code>--use_profile_info=file1[, file2,...]</code></td>
<td></td>
<td>Specifies the profile information file(s)</td>
<td>Section 3.8.1.3</td>
</tr>
</tbody>
</table>

### Table 2-15. Library Function Assumptions Options

<table>
<thead>
<tr>
<th>Option</th>
<th>Alias</th>
<th>Effect</th>
<th>Section</th>
</tr>
</thead>
<tbody>
<tr>
<td>`--printf_support={nofloat</td>
<td>full</td>
<td>minimal}`</td>
<td></td>
</tr>
<tr>
<td><code>--std_lib_func_defined</code></td>
<td>-ol1 or -oL1</td>
<td>Informs the optimizer that your file declares a standard library function</td>
<td>Section 3.6.1</td>
</tr>
<tr>
<td><code>--std_lib_func_not_defined</code></td>
<td>-ol2 or -oL2</td>
<td>Informs the optimizer that your file does not declare or alter library functions. Overrides the -ol0 and -ol1 options (default).</td>
<td>Section 3.6.1</td>
</tr>
<tr>
<td><code>--std_lib_func_redefined</code></td>
<td>-ol0 or -oL0</td>
<td>Informs the optimizer that your file alters a standard library function</td>
<td>Section 3.6.1</td>
</tr>
</tbody>
</table>
### Table 2-16. Assembler Options

<table>
<thead>
<tr>
<th>Option</th>
<th>Alias</th>
<th>Effect</th>
<th>Section</th>
</tr>
</thead>
<tbody>
<tr>
<td>--keep_asm</td>
<td>-k</td>
<td>Keeps the assembly language (.asm) file</td>
<td>Section 2.3.11</td>
</tr>
<tr>
<td>--asm_listing</td>
<td>-al</td>
<td>Generates an assembly listing file</td>
<td>Section 2.3.11</td>
</tr>
<tr>
<td>--c_src_interlist</td>
<td>-ss</td>
<td>Interlists C source and assembly statements</td>
<td>Section 2.3.11</td>
</tr>
<tr>
<td>--src_interlist</td>
<td>-s</td>
<td>Interlists optimizer comments (if available) and assembly source statements; otherwise interlists C and assembly source statements</td>
<td>Section 2.3.11</td>
</tr>
<tr>
<td>--absolute_listing</td>
<td>-aa</td>
<td>Enables absolute listing</td>
<td>Section 2.3.11</td>
</tr>
<tr>
<td>--asm_define=name[=def]</td>
<td>-ad</td>
<td>Sets the name symbol</td>
<td>Section 2.3.11</td>
</tr>
<tr>
<td>--asm_dependency</td>
<td>-apd</td>
<td>Performs preprocessing; lists only assembly dependencies</td>
<td>Section 2.3.11</td>
</tr>
<tr>
<td>--asm_includes</td>
<td>-api</td>
<td>Performs preprocessing; lists only included #include files</td>
<td>Section 2.3.11</td>
</tr>
<tr>
<td>--asm_undefine=name</td>
<td>-au</td>
<td>Undefines the predefined constant name</td>
<td>Section 2.3.11</td>
</tr>
<tr>
<td>--copy_file=filename</td>
<td>-ahc</td>
<td>Copies the specified file for the assembly module</td>
<td>Section 2.3.11</td>
</tr>
<tr>
<td>--cross_reference</td>
<td>-ax</td>
<td>Generates the cross-reference file</td>
<td>Section 2.3.11</td>
</tr>
<tr>
<td>--include_file=filename</td>
<td>-ahi</td>
<td>Includes the specified file for the assembly module</td>
<td>Section 2.3.11</td>
</tr>
<tr>
<td>--no_const_clink</td>
<td>-fs</td>
<td>Stops generation of .clink directives for const global arrays</td>
<td>Section 2.3.11</td>
</tr>
<tr>
<td>--output_all_syms</td>
<td>-as</td>
<td>Puts labels in the symbol table</td>
<td>Section 2.3.11</td>
</tr>
<tr>
<td>--strip_coff_underscore</td>
<td>-ac</td>
<td>Aids in transitioning hand-coded assembly from COFF to EABI</td>
<td>Section 2.3.11</td>
</tr>
<tr>
<td>--sysms_ignore_case</td>
<td>-ac</td>
<td>Makes case insignificant in assembly source files</td>
<td>Section 2.3.11</td>
</tr>
</tbody>
</table>

### Table 2-17. File TypeSpecifier Options

<table>
<thead>
<tr>
<th>Option</th>
<th>Alias</th>
<th>Effect</th>
<th>Section</th>
</tr>
</thead>
<tbody>
<tr>
<td>--ap_file=filename</td>
<td>-fl</td>
<td>Identifies filename as a linear assembly source file regardless of its extension. By default, the compiler and assembly optimizer treat .sa files as linear assembly source files.</td>
<td>Section 2.3.7</td>
</tr>
<tr>
<td>--asm_file=filename</td>
<td>-fa</td>
<td>Identifies filename as an assembly source file regardless of its extension. By default, the compiler and assembler treat .asm files as assembly source files.</td>
<td>Section 2.3.7</td>
</tr>
<tr>
<td>--c_file=filename</td>
<td>-fc</td>
<td>Identifies filename as a C source file regardless of its extension. By default, the compiler treats .c files as C source files.</td>
<td>Section 2.3.7</td>
</tr>
<tr>
<td>--cpp_file=filename</td>
<td>-fp</td>
<td>Identifies filename as a C++ file, regardless of its extension. By default, the compiler treats .c, .cpp, .cc and .cxx files as a C++ files.</td>
<td>Section 2.3.7</td>
</tr>
<tr>
<td>--obj_file=filename</td>
<td>-fo</td>
<td>Identifies filename as an object code file regardless of its extension. By default, the compiler and linken treat .obj files as object code files.</td>
<td>Section 2.3.7</td>
</tr>
</tbody>
</table>

### Table 2-18. Directory Specifier Options

<table>
<thead>
<tr>
<th>Option</th>
<th>Alias</th>
<th>Effect</th>
<th>Section</th>
</tr>
</thead>
<tbody>
<tr>
<td>--abs_directory=directory</td>
<td>-fb</td>
<td>Specifies an absolute listing file directory. By default, the compiler uses the .obj directory.</td>
<td>Section 2.3.10</td>
</tr>
<tr>
<td>--asm_directory=directory</td>
<td>-fs</td>
<td>Specifies an assembly file directory. By default, the compiler uses the current directory.</td>
<td>Section 2.3.10</td>
</tr>
<tr>
<td>--list_directory=directory</td>
<td>-ft</td>
<td>Specifies an assembly listing file and cross-reference listing file directory By default, the compiler uses the .obj directory.</td>
<td>Section 2.3.10</td>
</tr>
<tr>
<td>--obj_directory=directory</td>
<td>-fr</td>
<td>Specifies an object file directory. By default, the compiler uses the current directory.</td>
<td>Section 2.3.10</td>
</tr>
<tr>
<td>--output_file=filename</td>
<td>-fe</td>
<td>Specifies a compilation output file name; can override --obj_directory.</td>
<td>Section 2.3.10</td>
</tr>
<tr>
<td>--pp_directory=dir</td>
<td>-ft</td>
<td>Specifies a preprocessor file directory. By default, the compiler uses the current directory.</td>
<td>Section 2.3.10</td>
</tr>
<tr>
<td>--temp_directory=directory</td>
<td>-ft</td>
<td>Specifies a temporary file directory. By default, the compiler uses the current directory.</td>
<td>Section 2.3.10</td>
</tr>
</tbody>
</table>
### Table 2-19. Default File Extensions Options

<table>
<thead>
<tr>
<th>Option</th>
<th>Alias</th>
<th>Effect</th>
<th>Section</th>
</tr>
</thead>
<tbody>
<tr>
<td>--ap_extension=[.]*extension</td>
<td>-el</td>
<td>Sets a default extension for linear assembly source files.</td>
<td>Section 2.3.9</td>
</tr>
<tr>
<td>--asm_extension=[.]*extension</td>
<td>-ea</td>
<td>Sets a default extension for assembly source files</td>
<td>Section 2.3.9</td>
</tr>
<tr>
<td>--c_extension=[.]*extension</td>
<td>-ec</td>
<td>Sets a default extension for C source files</td>
<td>Section 2.3.9</td>
</tr>
<tr>
<td>--cpp_extension=[.]*extension</td>
<td>-ep</td>
<td>Sets a default extension for C++ source files</td>
<td>Section 2.3.9</td>
</tr>
<tr>
<td>--listing_extension=[.]*extension</td>
<td>-es</td>
<td>Sets a default extension for listing files</td>
<td>Section 2.3.9</td>
</tr>
<tr>
<td>--obj_extension=[.]*extension</td>
<td>-eo</td>
<td>Sets a default extension for object files</td>
<td>Section 2.3.9</td>
</tr>
</tbody>
</table>

### Table 2-20. Dynamic Linking Support Compiler Options

<table>
<thead>
<tr>
<th>Option</th>
<th>Alias</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>--dsbt</td>
<td></td>
<td>Generates addressing via Dynamic Segment Base Table</td>
</tr>
<tr>
<td>--export_all_cpp_vtbl</td>
<td></td>
<td>Exports C++ virtual tables by default</td>
</tr>
<tr>
<td>--import_helper_functions</td>
<td></td>
<td>Treats compiler helper functions as imported references</td>
</tr>
<tr>
<td>--import_undef={[off</td>
<td>on]}</td>
<td></td>
</tr>
<tr>
<td>--inline_plt={[off</td>
<td>on]}</td>
<td></td>
</tr>
<tr>
<td>--linux</td>
<td></td>
<td>Generates code for Linux</td>
</tr>
<tr>
<td>--pic={[near</td>
<td>far]}</td>
<td></td>
</tr>
<tr>
<td>--visibility={hidden</td>
<td>fhidden</td>
<td>default</td>
</tr>
</tbody>
</table>

(1) See Section 2.3.12 for more information.

### Table 2-21. Command Files Options

<table>
<thead>
<tr>
<th>Option</th>
<th>Alias</th>
<th>Effect</th>
<th>Section</th>
</tr>
</thead>
<tbody>
<tr>
<td>--cmd_file=filename</td>
<td>-@</td>
<td>Interprets contents of a file as an extension to the command line. Multiple -@ instances can be used.</td>
<td>Section 2.3.1</td>
</tr>
</tbody>
</table>

### Table 2-22. MISRA-C:2004 Options

<table>
<thead>
<tr>
<th>Option</th>
<th>Alias</th>
<th>Effect</th>
<th>Section</th>
</tr>
</thead>
<tbody>
<tr>
<td>--check_misra={[all</td>
<td>required] advisory} {[none</td>
<td>rulespec]}</td>
<td></td>
</tr>
<tr>
<td>--misra_advisory={[error</td>
<td>warning</td>
<td>remark</td>
<td>suppress]}</td>
</tr>
<tr>
<td>--misra_required={[error</td>
<td>warning</td>
<td>remark</td>
<td>suppress]}</td>
</tr>
</tbody>
</table>

### Table 2-23. Performance Advisor Options

<table>
<thead>
<tr>
<th>Option</th>
<th>Alias</th>
<th>Effect</th>
<th>Section</th>
</tr>
</thead>
<tbody>
<tr>
<td>--advice:performance={[all</td>
<td>none]}</td>
<td></td>
<td>Generates compiler optimization advice. Default is all.</td>
</tr>
<tr>
<td>--advice:performance_file={stdout</td>
<td>stderr</td>
<td>user_specified_filename}</td>
<td></td>
</tr>
<tr>
<td>--advice:performance_dir={user_specified_directory_name}</td>
<td></td>
<td>Specifies that advice file be created in the named directory.</td>
<td>Section 2.15</td>
</tr>
</tbody>
</table>

The following tables list the linker options. See the TMS320C6000 Assembly Language Tools User's Guide for details on these options.
### Table 2-24. Linker Basic Options

<table>
<thead>
<tr>
<th>Option</th>
<th>Alias</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>--output_file=file</td>
<td>-o</td>
<td>Names the executable output file. The default filename is a.out.</td>
</tr>
<tr>
<td>--map_file=file</td>
<td>-m</td>
<td>Produces a map or listing of the input and output sections, including holes, and places the listing in filename</td>
</tr>
<tr>
<td>--stack_size=size</td>
<td>-stack</td>
<td>Sets C system stack size to size bytes and defines a global symbol that specifies the stack size. Default = 1K bytes</td>
</tr>
<tr>
<td>--heap_size=size</td>
<td>-heap</td>
<td>Sets heap size (for the dynamic memory allocation in C) to size bytes and defines a global symbol that specifies the heap size. Default = 1K bytes</td>
</tr>
</tbody>
</table>

### Table 2-25. File Search Path Options

<table>
<thead>
<tr>
<th>Option</th>
<th>Alias</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>--library=file</td>
<td>-l</td>
<td>Names an archive library or link command file as linker input</td>
</tr>
<tr>
<td>--search_path=pathname</td>
<td>-I</td>
<td>Alters library-search algorithms to look in a directory named with pathname before looking in the default location. This option must appear before the --library option.</td>
</tr>
<tr>
<td>--priority</td>
<td>-priority</td>
<td>Satisfies unresolved references by the first library that contains a definition for that symbol</td>
</tr>
<tr>
<td>--reread_libs</td>
<td>-x</td>
<td>Forces rereading of libraries, which resolves back references</td>
</tr>
<tr>
<td>--disable_auto_rts</td>
<td></td>
<td>Disables the automatic selection of a run-time-support library</td>
</tr>
</tbody>
</table>

### Table 2-26. Command File Preprocessing Options

<table>
<thead>
<tr>
<th>Option</th>
<th>Alias</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>--define=name=value</td>
<td></td>
<td>Predefines name as a preprocessor macro.</td>
</tr>
<tr>
<td>--undefine=name</td>
<td></td>
<td>Removes the preprocessor macro name.</td>
</tr>
<tr>
<td>--disable_pp</td>
<td></td>
<td>Disables preprocessing for command files</td>
</tr>
</tbody>
</table>

### Table 2-27. Diagnostic Options

<table>
<thead>
<tr>
<th>Option</th>
<th>Alias</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>--diag_error=num</td>
<td></td>
<td>Categorizes the diagnostic identified by num as an error</td>
</tr>
<tr>
<td>--diag_remark=num</td>
<td></td>
<td>Categorizes the diagnostic identified by num as a remark</td>
</tr>
<tr>
<td>--diag_suppress=num</td>
<td></td>
<td>Suppresses the diagnostic identified by num</td>
</tr>
<tr>
<td>--diag_warning=num</td>
<td></td>
<td>Categorizes the diagnostic identified by num as a warning</td>
</tr>
<tr>
<td>--display_error_number</td>
<td></td>
<td>Displays a diagnostic's identifiers along with its text</td>
</tr>
<tr>
<td>--emit_warnings_as_errors</td>
<td>-pdew</td>
<td>Treat warnings as errors</td>
</tr>
<tr>
<td>--issue Remarks</td>
<td></td>
<td>Issues remarks (nonserious warnings)</td>
</tr>
<tr>
<td>--no demangle</td>
<td></td>
<td>Disables demangling of symbol names in diagnostics</td>
</tr>
<tr>
<td>--no warnings</td>
<td></td>
<td>Suppresses warning diagnostics (errors are still issued)</td>
</tr>
<tr>
<td>--set_error_limit=count</td>
<td></td>
<td>Sets the error limit to count. The linker abandons linking after this number of errors. (The default is 100.)</td>
</tr>
<tr>
<td>--verbose_diagnostics</td>
<td></td>
<td>Provides verbose diagnostics that display the original source with line-wrap</td>
</tr>
<tr>
<td>--warn_sections</td>
<td>-w</td>
<td>Displays a message when an undefined output section is created</td>
</tr>
</tbody>
</table>

### Table 2-28. Linker Output Options

<table>
<thead>
<tr>
<th>Option</th>
<th>Alias</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>--absolute_exe</td>
<td>-a</td>
<td>Produces an absolute, executable object file. This is the default; if neither --absolute_exe nor --relocatable is specified, the linker acts as if --absolute_exe were specified.</td>
</tr>
<tr>
<td>--mapfile_contents=attribute</td>
<td></td>
<td>Controls the information that appears in the map file.</td>
</tr>
<tr>
<td>--relocatable</td>
<td>-r</td>
<td>Produces a nonexecutable, relocatable output object file</td>
</tr>
<tr>
<td>--rom</td>
<td></td>
<td>Creates a ROM object</td>
</tr>
<tr>
<td>Option</td>
<td>Alias</td>
<td>Description</td>
</tr>
<tr>
<td>----------------------</td>
<td>-------</td>
<td>-----------------------------------------------------------------------------</td>
</tr>
<tr>
<td>--run_abs</td>
<td>-abs</td>
<td>Produces an absolute listing file</td>
</tr>
<tr>
<td>--xml_link_info=file</td>
<td></td>
<td>Generates a well-formed XML file containing detailed information about the result of a link</td>
</tr>
</tbody>
</table>
### Table 2-29. Symbol Management Options

<table>
<thead>
<tr>
<th>Option</th>
<th>Alias</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>--entry_point=symbol</td>
<td>-e</td>
<td>Defines a global symbol that specifies the primary entry point for the executable object file</td>
</tr>
<tr>
<td>--globalize=pattern</td>
<td></td>
<td>Changes the symbol linkage to global for symbols that match pattern</td>
</tr>
<tr>
<td>--hide=pattern</td>
<td></td>
<td>Hides symbols that match the specified pattern</td>
</tr>
<tr>
<td>--localize=pattern</td>
<td></td>
<td>Make the symbols that match the specified pattern local</td>
</tr>
<tr>
<td>--make_global=symbol</td>
<td>-g</td>
<td>Makes symbol global (overrides -h)</td>
</tr>
<tr>
<td>--make_static</td>
<td>-h</td>
<td>Makes all global symbols static</td>
</tr>
<tr>
<td>--no_sym_merge</td>
<td>-b</td>
<td>Disables merge of symbolic debugging information in COFF object files</td>
</tr>
<tr>
<td>--no_symtable</td>
<td>-s</td>
<td>Strips symbol table information and line number entries from the executable object file</td>
</tr>
<tr>
<td>--retain={symbol</td>
<td>section specification}</td>
<td></td>
</tr>
<tr>
<td>--scan_libraries</td>
<td>-scanlibs</td>
<td>Scans all libraries for duplicate symbol definitions</td>
</tr>
<tr>
<td>--symbol_map=refname=defname</td>
<td></td>
<td>Specifies a symbol mapping; references to the refname symbol are replaced with references to the defname symbol</td>
</tr>
<tr>
<td>--undef_sym=symbol</td>
<td>-u</td>
<td>Adds symbol to the symbol table as an unresolved symbol</td>
</tr>
<tr>
<td>--unhide=pattern</td>
<td></td>
<td>Excludes symbols that match the specified pattern from being hidden</td>
</tr>
</tbody>
</table>

### Table 2-30. Run-Time Environment Options

<table>
<thead>
<tr>
<th>Option</th>
<th>Alias</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>--arg_size=size</td>
<td>--args</td>
<td>Reserve size bytes for the argc/argv memory area</td>
</tr>
<tr>
<td>--fill_value=value</td>
<td>-f</td>
<td>Sets default fill value for holes within output sections</td>
</tr>
<tr>
<td>--ram_model</td>
<td>-cr</td>
<td>Initializes variables at load time</td>
</tr>
<tr>
<td>--rom_model</td>
<td>-c</td>
<td>Autoinitializes variables at run time</td>
</tr>
<tr>
<td>--trampolines=[off][on]</td>
<td></td>
<td>Generates far call trampolines. Default is on.</td>
</tr>
</tbody>
</table>

### Table 2-31. Link-Time Optimization Options

<table>
<thead>
<tr>
<th>Option</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>--cinit_compression=[compression_kind]</td>
<td>Specifies the type of compression to apply to the c auto initialization data. Default is rle.</td>
</tr>
<tr>
<td>--compress_dwarf=[off][on]</td>
<td>Aggressively reduces the size of DWARF information from input object files. Default is on.</td>
</tr>
<tr>
<td>--copy_compression=[compression_kind]</td>
<td>Compresses data copied by linker copy tables. Default is rle.</td>
</tr>
<tr>
<td>--unused_section_elimination=[off][on]</td>
<td>Eliminates sections that are not needed in the executable module. Default is on.</td>
</tr>
</tbody>
</table>

### Table 2-32. Miscellaneous Options

<table>
<thead>
<tr>
<th>Option</th>
<th>Alias</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>--disable_clink</td>
<td>-j</td>
<td>Disables conditional linking of COFF object files</td>
</tr>
<tr>
<td>--linker_help</td>
<td>[-]help</td>
<td>Displays information about syntax and available options</td>
</tr>
<tr>
<td>--minimize_trampoline=[off][postorder]</td>
<td>Places sections to minimize number of far trampolines required. Default is postorder.</td>
<td></td>
</tr>
<tr>
<td>--preferred_order=function</td>
<td></td>
<td>Prioritizes placement of functions</td>
</tr>
<tr>
<td>--strict_compatibility=[off][on]</td>
<td>Performs more conservative and rigorous compatibility checking of input object files. Default is on.</td>
<td></td>
</tr>
<tr>
<td>--trampoline_min_spacing=size</td>
<td>When trampoline reservations are spaced more closely than the specified limit, tries to make them adjacent</td>
<td></td>
</tr>
<tr>
<td>--zero_init=[off][on]</td>
<td></td>
<td>Controls preinitialization of uninitialized variables. Default is on.</td>
</tr>
</tbody>
</table>
### Table 2-33. Dynamic Linking Support Options

<table>
<thead>
<tr>
<th>Option</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>--bind_now</td>
<td>Disables Linux default lazy binding mechanisms</td>
</tr>
<tr>
<td>--dsbt_index=index</td>
<td>Specifies the Data Segment Base Table (DSBT) index of this component</td>
</tr>
<tr>
<td>--dsbt_size=size</td>
<td>Specifies the size of the DSBT in words</td>
</tr>
<tr>
<td>--dynamic=[exe</td>
<td>lib]]</td>
</tr>
<tr>
<td>--export=symbol</td>
<td>Specifies symbol exported by ELF object</td>
</tr>
<tr>
<td>--fini=symbol</td>
<td>Specifies symbol name of termination code</td>
</tr>
<tr>
<td>--forced_static_binding=[off</td>
<td>on]</td>
</tr>
<tr>
<td>--import=symbol</td>
<td>Specifies symbol imported by ELF object</td>
</tr>
<tr>
<td>--init=symbol</td>
<td>Specifies symbol name of termination code</td>
</tr>
<tr>
<td>--rpath=dir</td>
<td>Adds directory to beginning of library search path</td>
</tr>
<tr>
<td>--runpath=dir</td>
<td>Adds directory to end of library search path</td>
</tr>
<tr>
<td>--soname=soname</td>
<td>Specifies ELF shared object file name</td>
</tr>
</tbody>
</table>

### 2.3.1 Frequently Used Options

Following are detailed descriptions of options that you will probably use frequently:

**--c_src_interlist**

Invokes the interlist feature, which interweaves original C/C++ source with compiler-generated assembly language. The interlisted C statements may appear to be out of sequence. You can use the interlist feature with the optimizer by combining the --optimizer_interlist and --c_src_interlist options. See Section 3.14.2. The --c_src_interlist option can have a negative performance and/or code size impact.

**--cmd_file=filename**

Appends the contents of a file to the option set. You can use this option to avoid limitations on command line length or C style comments imposed by the host operating system. Use a # or ; at the beginning of a line in the command file to include comments. You can also include comments by delimiting them with /* and */. To specify options, surround hyphens with quotation marks. For example, "--"quiet.

You can use the --cmd_file option multiple times to specify multiple files. For instance, the following indicates that file3 should be compiled as source and file1 and file2 are --cmd_file files:

```bash
c16x --cmd_file=file1 --cmd_file=file2 file3
```

**--compile_only**

Suppresses the linker and overrides the --run_linker option, which specifies linking. The --compile_only option's short form is -c. Use this option when you have --run_linker specified in the C6X_C_OPTION environment variable and you do not want to link. See Section 5.1.3.

**--define=name[=def]**

Predefines the constant name for the preprocessor. This is equivalent to inserting #define name def at the top of each C source file. If the optional[=def] is omitted, the name is set to 1. The --define option's short form is -D.

If you want to define a quoted string and keep the quotation marks, do one of the following:

- For Windows, use --define=name="\"string def\"". For example, --define=car="\"sedan\""
- For UNIX, use --define=name="string def". For example, --define=car="sedan"
- For Code Composer Studio, enter the definition in a file and include that file with the --cmd_file option.
Changing the Compiler's Behavior With Options

--help
Displays the syntax for invoking the compiler and lists available options. If the --help option is followed by another option or phrase, detailed information about the option or phrase is displayed. For example, to see information about debugging options use --help debug.

--include_path=directory
Adds directory to the list of directories that the compiler searches for #include files. The --include_path option's short form is -I. You can use this option several times to define several directories; be sure to separate the --include_path options with spaces. If you do not specify a directory name, the preprocessor ignores the --include_path option. See Section 2.6.2.1.

--keep_asm
Retains the assembly language output from the compiler or assembly optimizer. Normally, the compiler deletes the output assembly language file after assembly is complete. The --keep_asm option's short form is -k.

--quiet
Suppresses banners and progress information from all the tools. Only source filenames and error messages are output. The --quiet option's short form is -q.

--run_linker
Runs the linker on the specified object files. The --run_linker option and its parameters follow all other options on the command line. All arguments that follow --run_linker are passed to the linker. The --run_linker option's short form is -z. See Section 5.1.

--skip_assembler
Compiles only. The specified source files are compiled but not assembled or linked. The --skip_assembler option's short form is -n. This option overrides --run_linker. The output is assembly language output from the compiler.

--src_interlist
Invokes the interlist feature, which interweaves optimizer comments or C/C++ source with assembly source. If the optimizer is invoked (--opt_level=n option), optimizer comments are interlisted with the assembly language output of the compiler, which may rearrange code significantly. If the optimizer is not invoked, C/C++ source statements are interlisted with the assembly language output of the compiler, which allows you to inspect the code generated for each C/C++ statement. The --src_interlist option implies the --keep_asm option. The --src_interlist option's short form is -s.

--tool_version
Prints the version number for each tool in the compiler. No compiling occurs.

--undefine=name
Undefines the predefined constant name. This option overrides any --define options for the specified constant. The --undefine option's short form is -U.

--verbose
Displays progress information and toolset version while compiling. Resets the --quiet option.

2.3.2 Miscellaneous Useful Options
Following are detailed descriptions of miscellaneous options:

--check_misra={all|required|advisory|none|rulespec}
Displays the specified amount or type of MISRA-C documentation. The rulespec parameter is a comma-separated list of specifiers. See Section 6.3 for details.

--fp_reassoc={on|off}
Enables or disables the reassociation of floating-point arithmetic. If --strict_ansi is set, --fp_reassoc=off is set since reassociation of floating-point arithmetic is an ANSI violation.
--keep_unneeded_statics

Does not delete unreferenced static variables. The parser by default remarks about and then removes any unreferenced static variables. The --keep_unneeded_statics option keeps the parser from deleting unreferenced static variables and any static functions that are referenced by these variable definitions. Unreferenced static functions will still be removed.

--no_const_clink

Tells the compiler to not generate .clink directives for const global arrays. By default, these arrays are placed in a .const subsection and conditionally linked.

--misra_advisory={error|warning|remark|suppress}

Sets the diagnostic severity for advisory MISRA-C:2004 rules.

--misra_required={error|warning|remark|suppress}

Sets the diagnostic severity for required MISRA-C:2004 rules.

--preinclude=filename

Includes the source code of filename at the beginning of the compilation. This can be used to establish standard macro definitions. The filename is searched for in the directories on the include search list. The files are processed in the order in which they were specified.

--printf_support={full|nofloat|minimal}

Enables support for smaller, limited versions of the printf and sprintf run-time-support functions. The valid values are:

- full: Supports all format specifiers. This is the default.
- nofloat: Excludes support for printing and scanning floating-point values. Supports all format specifiers except %f, %F, %g, %G, %e, and %E.
- minimal: Supports the printing and scanning of integer, char, or string values without width or precision flags. Specifically, only the %%, %d, %o, %c, %s, and %x format specifiers are supported.

There is no run-time error checking to detect if a format specifier is used for which support is not included. The --printf_support option precedes the --run_linker option, and must be used when performing the final link.

--sat_reassoc={on|off}

Enables or disables the reassociation of saturating arithmetic.

2.3.3 Run-Time Model Options

These options are specific to the TMS302C6000 toolset. See the referenced sections for more information. TMS320C6000-specific assembler options are listed in Section 2.3.11.

--abi={eabi|coffabi}

Specifies application binary interface (ABI). Default support is for COFF ABI. See Section 2.16. Also, refer to The C6000 Embedded Application Binary Interface Application Report (SPRB89).

All code in an EABI application must be built for EABI. Make sure all your libraries are available in EABI mode before migrating your existing COFF ABI systems to C6000 EABI. See http://tiexpressdsp.com/index.php/EABI_Support_in_C6000_Compiler for full details.

--big_endian

Produces code in big-endian format. By default, little-endian code is produced.

--advice:performance

Generates compile-time optimization Advice. See Section 2.15.

--debug_software_pipeline

Produces verbose software pipelining report. See Section 3.2.2.

--disable_software_pipelining

Turns off software pipelining. See Section 3.2.1.

--fp_not_associative

Compiler does not reorder floating-point operations. See Section 3.11.
### Changing the Compiler’s Behavior With Options

#### --interrupt_threshold=n
Specifies an interrupt threshold value \( n \) that sets the maximum cycles the compiler can disable interrupts. See Section 2.12.

#### --mem_model:const=type
Allows const objects to be made far independently of the --mem_model:data option. The \( \text{type} \) can be data, far, or far_aggregates. See Section 7.1.5.3

#### --mem_model:data=type
Specifies data access model as \( \text{type} \) far, far_aggregates, or near. Default is far_aggregates. See Section 7.1.5.1.

#### --silicon_version=num
Selects the target CPU version. See Section 2.3.4.

#### --small_enum
By default, the C6000 compiler uses 32 bits for every enum. When you use the --small_enum option, the smallest possible byte size for the enumeration type is used. For example, enum example_enum (first = -128, second = 0, third = 127) uses only one byte instead of 32 bits when the --small_enum option is used. Similarly, enum a_short_enum (bottom = -32768, middle = 0, top = 32767) fits into two bytes instead of four. Do not link object files compiled with the --small_enum option with object files that have been compiled without it. If you use the --small_enum option, you must use it with all of your C/C++ files; otherwise, you will encounter errors that cannot be detected until run time.

#### --speculate_loads=n
Specifies speculative load byte count threshold. Allows speculative execution of loads with bounded addresses. See Section 3.2.3.1.

#### --speculate_unknown_loads
Allows speculative execution of loads with unbounded addresses.

#### --target_compatibility_6200
Compiles C6400 code that is compatible with array alignment restrictions of version 4.0 tools or C6200/C6700 object code. This option is deprecated. See Section 2.13

#### --use_const_for_alias_analysis
Uses const to disambiguate pointers.

#### --wchar_t={32|16}
Sets the size (in bits) of the C/C++ type wchar_t. The --abi=eabi option is required when --wchar_t=32 is used. By default the compiler generates 16-bit wchar_t. In COFF ABI mode, a warning is generated and --wchar_t=32 is ignored. 16-bit wchar_t objects are not compatible with the 32-bit wchar_t objects; an error is generated if they are combined. When the --linux option is specified, it implies --wchar_t=32 since Linux uses 32-bit extended characters.

### 2.3.4 Selecting Target CPU Version (--silicon_version Option)

Select the target CPU version using the last four digits of the TMS320C6000 part number. This selection controls the use of target-specific instructions and alignment, such as --silicon_version=6701 or --silicon_version=6412. Alternatively, you can also specify the family of the part, for example, --silicon_version=6400 or --silicon_version=6700. If this option is not used, the compiler generates code for the C6200 parts. If the --silicon_version option is not specified, the code generated runs on all C6000 parts; however, the compiler does not take advantage of target-specific instructions or alignment. This option has the alias -mv. Common target CPU version options include:

- -mv6200
- -mv6700
- -mv6700+
- -mv6400+
- -mv6740
- -mv6600
2.3.5 Symbolic Debugging and Profiling Options

The following options are used to select symbolic debugging or profiling:

---profile:breakpt
Disables optimizations that would cause incorrect behavior when using a breakpoint-based profiler.

---profile:power
Enables power profiling support by inserting NOPs into the frame code. These NOPs can then be instrumented by the power profiling tooling to track the power usage of functions. If the power profiling tool is not used, this option increases the cycle count of each function because of the NOPs. The --profile:power option also disables optimizations that cannot be handled by the power-profiler.

---symdebug:coff
Enables symbolic debugging using the alternate STABS debugging format. This may be necessary to allow debugging with older debuggers or custom tools, which do not read the DWARF format. STABS format is not supported for C6400+ or ELF.

---symdebug:dwarf
Generates directives that are used by the C/C++ source-level debugger and enables assembly source debugging in the assembler. The --symdebug:dwarf option's short form is -g. The --symdebug:dwarf option disables many code generator optimizations, because they disrupt the debugger. You can use the --symdebug:dwarf option with the --opt_level (aliased as -O) option to maximize the amount of optimization that is compatible with debugging (see Section 3.14.3.1).

For more information on the DWARF debug format, see The DWARF Debugging Standard.

---symdebug:keep_all_types
Effects the ability to view unused types in the debugger that are from a COFF executable. Use this option to view the details of a type that is defined but not used to define any symbols. Such unused types are not included in the debug information by default for COFF. However, in EABI mode, all types are included in the debug information and this option has no effect.

---symdebug:dwarf_version={2|3}
Specifies the DWARF debugging format version (2 or 3) to be generated when --symdebug:dwarf or --symdebug:skeletal is specified. By default, the compiler generates DWARF version 3 debug information. For more information on TI extensions to the DWARF language, see The Impact of DWARF on TI Object Files (SPRAAB5).

---symdebug:none
Disables all symbolic debugging output. This option is not recommended; it prevents debugging and most performance analysis capabilities.

---symdebug:profile_coff
Adds the necessary debug directives to the object file which are needed by the profiler to allow function level profiling with minimal impact on optimization (when used). Using --symdebug:coff may hinder some optimizations to ensure that debug ability is maintained, while this option will not hinder optimization. STABS format is not supported for C6400+ or ELF.

You can set breakpoints and profile on function-level boundaries in Code Composer Studio, but you cannot single-step through code as with full debug ability.

---symdebug:skeletal
Generates as much symbolic debugging information as possible without hindering optimization. Generally, this consists of global-scope information only. This option reflects the default behavior of the compiler.

See Section 2.3.13 for a list of deprecated symbolic debugging options.
### 2.3.6 Specifying Filenames

The input files that you specify on the command line can be C source files, C++ source files, assembly source files, linear assembly files, or object files. The compiler uses filename extensions to determine the file type.

<table>
<thead>
<tr>
<th>Extension</th>
<th>File Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>.asm, .abs, or .s* (extension begins with s)</td>
<td>Assembly source</td>
</tr>
<tr>
<td>.c</td>
<td>C source</td>
</tr>
<tr>
<td>.C</td>
<td>Depends on operating system</td>
</tr>
<tr>
<td>.cpp, .cxx, .cc</td>
<td>C++ source</td>
</tr>
<tr>
<td>.obj, .o*, .dll, .so</td>
<td>Object</td>
</tr>
<tr>
<td>.sa</td>
<td>Linear assembly</td>
</tr>
</tbody>
</table>

#### NOTE: Case Sensitivity in Filename Extensions

Case sensitivity in filename extensions is determined by your operating system. If your operating system is not case sensitive, a file with a .C extension is interpreted as a C file. If your operating system is case sensitive, a file with a .C extension is interpreted as a C++ file.

For information about how you can alter the way that the compiler interprets individual filenames, see Section 2.3.7. For information about how you can alter the way that the compiler interprets and names the extensions of assembly source and object files, see Section 2.3.10.

You can use wildcard characters to compile or assemble multiple files. Wildcard specifications vary by system; use the appropriate form listed in your operating system manual. For example, to compile all of the files in a directory with the extension .cpp, enter the following:

```
c16x *.cpp
```

#### NOTE: No Default Extension for Source Files is Assumed

If you list a filename called example on the command line, the compiler assumes that the entire filename is example not example.c. No default extensions are added onto files that do not contain an extension.

### 2.3.7 Changing How the Compiler Interprets Filenames

You can use options to change how the compiler interprets your filenames. If the extensions that you use are different from those recognized by the compiler, you can use the filename options to specify the type of file. You can insert an optional space between the option and the filename. Select the appropriate option for the type of file you want to specify:

- `--ap_file=filename` for a linear assembly source file
- `--asm_file=filename` for an assembly language source file
- `--c_file=filename` for a C source file
- `--cpp_file=filename` for a C++ source file
- `--obj_file=filename` for an object file

For example, if you have a C source file called file.s and an assembly language source file called assy, use the `--asm_file` and `--c_file` options to force the correct interpretation:

```
c16x --c_file=file.s --asm_file=assy
```

You cannot use the filename options with wildcard specifications.
2.3.8 Changing How the Compiler Processes C Files

The --cpp_default option causes the compiler to process C files as C++ files. By default, the compiler treats files with a .c extension as C files. See Section 2.3.9 for more information about filename extension conventions.

2.3.9 Changing How the Compiler Interprets and Names Extensions

You can use options to change how the compiler program interprets filename extensions and names the extensions of the files that it creates. The filename extension options must precede the filenames they apply to on the command line. You can use wildcard specifications with these options. An extension can be up to nine characters in length. Select the appropriate option for the type of extension you want to specify:

- `--ap_extension=new extension` for a linear assembly source file
- `--asm_extension=new extension` for an assembly language file
- `--c_extension=new extension` for a C source file
- `--cpp_extension=new extension` for a C++ source file
- `--listing_extension=new extension` sets default extension for listing files
- `--obj_extension=new extension` for an object file

The following example assembles the file fit.rrr and creates an object file named fit.o:

```
c16x --asm_extension=.rrr --obj_extension=.o fit.rrr
```

The period (.) in the extension is optional. You can also write the example above as:

```
c16x --asm_extension=rrr --obj_extension=o fit.rrr
```

2.3.10 Specifying Directories

By default, the compiler program places the object, assembly, and temporary files that it creates into the current directory. If you want the compiler program to place these files in different directories, use the following options:

- `--abs_directory=directory` Specifies the destination directory for absolute listing files. The default is to use the same directory as the object file directory. For example:
  
  ```
c16x --abs_directory=d:\abso_list
  ```

- `--asm_directory=directory` Specifies a directory for assembly files. For example:
  
  ```
c16x --asm_directory=d:\assembly
  ```

- `--list_directory=directory` Specifies the destination directory for assembly listing files and cross-reference listing files. The default is to use the same directory as the object file directory. For example:
  
  ```
c16x --list_directory=d:\listing
  ```

- `--obj_directory=directory` Specifies a directory for object files. For example:
  
  ```
c16x --obj_directory=d:\object
  ```

- `--output_file=filename` Specifies a compilation output file name; can override --obj_directory. For example:
  
  ```
c16x --output_file=transfer
  ```

- `--pp_directory=directory` Specifies a preprocessor file directory for object files (default is .). For example:
  
  ```
c16x --pp_directory=d:\preproc
  ```

- `--temp_directory=directory` Specifies a directory for temporary intermediate files. For example:
  
  ```
c16x --temp_directory=d:\temp
  ```
Assembler Options

Following are assembler options that you can use with the compiler. For more information, see the TMS320C6000 Assembly Language Tools User's Guide.

---absolute_listing
Generates a listing with absolute addresses rather than section-relative offsets.

---asm_define=name[=def]
Predefines the constant name for the assembler; produces a .set directive for a constant or a .arg directive for a string. If the optional [=def] is omitted, the name is set to 1. If you want to define a quoted string and keep the quotation marks, do one of the following:

- For Windows, use --asm_define=name="string def". For example: --asm_define=car="sedan"
- For UNIX, use --asm_define=name="string def". For example: --asm_define=car="sedan"
- For Code Composer Studio, enter the definition in a file and include that file with the --cmd_file option.

---asm_dependency
Performs preprocessing for assembly files, but instead of writing preprocessed output, writes a list of dependency lines suitable for input to a standard make utility. The list is written to a file with the same name as the source file but with a .ppa extension.

---asm_includes
Performs preprocessing for assembly files, but instead of writing preprocessed output, writes a list of files included with the #include directive. The list is written to a file with the same name as the source file but with a .ppa extension.

---asm_listing
Produces an assembly listing file.

---asm_undefine=name
Undefines the predefined constant name. This option overrides any --asm_define options for the specified name.

---copy_file=filename
Copies the specified file for the assembly module; acts like a .copy directive. The file is inserted before source file statements. The copied file appears in the assembly listing files.

---cross_reference
Produces a symbolic cross-reference in the listing file.

---include_file=filename
Includes the specified file for the assembly module; acts like a .include directive. The file is included before source file statements. The included file does not appear in the assembly listing files.

---machine_regs
Displays reg operands as machine registers in the assembly file for debugging purposes.

---no_compress
Prevents compression in the assembler. For C6400+, C6740, and C6600, compression is the changing of 32-bit instructions to 16-bit instructions, where possible/profitable.

---no_reload_errors
Turns off all reload-related loop buffer error messages in assembly code for C6400+, C6740, and C6600.

---output_all_syms
Puts labels in the symbol table. Label definitions are written to the COFF symbol table for use with symbolic debugging.

---strip_coff_underscore
Aids in transitioning hand-coded assembly from COFF to EABI.

---syms_ignore_case
Makes letter case insignificant in the assembly language source files. For example, --syms_ignore_case makes the symbols ABC and abc equivalent. If you do not use this option, case is significant (this is the default).
2.3.12 Dynamic Linking

The C6000 Code Generation Tools (CGT) (beginning with v7.3) support dynamic linking provided you build with EABI. For details on dynamic linking with the C6000 CGT, see the TMS320C6000 Assembly Language Tools User's Guide and http://processors.wiki.ti.com/index.php/C6000_Dynamic_Linking.

If you are not already familiar with the limitations of EABI support in the C6000 compiler, see http://processors.wiki.ti.com/index.php/EABI_Support_in_C6000_Compiler.

For more information about support for C6000 Linux ABI in the C6000 Code Generation Tools, see http://processors.wiki.ti.com/index.php/C6000_Linux_Support

Table 2-34 and Table 2-35 provide a brief summary of the compiler and linker options that are related to support for the Dynamic Linking Model in the C6000 CGT.

<table>
<thead>
<tr>
<th>Option</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>--abi=eabi</td>
<td>Specifies that EABI run-time model is to be used.</td>
</tr>
<tr>
<td>--dsbt</td>
<td>Generates addressing via Dynamic Segment Base Table.</td>
</tr>
<tr>
<td>--export_all_cpp_vtbl</td>
<td>Exports C++ virtual tables by default.</td>
</tr>
<tr>
<td>--import_undef[=off</td>
<td>on]</td>
</tr>
<tr>
<td>--import_helper_functions</td>
<td>Specifies that all compiler generated calls to run-time-support functions are treated as calls to imported functions.</td>
</tr>
<tr>
<td>--inline_ptr[=off</td>
<td>on]</td>
</tr>
<tr>
<td>--linux</td>
<td>Generates C6000 Linux ABI compliant code.</td>
</tr>
<tr>
<td>--pic</td>
<td>Generates position independent code suitable for a dynamic shared object.</td>
</tr>
<tr>
<td>--visibility=</td>
<td>Specifies a default visibility to be assumed for global symbols.</td>
</tr>
<tr>
<td></td>
<td>{hidden</td>
</tr>
<tr>
<td>-wchar_t</td>
<td>Generates 32-bit wchar_t type when --abi=eabi is specified.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Option</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>--dsbt_index=int</td>
<td>Requests a specific Data Segment Base Table (DSBT) index to be associated with the current output file. If the DSBT model is being used, and you do not request a specific DSBT index for the output file, then a DSBT index is assigned to the module at load time.</td>
</tr>
<tr>
<td>--dsbt_size=int</td>
<td>Specifies the size of the Data Segment Base Table (DSBT) for the current output file, in words. If the DSBT model is being used, this option can be used to override the default DSBT size (8 words).</td>
</tr>
<tr>
<td>--dynamic[=exe]</td>
<td>Specifies that the result of a link will be a lightweight dynamic executable.</td>
</tr>
<tr>
<td>--dynamic=lib</td>
<td>Specifies that the result of a link will be a dynamic library.</td>
</tr>
<tr>
<td>--export=symbol</td>
<td>Specifies that symbol is exported by the ELF object that is generated for this link.</td>
</tr>
<tr>
<td>--fini=symbol</td>
<td>Specifies the symbol name of the termination code for the output file currently being linked.</td>
</tr>
<tr>
<td>--import=symbol</td>
<td>Specifies that symbol is imported by the ELF object that is generated for this link.</td>
</tr>
<tr>
<td>--init=symbol</td>
<td>Specifies the symbol name of the initialization code for the output file currently being linked.</td>
</tr>
<tr>
<td>--rpath=dir</td>
<td>Adds a directory to the beginning of the dynamic library search path.</td>
</tr>
<tr>
<td>--runpath=dir</td>
<td>Adds a directory to the end of the dynamic library search path.</td>
</tr>
<tr>
<td>--shared</td>
<td>Generates an ELF dynamic shared object (DSO)</td>
</tr>
<tr>
<td>--soname=string</td>
<td>Specifies shared object name to be used to identify this ELF object to the any downstream ELF object consumers.</td>
</tr>
<tr>
<td>--sysv</td>
<td>Generates SysV ELF dynamic object module.</td>
</tr>
</tbody>
</table>
2.3.13 Deprecated Options

Several compiler options have been deprecated. The compiler continues to accept these options, but they are not recommended for use. Future releases of the tools will not support these options. Table 2-36 lists the deprecated options and the options that have replaced them.

Table 2-36. Compiler Backwards-Compatibility Options Summary

<table>
<thead>
<tr>
<th>Old Option</th>
<th>Effect</th>
<th>New Option</th>
</tr>
</thead>
<tbody>
<tr>
<td>-gp</td>
<td>Allows function-level profiling of optimized code</td>
<td>--symdebug:dwarf or -g</td>
</tr>
<tr>
<td>-gt</td>
<td>Enables symbolic debugging using the alternate STABS debugging format</td>
<td>--symdebug:coff</td>
</tr>
<tr>
<td>-gw</td>
<td>Enables symbolic debugging using the DWARF debugging format</td>
<td>--symdebug:dwarf or -g</td>
</tr>
</tbody>
</table>

Additionally, the --symdebug:profile_coff option has been added to enable function-level profiling of optimized code with symbolic debugging using the STABS debugging format (the --symdebug:coff or -gt option).

Since C6400+, C6740, and C6600 produce only DWARF debug information, the -gp, -gt/--symdebug:coff, and --symdebug:profile_coff options are not supported for C6400+, C6740, and C6600.

2.4 Controlling the Compiler Through Environment Variables

An environment variable is a system symbol that you define and assign a string to. Setting environment variables is useful when you want to run the compiler repeatedly without re-entering options, input filenames, or pathnames.

### NOTE: C_OPTION and C_DIR

The C_OPTION and C_DIR environment variables are deprecated. Use the device-specific environment variables instead.

2.4.1 Setting Default Compiler Options (C6X_C_OPTION)

You might find it useful to set the compiler, assembler, and linker default options using the C6X_C_OPTION environment variable. If you do this, the compiler uses the default options and/or input filenames that you name C6X_C_OPTION every time you run the compiler.

Setting the default options with these environment variables is useful when you want to run the compiler repeatedly with the same set of options and/or input files. After the compiler reads the command line and the input filenames, it looks for the C6X_C_OPTION environment variable and processes it.

The table below shows how to set the C6X_C_OPTION environment variable. Select the command for your operating system:

<table>
<thead>
<tr>
<th>Operating System</th>
<th>Enter</th>
</tr>
</thead>
<tbody>
<tr>
<td>UNIX (Bourne shell)</td>
<td>C6X_C_OPTION=&quot; option1, [option2 . . .]&quot;; export C6X_C_OPTION</td>
</tr>
<tr>
<td>Windows</td>
<td>set C6X_C_OPTION= option1, [option2 . . .]</td>
</tr>
</tbody>
</table>

Environment variable options are specified in the same way and have the same meaning as they do on the command line. For example, if you want to always run quietly (the --quiet option), enable C/C++ source interlisting (the --src_interlist option), and link (the --run_linker option) for Windows, set up the C6X_C_OPTION environment variable as follows:

set C6X_C_OPTION=--quiet --src_interlist --run_linker
Controlling the Compiler Through Environment Variables

In the following examples, each time you run the compiler, it runs the linker. Any options following --run_linker on the command line or in C6X_C_OPTION are passed to the linker. Thus, you can use the C6X_C_OPTION environment variable to specify default compiler and linker options and then specify additional compiler and linker options on the command line. If you have set --run_linker in the environment variable and want to compile only, use the compiler --compile_only option. These additional examples assume C6X_C_OPTION is set as shown above:

cl6x *.c ; compiles and links
cl6x --compile_only *.c ; only compiles
cl6x *.c --run_linker lnk.cmd ; compiles and links using a command file
cl6x --compile_only *.c --run_linker lnk.cmd ; only compiles (--compile_only overrides --run_linker)

For details on compiler options, see Section 2.3. For details on linker options, see the Linker Description chapter in the TMS320C6000 Assembly Language Tools User's Guide.

2.4.2 Naming an Alternate Directory (C6X_C_DIR)

The linker uses the C6X_C_DIR environment variable to name alternate directories that contain object libraries. The command syntaxes for assigning the environment variable are:

<table>
<thead>
<tr>
<th>Operating System</th>
<th>Enter</th>
</tr>
</thead>
<tbody>
<tr>
<td>UNIX (Bourne shell)</td>
<td>C6X_C_DIR=&quot;pathname1; pathname2;...&quot;; export C6X_C_DIR</td>
</tr>
<tr>
<td>Windows</td>
<td>set C6X_C_DIR=.pathname1; pathname2;...</td>
</tr>
</tbody>
</table>

The pathnames are directories that contain input files. The pathnames must follow these constraints:

- Pathnames must be separated with a semicolon.
- Spaces or tabs at the beginning or end of a path are ignored. For example, the space before and after the semicolon in the following is ignored:
  set C6X_C_DIR=c:\path\one\to\tools ; c:\path\two\to\tools
- Spaces and tabs are allowed within paths to accommodate Windows directories that contain spaces. For example, the pathnames in the following are valid:
  set C6X_C_DIR=c:\first path\to\tools;d:\second path\to\tools

The environment variable remains set until you reboot the system or reset the variable by entering:

<table>
<thead>
<tr>
<th>Operating System</th>
<th>Enter</th>
</tr>
</thead>
<tbody>
<tr>
<td>UNIX (Bourne shell)</td>
<td>unset C6X_C_DIR</td>
</tr>
<tr>
<td>Windows</td>
<td>set C6X_C_DIR=</td>
</tr>
</tbody>
</table>
Precompiled Header Support

Precompiled header files may reduce the compile time for applications whose source files share a common set of headers, or a single file which has a large set of header files. Using precompiled headers, some recompilation is avoided thus saving compilation time.

There are two ways to use precompiled header files. One is the automatic precompiled header file processing and the other is called the manual precompiled header file processing.

2.5.1 Automatic Precompiled Header

The option to turn on automatic precompiled header processing is: --pch. Under this option, the compile step takes a snapshot of all the code prior to the header stop point, and dump it out to a file with suffix .pch. This snapshot does not have to be recompiled in the future compilations of this file or compilations of files with the same header files.

The stop point typically is the first token in the primary source file that does not belong to a preprocessing directive. For example, in the following the stopping point is before int i:

```c
#include "x.h"
#include "y.h"
int i;
```

Carefully organizing the include directives across multiple files so that their header files maximize common usage can increase the compile time savings when using precompiled headers.

A precompiled header file is produced only if the header stop point and the code prior to it meet certain requirements.

2.5.2 Manual Precompiled Header

You can manually control the creation and use of precompiled headers by using several command line options. You specify a precompiled header file with a specific filename as follows:

```
--create_pch=filename
```

The --use_pch=filename option specifies that the indicated precompiled header file should be used for this compilation. If this precompiled header file is invalid, if its prefix does not match the prefix for the current primary source file for example, a warning is issued and the header file is not used.

If --create_pch=filename or --use_pch=filename is used with --pch_dir, the indicated filename, which can be a path name, is tacked on to the directory name, unless the filename is an absolute path name.

The --create_pch, --use_pch, and --pch options cannot be used together. If more than one of these options is specified, only the last one is applied. In manual mode, the header stop points are determined in the same way as in automatic mode. The precompiled header file applicability is determined in the same manner.

2.5.3 Additional Precompiled Header Options

The --pch_verbose option displays a message for each precompiled header file that is considered but not used. The --pch_dir=pathname option specifies the path where the precompiled header file resides.
2.6 Controlling the Preprocessor

This section describes specific features that control the preprocessor, which is part of the parser. A general description of C preprocessing is in section A12 of K&R. The C/C++ compiler includes standard C/C++ preprocessing functions, which are built into the first pass of the compiler. The preprocessor handles:

- Macro definitions and expansions
- #include files
- Conditional compilation
- Various preprocessor directives, specified in the source file as lines beginning with the # character

The preprocessor produces self-explanatory error messages. The line number and the filename where the error occurred are printed along with a diagnostic message.

2.6.1 Predefined Macro Names

The compiler maintains and recognizes the predefined macro names listed in Table 2-37.

Table 2-37. Predefined C6000 Macro Names

<table>
<thead>
<tr>
<th>Macro Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>DATE</em></td>
<td>Expands to the compilation date in the form mmm dd yyyy</td>
</tr>
<tr>
<td><em>FILE</em></td>
<td>Expands to the current source filename</td>
</tr>
<tr>
<td><em>LINE</em></td>
<td>Expands to the current line number</td>
</tr>
<tr>
<td><em>STDC</em></td>
<td>Defined to indicate that compiler conforms to ISO C Standard. See Section 6.1 for exceptions to ISO C conformance.</td>
</tr>
<tr>
<td><em>STDC_VERSION</em></td>
<td>C standard macro</td>
</tr>
<tr>
<td><em>TI_32BIT_LONG</em></td>
<td>Defined to 1 if the EABI ABI is enabled (see Section 2.16); otherwise, it is undefined.</td>
</tr>
<tr>
<td><em>TI_40BIT_LONG</em></td>
<td>Defined to 1 if <em>TI_32BIT_LONG</em> is not defined; otherwise, it is undefined.</td>
</tr>
<tr>
<td><em>TI_COMPILER_VERSION</em></td>
<td>Defined to a 7-9 digit integer, depending on if X has 1, 2, or 3 digits. The number does not contain a decimal. For example, version 3.2.1 is represented as 3002001. The leading zeros are dropped to prevent the number being interpreted as an octal.</td>
</tr>
<tr>
<td><em>TI_EABI</em></td>
<td>Defined to 1 if the EABI is enabled (see Section 2.16); otherwise, it is undefined.</td>
</tr>
<tr>
<td><em>TI_GNU_ATTRIBUTE_SUPPORT</em></td>
<td>Defined if GCC extensions are enabled (the --gcc option is used); otherwise, it is undefined.</td>
</tr>
<tr>
<td><em>TI_STRICT_ANSI_MODE</em>_</td>
<td>Defined if strict ANSI/ISO mode is enabled (the --strict_ansi option is used); otherwise, it is undefined.</td>
</tr>
<tr>
<td><em>TI_WCHAR_T_BITS</em></td>
<td>Expands to the compilation time in the form &quot;hh:mm:ss&quot;</td>
</tr>
<tr>
<td><em>TIME</em></td>
<td>Expands to the current source filename</td>
</tr>
<tr>
<td><em>WCHAR_T_TYPE</em></td>
<td>Defined if big-endian mode is selected (the --big_endian option is used); otherwise, it is undefined.</td>
</tr>
<tr>
<td>_BIG_ENDIAN</td>
<td>Defined if little-endian mode is selected (the --little_endian option is not used); otherwise, it is undefined.</td>
</tr>
<tr>
<td><em>INLINE</em></td>
<td>Expands to 1 if optimization is used (--opt_level or -O option); undefined otherwise. Regardless of any optimization, always undefined when --no_inlining is used.</td>
</tr>
<tr>
<td><em>LITTLE_ENDIAN</em></td>
<td>Defined if little-endian mode is selected (the --little_endian option is not used); otherwise, it is undefined.</td>
</tr>
<tr>
<td><em>TMS320C6X</em></td>
<td>Always defined</td>
</tr>
<tr>
<td><em>TMS320C6200</em></td>
<td>Defined if target is C6200</td>
</tr>
<tr>
<td><em>TMS320C6400</em></td>
<td>Defined if target is C6400, C6400+, C6740, or C6600</td>
</tr>
<tr>
<td><em>TMS320C6400_PLUS</em></td>
<td>Defined if target is C6400+, C6740, or C6600</td>
</tr>
<tr>
<td><em>TMS320C6600</em></td>
<td>Defined if target is C6600</td>
</tr>
<tr>
<td><em>TMS320C6700</em></td>
<td>Defined if target is C6700, C6700+, C6740, or C6600</td>
</tr>
<tr>
<td><em>TMS320C6700_PLUS</em></td>
<td>Defined if target is C6700+, C6740, or C6600</td>
</tr>
<tr>
<td><em>TMS320C6740</em></td>
<td>Defined if target is C6740 or C6600</td>
</tr>
<tr>
<td><em>TMS320C6X</em></td>
<td>Always defined for use as alternate name for _TMS320C6x</td>
</tr>
</tbody>
</table>

(1) Specified by the ISO standard
You can use the names listed in Table 2-37 in the same manner as any other defined name. For example,

```c
printf ( "%s %s", __TIME__, __DATE__);
```

translates to a line such as:

```c
printf("%s %s", "13:58:17", "Jan 14 1997");
```

### 2.6.2 The Search Path for #include Files

The #include preprocessor directive tells the compiler to read source statements from another file. When specifying the file, you can enclose the filename in double quotes or in angle brackets. The filename can be a complete pathname, partial path information, or a filename with no path information.

- If you enclose the filename in double quotes (" "), the compiler searches for the file in the following directories in this order:
  1. The directory of the file that contains the #include directive and in the directories of any files that contain that file.
  2. Directories named with the --include_path option.
  3. Directories set with the C6X_C_DIR environment variable.
- If you enclose the filename in angle brackets (< >), the compiler searches for the file in the following directories in this order:
  1. Directories named with the --include_path option.
  2. Directories set with the C6X_C_DIR environment variable.

See Section 2.6.2.1 for information on using the --include_path option. See Section 2.4.2 for more information on input file directories.

#### 2.6.2.1 Changing the #include File Search Path (--include_path Option)

The --include_path option names an alternate directory that contains #include files. The --include_path option's short form is -I. The format of the --include_path option is:

```c
--include_path=directory1 [--include_path=directory2 ...]
```

There is no limit to the number of --include_path options per invocation of the compiler; each --include_path option names one directory. In C source, you can use the #include directive without specifying any directory information for the file; instead, you can specify the directory information with the --include_path option. For example, assume that a file called source.c is in the current directory. The file source.c contains the following directive statement:

```c
#include "alt.h"
```

Assume that the complete pathname for alt.h is:

- UNIX /tools/files/alt.h
- Windows c:\tools\files\alt.h

The table below shows how to invoke the compiler. Select the command for your operating system:

<table>
<thead>
<tr>
<th>Operating System</th>
<th>Enter</th>
</tr>
</thead>
<tbody>
<tr>
<td>UNIX</td>
<td>cl6x --include_path=/tools/files source.c</td>
</tr>
<tr>
<td>Windows</td>
<td>cl6x --include_path=c:\tools\files source.c</td>
</tr>
</tbody>
</table>
NOTE: Specifying Path Information in Angle Brackets

If you specify the path information in angle brackets, the compiler applies that information relative to the path information specified with --include_path options and the C6X_C_DIR environment variable.

For example, if you set up C6X_C_DIR with the following command:

```
C6X_C_DIR */usr/include;/usr/ucb"; export C6X_C_DIR
```

or invoke the compiler with the following command:

```
c16x --include_path=/usr/include file.c
```

and file.c contains this line:

```
#include <sys/proc.h>
```

the result is that the included file is in the following path:

```
/usr/include/sys/proc.h
```

2.6.3 Generating a Preprocessed Listing File (--preproc_only Option)

The --preproc_only option allows you to generate a preprocessed version of your source file with an extension of .pp. The compiler’s preprocessing functions perform the following operations on the source file:

- Each source line ending in a backslash (\) is joined with the following line.
- Trigraph sequences are expanded.
- Comments are removed.
- #include files are copied into the file.
- Macro definitions are processed.
- All macros are expanded.
- All other preprocessing directives, including #line directives and conditional compilation, are expanded.

2.6.4 Continuing Compilation After Preprocessing (--preproc_with_compile Option)

If you are preprocessing, the preprocessor performs preprocessing only; it does not compile your source code. To override this feature and continue to compile after your source code is preprocessed, use the --preproc_with_compile option along with the other preprocessing options. For example, use --preproc_with_compile with --preproc_only to perform preprocessing, write preprocessed output to a file with a .pp extension, and compile your source code.

2.6.5 Generating a Preprocessed Listing File With Comments (--preproc_with_comment Option)

The --preproc_with_comment option performs all of the preprocessing functions except removing comments and generates a preprocessed version of your source file with a .pp extension. Use the --preproc_with_comment option instead of the --preproc_only option if you want to keep the comments.

2.6.6 Generating a Preprocessed Listing File With Line-Control Information (--preproc_with_line Option)

By default, the preprocessed output file contains no preprocessor directives. To include the #line directives, use the --preproc_with_line option. The --preproc_with_line option performs preprocessing only and writes preprocessed output with line-control information (#line directives) to a file named the source file but with a .pp extension.
2.6.7 Generating Preprocessed Output for a Make Utility (--preproc_dependency Option)

The --preproc_dependency option performs preprocessing only, but instead of writing preprocessed output, writes a list of dependency lines suitable for input to a standard make utility. If you do not supply an optional filename, the list is written to a file with the same name as the source file but with a .pp extension.

2.6.8 Generating a List of Files Included With the #include Directive (--preproc_includes Option)

The --preproc_includes option performs preprocessing only, but instead of writing preprocessed output, writes a list of files included with the #include directive. If you do not supply an optional filename, the list is written to a file with the same name as the source file but with a .pp extension.

2.6.9 Generating a List of Macros in a File (--preproc_macros Option)

The --preproc_macros option generates a list of all predefined and user-defined macros. If you do not supply an optional filename, the list is written to a file with the same name as the source file but with a .pp extension. Predefined macros are listed first and indicated by the comment /* Predefined */. User-defined macros are listed next and indicated by the source filename.

2.7 Understanding Diagnostic Messages

One of the compiler's primary functions is to report diagnostics for the source program. The new linker also reports diagnostics. When the compiler or linker detects a suspect condition, it displays a message in the following format:

"file.c", line n : diagnostic severity : diagnostic message

"file.c" The name of the file involved
line n : The line number where the diagnostic applies
diagnostic severity The diagnostic message severity (severity category descriptions follow)
diagnostic message The text that describes the problem

Diagnostic messages have an associated severity, as follows:

• A fatal error indicates a problem so severe that the compilation cannot continue. Examples of such problems include command-line errors, internal errors, and missing include files. If multiple source files are being compiled, any source files after the current one will not be compiled.

• An error indicates a violation of the syntax or semantic rules of the C/C++ language. Compilation continues, but object code is not generated.

• A warning indicates something that is valid but questionable. Compilation continues and object code is generated (if no errors are detected).

• A remark is less serious than a warning. It indicates something that is valid and probably intended, but may need to be checked. Compilation continues and object code is generated (if no errors are detected). By default, remarks are not issued. Use the --issue_remarks compiler option to enable remarks.

Diagnostics are written to standard error with a form like the following example:

"test.c", line 5: error: a break statement may only be used within a loop or switch
break;
^

By default, the source line is omitted. Use the --verbose_diagnostics compiler option to enable the display of the source line and the error position. The above example makes use of this option.

The message identifies the file and line involved in the diagnostic, and the source line itself (with the position indicated by the ^ character) follows the message. If several diagnostics apply to one source line, each diagnostic has the form shown; the text of the source line is displayed several times, with an appropriate position indicated each time.
Understanding Diagnostic Messages

Long messages are wrapped to additional lines, when necessary.

You can use the --display_error_number command-line option to request that the diagnostic's numeric identifier be included in the diagnostic message. When displayed, the diagnostic identifier also indicates whether the diagnostic can have its severity overridden on the command line. If the severity can be overridden, the diagnostic identifier includes the suffix -D (for discretionary); otherwise, no suffix is present. For example:

"Test_name.c", line 7: error #64-D: declaration does not declare anything
struct {};

"Test_name.c", line 9: error #77: this declaration has no storage class or type specifier
xxxxx;

Because an error is determined to be discretionary based on the error severity associated with a specific context, an error can be discretionary in some cases and not in others. All warnings and remarks are discretionary.

For some messages, a list of entities (functions, local variables, source files, etc.) is useful; the entities are listed following the initial error message:

"test.c", line 4: error: more than one instance of overloaded function "f"
matches the argument list:
 function "f(int)"
 function "f(float)"
 argument types are: (double)
 f(1.5);

In some cases, additional context information is provided. Specifically, the context information is useful when the front end issues a diagnostic while doing a template instantiation or while generating a constructor, destructor, or assignment operator function. For example:

"test.c", line 7: error: "A::A()" is inaccessible
 B x;
^ detected during implicit generation of "B::B()" at line 7

Without the context information, it is difficult to determine to what the error refers.

2.7.1 Controlling Diagnostics

The C/C++ compiler provides diagnostic options to control compiler- and linker-generated diagnostics. The diagnostic options must be specified before the --run_linker option.

--diag_error=num Categorizes the diagnostic identified by num as an error. To determine the numeric identifier of a diagnostic message, use the --display_error_number option first in a separate compile. Then use --diag_error=num to recategorize the diagnostic as an error. You can only alter the severity of discretionary diagnostics.

--diag_remark=num Categorizes the diagnostic identified by num as a remark. To determine the numeric identifier of a diagnostic message, use the --display_error_number option first in a separate compile. Then use --diag_remark=num to recategorize the diagnostic as a remark. You can only alter the severity of discretionary diagnostics.

--diag_suppress=num Suppresses the diagnostic identified by num. To determine the numeric identifier of a diagnostic message, use the --display_error_number option first in a separate compile. Then use --diag_suppress=num to suppress the diagnostic. You can only suppress discretionary diagnostics.

--diag_warning=num Categorizes the diagnostic identified by num as a warning. To determine the numeric identifier of a diagnostic message, use the --display_error_number option first in a separate compile. Then use --diag_warning=num to recategorize the diagnostic as a warning. You can only alter the severity of discretionary diagnostics.
Understanding Diagnostic Messages

--display_error_number Displays a diagnostic's numeric identifier along with its text. Use this option in determining which arguments you need to supply to the diagnostic suppression options (--diag_suppress, --diag_error, --diag_remark, and --diag_warning). This option also indicates whether a diagnostic is discretionary. A discretionary diagnostic is one whose severity can be overridden. A discretionary diagnostic includes the suffix -D; otherwise, no suffix is present. See Section 2.7.

--emit_warnings_as_errors Treats all warnings as errors. This option cannot be used with the --no_warnings option. The --diag_remark option takes precedence over this option. This option takes precedence over the --diag_warning option.

--issue_remarks Issues remarks (nonserious warnings), which are suppressed by default.

--no_warnings Suppresses warning diagnostics (errors are still issued).

--set_error_limit=num Sets the error limit to num, which can be any decimal value. The compiler abandons compiling after this number of errors. (The default is 100.)

--verbose_diagnostics Provides verbose diagnostics that display the original source with line-wrap and indicate the position of the error in the source line.

--write_diagnostics_file Produces a diagnostics information file with the same source file name with an .err extension. (The --write_diagnostics_file option is not supported by the linker.)

2.7.2 How You Can Use Diagnostic Suppression Options

The following example demonstrates how you can control diagnostic messages issued by the compiler. You control the linker diagnostic messages in a similar manner.

```c
int one();
int I;
int main()
{
    switch (I){
    case 1;
        return one ();
        break;
    default:
        return 0;
        break;
    }
}
```

If you invoke the compiler with the --quiet option, this is the result:

"err.c", line 9: warning: statement is unreachable
"err.c", line 12: warning: statement is unreachable

Because it is standard programming practice to include break statements at the end of each case arm to avoid the fall-through condition, these warnings can be ignored. Using the --display_error_number option, you can find out the diagnostic identifier for these warnings. Here is the result:

[err.c]
"err.c", line 9: warning #111-D: statement is unreachable
"err.c", line 12: warning #111-D: statement is unreachable

Next, you can use the diagnostic identifier of 111 as the argument to the --diag_remark option to treat this warning as a remark. This compilation now produces no diagnostic messages (because remarks are disabled by default).

Although this type of control is useful, it can also be extremely dangerous. The compiler often emits messages that indicate a less than obvious problem. Be careful to analyze all diagnostics emitted before using the suppression options.
2.8 Other Messages

Other error messages that are unrelated to the source, such as incorrect command-line syntax or inability to find specified files, are usually fatal. They are identified by the symbol >> preceding the message.

2.9 Generating Cross-Reference Listing Information (--gen_acp_xref Option)

The --gen_acp_xref option generates a cross-reference listing file that contains reference information for each identifier in the source file. (The --gen_acp_xref option is separate from --cross_reference, which is an assembler rather than a compiler option.) The cross-reference listing file has the same name as the source file with a .crl extension.

The information in the cross-reference listing file is displayed in the following format:

```
sym-id name X filename line number column number
```

- **sym-id**: An integer uniquely assigned to each identifier
- **name**: The identifier name
- **X**: One of the following values:
  - D: Definition
  - d: Declaration (not a definition)
  - M: Modification
  - A: Address taken
  - U: Used
  - C: Changed (used and modified in a single operation)
  - R: Any other kind of reference
  - E: Error; reference is indeterminate
- **filename**: The source file
- **line number**: The line number in the source file
- **column number**: The column number in the source file

2.10 Generating a Raw Listing File (--gen_acp_raw Option)

The --gen_acp_raw option generates a raw listing file that can help you understand how the compiler is preprocessing your source file. Whereas the preprocessed listing file (generated with the --preproc_only, --preproc_with_comment, --preproc_with_line, and --preproc_dependency preprocessor options) shows a preprocessed version of your source file, a raw listing file provides a comparison between the original source line and the preprocessed output. The raw listing file has the same name as the corresponding source file with an .rl extension.

The raw listing file contains the following information:

- Each original source line
- Transitions into and out of include files
- Diagnostics
- Preprocessed source line if nontrivial processing was performed (comment removal is considered trivial; other preprocessing is nontrivial)

Each source line in the raw listing file begins with one of the identifiers listed in Table 2-38.
Table 2-38. Raw Listing File Identifiers

<table>
<thead>
<tr>
<th>Identifier</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>Normal line of source</td>
</tr>
<tr>
<td>X</td>
<td>Expanded line of source. It appears immediately following the normal line of source if nontrivial preprocessing occurs.</td>
</tr>
<tr>
<td>S</td>
<td>Skipped source line (false #if clause)</td>
</tr>
<tr>
<td>L</td>
<td>Change in source position, given in the following format:</td>
</tr>
<tr>
<td></td>
<td>L line number filename key</td>
</tr>
<tr>
<td></td>
<td>Where line number is the line number in the source file. The key is present only when the change is due to entry/exit of an include file. Possible values of key are:</td>
</tr>
<tr>
<td></td>
<td>1 = entry into an include file</td>
</tr>
<tr>
<td></td>
<td>2 = exit from an include file</td>
</tr>
</tbody>
</table>

The --gen_acp_raw option also includes diagnostic identifiers as defined in Table 2-39.

Table 2-39. Raw Listing File Diagnostic Identifiers

<table>
<thead>
<tr>
<th>Diagnostic Identifier</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>E</td>
<td>Error</td>
</tr>
<tr>
<td>F</td>
<td>Fatal</td>
</tr>
<tr>
<td>R</td>
<td>Remark</td>
</tr>
<tr>
<td>W</td>
<td>Warning</td>
</tr>
</tbody>
</table>

Diagnostic raw listing information is displayed in the following format:

S filename line number column number diagnostic

S One of the identifiers in Table 2-39 that indicates the severity of the diagnostic
filename The source file
line number The line number in the source file
column number The column number in the source file
diagnostic The message text for the diagnostic

Diagnostics after the end of file are indicated as the last line of the file with a column number of 0. When diagnostic message text requires more than one line, each subsequent line contains the same file, line, and column information but uses a lowercase version of the diagnostic identifier. For more information about diagnostic messages, see Section 2.7.
2.11 Using Inline Function Expansion

When an inline function is called, the C/C++ source code for the function is inserted at the point of the call. This is known as inline function expansion. Inline function expansion is advantageous in short functions for the following reasons:

There are several types of inline function expansion:

- Inlining with intrinsic operators (intrinsics are always inlined)
- Automatic inlining
- Definition-controlled inlining with the unguarded inline keyword
- Definition-controlled inlining with the guarded inline keyword

NOTE: Function Inlining Can Greatly Increase Code Size

Expanding functions inline increases code size, especially inlining a function that is called in a number of places. Function inlining is optimal for functions that are called only from a small number of places and for small functions. If your code size seems too large, see Section 3.5.

2.11.1 Inlining Intrinsic Operators

There are many intrinsic operators for the C6000. All of them are automatically inlined by the compiler. The inlining happens automatically whether or not you use the optimizer.

For details about intrinsics, and a list of the intrinsics, see Section 7.5.5.

2.11.2 Automatic Inlining

When optimizing with the --opt_level=3 or --opt_level=2 option (aliased as -O3 or -O2), the compiler automatically inlines certain functions. For more information, see Section 3.13.

2.11.3 Unguarded Definition-Controlled Inlining

The inline keyword specifies that a function is expanded inline at the point at which it is called rather than by using standard calling procedures. The compiler performs inline expansion of functions declared with the inline keyword.

You must invoke the optimizer with any --opt_level option (--opt_level=0, --opt_level=1, --opt_level=2, or --opt_level=3) to turn on definition-controlled inlining. Automatic inlining is also turned on when using --opt_level=3.

The --no_inlining option turns off definition-controlled inlining. This option is useful when you need a certain level of optimization but do not want definition-controlled inlining.

Example 2-1 shows usage of the inline keyword, where the function call is replaced by the code in the called function.

**Example 2-1. Using the Inline Keyword**

```c
inline float volume_sphere(float r)
{
    return 4.0/3.0 * PI * r * r * r;
}
int foo(...)
{
    ...
    volume = volume_sphere(radius);
    ...
}
```
2.11.4 Guarded Inlining and the \_INLINE Preprocessor Symbol

When declaring a function in a header file as static inline, you must follow additional procedures to avoid a potential code size increase when inlining is turned off with --no_inlining or the optimizer is not run.

To prevent a static inline function in a header file from causing an increase in code size when inlining gets turned off, use the following procedure. This allows external-linkage when inlining is turned off; thus, only one function definition will exist throughout the object files.

- Prototype a static inline version of the function. Then, prototype an alternative, nonstatic, externally-linked version of the function. Conditionally preprocess these two prototypes with the \_INLINE preprocessor symbol, as shown in Example 2-2.

- Create an identical version of the function definition in a .c or .cpp file, as shown in Example 2-3.

In the following examples there are two definitions of the strlen function. The first (Example 2-2), in the header file, is an inline definition. This definition is enabled and the prototype is declared as static inline only if \_INLINE is true (\_INLINE is automatically defined for you when the optimizer is used and --no_inlining is not specified).

The second definition (see Example 2-3) for the library, ensures that the callable version of strlen exists when inlining is disabled. Since this is not an inline function, the \_INLINE preprocessor symbol is undefined (#undef) before string.h is included to generate a noninline version of strlen's prototype.

Example 2-2. Header File string.h

```
#include <string.h>

#ifdef _INLINE
#define _IDECL static inline
#else
#define _IDECL extern _CODE_ACCESS
#endif

 IDECL size_t strlen(const char *string);

#ifdef _INLINE

/***************************************************************************/
/* strlen */
/***************************************************************************/
static inline size_t strlen(const char *string)
{
    size_t n = (size_t)-1;
    const char *s = string - 1;
    do n++; while (*++s);
    return n
}
#endif
```
Example 2-3. Library Definition File

```c
/****************************************************************************
/* strlen */
/****************************************************************************
#undef _INLINE
#include <string.h>
{
_CODE_ACCESS size_t strlen(const char * string)
    size_t n = (size_t)-1;
    const char *s = string - 1;
    do n++; while (*++s);
    return n;
}
```

2.11.5 Inlining Restrictions

There are several restrictions on what functions can be inlined for both automatic inlining and definition-controlled inlining. Functions with local static variables or a variable number of arguments are not inlined, with the exception of functions declared as static inline. In functions declared as static inline, expansion occurs despite the presence of local static variables. In addition, a limit is placed on the depth of inlining for recursive or nonleaf functions. Furthermore, inlining should be used for small functions or functions that are called in a few places (though the compiler does not enforce this).

At a given call site, a function may be disqualified from inlining if it:

- Is not defined in the current compilation unit
- Never returns
- Is recursive
- Has a FUNC_CANNOT_INLINE pragma
- Has a variable length argument list
- Has a different number of arguments than the call site
- Has an argument whose type is incompatible with the corresponding call site argument
- Has a class, struct or union parameter
- Contains a volatile local variable or argument
- Is not declared inline and contains an asm() statement that is not a comment
- Is not declared inline and it is main()
- Is not declared inline and it is an interrupt function
- Is not declared inline and returns void but its return value is needed.
- Is not declared inline and will require too much stack space for local array or structure variables.
2.12 Interrupt Flexibility Options (--interrupt_threshold Option)

On the C6000 architecture, interrupts cannot be taken in the delay slots of a branch. In some instances the compiler can generate code that cannot be interrupted for a potentially large number of cycles. For a given real-time system, there may be a hard limit on how long interrupts can be disabled.

The --interrupt_threshold=n option specifies an interrupt threshold value $n$. The threshold value specifies the maximum number of cycles that the compiler can disable interrupts. If the $n$ is omitted, the compiler assumes that the code is never interrupted. In Code Composer Studio, to specify that the code is never interrupted, select the Interrupt Threshold check box and leave the text box blank in the Build Options dialog box on the Compiler tab, Advanced category.

If the --interrupt_threshold=n option is not specified, then interrupts are only explicitly disabled around software pipelined loops. When using the --interrupt_threshold=n option, the compiler analyzes the loop structure and loop counter to determine the maximum number of cycles it takes to execute a loop. If it can determine that the maximum number of cycles is less than the threshold value, the compiler generates the fastest/optimal version of the loop. If the loop is smaller than six cycles, interrupts are not able to occur because the loop is always executing inside the delay slots of a branch. Otherwise, the compiler generates a loop that can be interrupted (and still generate correct results—single assignment code), which in most cases degrades the performance of the loop.

The --interrupt_threshold=n option does not comprehend the effects of the memory system. When determining the maximum number of execution cycles for a loop, the compiler does not compute the effects of using slow off-chip memory or memory bank conflicts. It is recommended that a conservative threshold value is used to adjust for the effects of the memory system.

See Section 6.9.11 or the TMS320C6000 Programmer's Guide for more information.

---

RTS Library Files Are Not Built With the --interrupt_threshold Option

NOTE: The run-time-support library files provided with the compiler are not built with the interrupt flexibility option. Refer to the readme file to see how the run-time-support library files were built for your release. See Section 8.5 to build your own run-time-support library files with the interrupt flexibility option.

---

Special Cases With the --interrupt_threshold Option

NOTE: The --interrupt_threshold=0 option generates the same code to disable interrupts around software-pipelined loops as when the --interrupt_threshold option is not used.

The --interrupt_threshold option (the threshold value is omitted) means that no code is added to disable interrupts around software pipelined loops, which means that the code cannot be safely interrupted. Also, loop performance does not degrade because the compiler is not trying to make the loop interruptible by ensuring that there is at least one cycle in the loop kernel that is not in the delay slot of a branch instruction.
2.13 Linking C6400 Code With C6200/C6700/Older C6400 Object Code

In order to facilitate certain packed-data optimizations, the alignment of top-level arrays for the C6400 family was changed from 4 bytes to 8 bytes. (For C6200 and C6700 code, the alignment for top-level arrays is always 4 bytes.)

If you are linking C6400/C6400+/C6740/C6600 with C6200/C6700 code or older C6400 code, you may need to take steps to ensure compatibility. The following lists the potential alignment conflicts and possible solutions.

Potential alignment conflicts occur when:

- Linking new C6400/C6400+/C6740/C6600 code with any C6400 code already compiled with the 4.0 tools.
- Linking new C6400/C6400+/C6740/C6600 code with code already compiled with any version of the tools for the C6200 or C6700 family.

Solutions (pick one):

- Recompile the entire application with the --silicon_version=6400 switch. This solution, if possible, is recommended because it can lead to better performance.
- Compile the new code with the --target_compatibility_6200 option. When using this option, link with the 6200 RTS library to ensure proper compatibility. The --target_compatibility_6200 option changes the alignment of top-level arrays to 4 bytes when the --silicon_version=6400 or --silicon_version=6400+ option is used.

This option is deprecated; it may be removed in the future.

The alignment of top-level arrays for the C6600 family is 16 bytes to facilitate compatibility with future C6600 family devices. This change in alignment does not have any compatibility issues with the C6400/C6400+/C6740 device code as the C6600 can safely accept top-level arrays aligned to an 8-byte boundary.

2.14 Using Interlist

The compiler tools include a feature that interlists C/C++ source statements into the assembly language output of the compiler. The interlist feature enables you to inspect the assembly code generated for each C statement. The interlist behaves differently, depending on whether or not the optimizer is used, and depending on which options you specify.

The easiest way to invoke the interlist feature is to use the --c_src_interlist option. To compile and run the interlist on a program called function.c, enter:

```
cl6x --c_src_interlist function
```

The --c_src_interlist option prevents the compiler from deleting the interlisted assembly language output file. The output assembly file, function.asm, is assembled normally.

When you invoke the interlist feature without the optimizer, the interlist runs as a separate pass between the code generator and the assembler. It reads both the assembly and C/C++ source files, merges them, and writes the C/C++ statements into the assembly file as comments.

Using the --c_src_interlist option can cause performance and/or code size degradation.

Example 2-4 shows a typical interlisted assembly file.

For more information about using the interlist feature with the optimizer, see Section 3.14.2.
Example 2.4. An Interlisted Assembly Language File

```asm
_main:
  STW .D2 B3,*SP--(12)
  STW .D2 A10,*+SP(8)
;------------------------------------------------------------------------------
; 5  | printf("Hello, world\n");
;------------------------------------------------------------------------------
  B .S1 _printf
  NOP 2
  MVKL .S1 SL1+0,A0
  MVKH .S1 SL1+0,A0
|| MVKL .S2 RL0,B3
  STW .D2 A0,++SP(4)
|| MVKH .S2 RL0,B3
RL0:
; 6  | return 0;
;------------------------------------------------------------------------------
  ZERO .L1 A10
  MV .L1 A10,A4
  LDW .D2 *+SP(8),A10
  LDW .D2 ++SP(12),B3
  NOP 4
  B .S2 B3
  NOP 5
; 7  | ; BRANCH OCCURS

2.15 Generating and Using Performance Advice

The compiler can do better optimization in some cases, if the user aids the compiler by providing additional information in the code. The compiler can prompt you to take certain actions to improve performance, by emitting "Advice". To get this Advice, use the --advice:performance option:

c16x --advice:performance -o3 filename.c

This Performance Advice is of 3 different types:

- Advice to use correct compiler options
- Advice to prevent software pipeline disqualification
- Advice to improve loop performance

For more details on Using Performance Advice to Optimize your Code, see Section 3.14

2.16 Controlling Application Binary Interface

An Application Binary Interface (ABI) defines the low level interface between object files, and between an executable and its execution environment. An ABI allows ABI-compliant object code to link together, regardless of its source, and allows the resulting executable to run on any system that supports that ABI.

Object files conforming to different ABIs cannot be linked together. The linker detects this situation and generates an error.

The C6000 compiler supports two ABIs. The ABI is chosen through the --abi option as follows:

- **COFF ABI (--abi=coffabi)**
  The COFF ABI is the original ABI format. There is no COFF to ELF conversion possible; recompile or reassemble assembly code.

- **C6000 EABI (--abi=eabi)**
  Use this option to select the C6000 Embedded Application Binary Interface (EABI).
  All code in an EABI application must be built for EABI. Make sure all your libraries are available in
EABI mode before migrating your existing COFF ABI systems to C6000 EABI. See http://tiexpressdsp.com/index.php/EABI_Support_in_C6000_COMPILER for full details.

For more details on the different ABIs, see Section 6.11.
2.17 Enabling Entry Hook and Exit Hook Functions

An entry hook is a routine that is called upon entry to each function in the program. An exit hook is a routine that is called upon exit of each function. Applications for hooks include debugging, trace, profiling, and stack overflow checking.

Entry and exit hooks are enabled using the following options:

- **--entry_hook** [=name] Enables entry hooks. If specified, the hook function is called *name*. Otherwise, the default entry hook function name is __entry_hook.

- **--entry_parm** [=name|address|none] Specify the parameters to the hook function. The name parameter specifies that the name of the calling function is passed to the hook function as an argument. In this case the signature for the hook function is: void hook(const char *name);

  The address parameter specifies that the address of the calling function is passed to the hook function. In this case the signature for the hook function is: void hook(void (*addr)());

  The none parameter specifies that the hook is called with no parameters. This is the default. In this case the signature for the hook function is: void hook(void);

- **--exit_hook** [=name] Enables exit hooks. If specified, the hook function is called *name*. Otherwise, the default exit hook function name is __exit_hook.

- **--exit_parm** [=name|address|none] Specify the parameters to the hook function. The name parameter specifies that the name of the calling function is passed to the hook function as an argument. In this case the signature for the hook function is: void hook(const char *name);

  The address parameter specifies that the address of the calling function is passed to the hook function. In this case the signature for the hook function is: void hook(void (*addr)());

  The none parameter specifies that the hook is called with no parameters. This is the default. In this case the signature for the hook function is: void hook(void);

The presence of the hook options creates an implicit declaration of the hook function with the given signature. If a declaration or definition of the hook function appears in the compilation unit compiled with the options, it must agree with the signatures listed above.

In C++, the hooks are declared extern "C". Thus you can define them in C (or assembly) without being concerned with name mangling.

Hooks can be declared inline, in which case the compiler tries to inline them using the same criteria as other inline functions.

Entry hooks and exit hooks are independent. You can enable one but not the other, or both. The same function can be used as both the entry and exit hook.

You must take care to avoid recursive calls to hook functions. The hook function should not call any function which itself has hook calls inserted. To help prevent this, hooks are not generated for inline functions, or for the hook functions themselves.

You can use the --remove_hooks_when_inlining option to remove entry/exit hooks for functions that are auto-inlined by the optimizer.

See Section 6.9.23 for information about the NO_HOOKS pragma.
Optimizing Your Code

The compiler tools can perform many optimizations to improve the execution speed and reduce the size of C and C++ programs by simplifying loops, software pipelining, rearranging statements and expressions, and allocating variables into registers.

This chapter describes how to invoke different levels of optimization and describes which optimizations are performed at each level. This chapter also describes how you can use the Interlist feature when performing optimization and how you can profile or debug optimized code.

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Invoking Optimization

The C/C++ compiler is able to perform various optimizations. High-level optimizations are performed in the optimizer and low-level, target-specific optimizations occur in the code generator. Use high-level optimization levels, such as --opt_level=2 and --opt_level=3, to achieve optimal code.

The easiest way to invoke optimization is to use the compiler program, specifying the --opt_level=n option on the compiler command line. You can use -O to alias the --opt_level option. The n denotes the level of optimization (0, 1, 2, and 3), which controls the type and degree of optimization.

- **--opt_level=0 or -O0**
  - Performs control-flow-graph simplification
  - Allocates variables to registers
  - Performs loop rotation
  - Eliminates unused code
  - Simplifies expressions and statements
  - Expands calls to functions declared inline

- **--opt_level=1 or -O1**
  Performs all --opt_level=0 (-O0) optimizations, plus:
  - Performs local copy/constant propagation
  - Removes unused assignments
  - Eliminates local common expressions

- **--opt_level=2 or -O2**
  Performs all --opt_level=1 (-O1) optimizations, plus:
  - Performs software pipelining (see Section 3.2)
  - Performs loop optimizations
  - Eliminates global common subexpressions
  - Eliminates global unused assignments
  - Converts array references in loops to incremented pointer form
  - Performs loop unrolling

The optimizer uses --opt_level=2 (-O2) as the default if you use --opt_level (-O) without an optimization level.

- **--opt_level=3 or -O3**
  Performs all --opt_level=2 (-O2) optimizations, plus:
  - Removes all functions that are never called
  - Simplifies functions with return values that are never used
  - Inlines calls to small functions
  - Reorders function declarations; the called functions attributes are known when the caller is optimized
  - Propagates arguments into function bodies when all calls pass the same value in the same argument position
  - Identifies file-level variable characteristics

  If you use --opt_level=3 (-O3), see Section 3.6 and Section 3.7 for more information.

The levels of optimizations described above are performed by the stand-alone optimization pass. The code generator performs several additional optimizations, particularly processor-specific optimizations. It does so regardless of whether you invoke the optimizer. These optimizations are always enabled, although they are more effective when the optimizer is used.
Optimizing Software Pipelining

Do Not Lower the Optimization Level to Control Code Size

**NOTE:** To reduce code size, do not lower the level of optimization. Instead, use the --opt_for_space option to control the code size/performance tradeoff. Higher optimization levels (--opt_level or -O) combined with high --opt_for_space levels result in the smallest code size. For more information, see Section 3.5.

The --opt_level= n (-O n ) Option Applies to the Assembly Optimizer

**NOTE:** The --opt_level=n (-On) option should also be used with the assembly optimizer. Although the assembly optimizer does not perform all the optimizations described here, key optimizations such as software pipelining and loop unrolling require the --opt_level (-O) option.

3.2 Optimizing Software Pipelining

Software pipelining schedules instructions from a loop so that multiple iterations of the loop execute in parallel. At optimization levels --opt_level=2 (or -O2) and --opt_level=3 (or -O3), the compiler usually attempts to software pipeline your loops. The --opt_for_space option also affects the compiler’s decision to attempt to software pipeline loops. In general, code size and performance are better when you use the --opt_level=2 or --opt_level=3 options. (See Section 3.1.)

Figure 3-1 illustrates a software-pipelined loop. The stages of the loop are represented by A, B, C, D, and E. In this figure, a maximum of five iterations of the loop can execute at one time. The shaded area represents the loop kernel. In the loop kernel, all five stages execute in parallel. The area above the kernel is known as the pipelined loop prolog, and the area below the kernel is known as the pipelined loop epilog.

If you enter comments on instructions in your linear assembly input file, the compiler moves the comments to the output file along with additional information. It attaches a 2-tuple <x, y> to the comments to specify the iteration and cycle of the loop an instruction is on in the software pipeline. The zero-based number x represents the iteration the instruction is on during the first execution of the loop kernel. The zero-based number y represents the cycle that the instruction is scheduled on within a single iteration of the loop.

For more information about software pipelining, see the TMS320C6000 Programmer’s Guide.
3.2.1 Turn Off Software Pipelining (--disable_software_pipelining Option)

At optimization levels --opt_level=2 (or -O2) and -O3, the compiler attempts to software pipeline your loops. You might not want your loops to be software pipelined for debugging reasons. Software-pipelined loops are sometimes difficult to debug because the code is not presented serially. The --disable_software_pipelining option affects both compiled C/C++ code and assembly optimized code.

Software Pipelining May Increase Code Size

NOTE: Software pipelining without the use of SPLOOP can lead to significant increases in code size. To control code size for loops that get software pipelined, it is preferable to use the --opt_for_space option rather than the --disable_software_pipelining option. The --opt_for_space option is capable of disabling non-SPLOOP software pipelining if necessary to achieve code size savings, but it does not affect the SPLOOP capability of C64x+ and C674x devices. SPLOOP does not significantly increase code size, but can greatly speed up a loop. Using --disable_software_pipelining disables all software pipelining including SPLOOP.

3.2.2 Software Pipelining Information

The compiler embeds software pipelined loop information in the .asm file. This information is used to optimize C/C++ code or linear assembly code.

The software pipelining information appears as a comment in the .asm file before a loop and for the assembly optimizer the information is displayed as the tool is running. Example 3-1 illustrates the information that is generated for each loop.

The --debug_software_pipeline option adds additional information displaying the register usage at each cycle of the loop kernel and displays the instruction ordering of a single iteration of the software pipelined loop.

More Details on Software Pipelining Information

NOTE: Refer to the TMS320C6000 Programmer’s Guide for details on the information and messages that can appear in the Software Pipelining Information comment block before each loop.
Example 3-1. Software Pipelining Information

The terms defined below appear in the software pipelining information. For more information on each term, see the TMS320C6000 Programmer’s Guide.

- **Loop unroll factor.** The number of times the loop was unrolled specifically to increase performance based on the resource bound constraint in a software pipelined loop.
- **Known minimum trip count.** The minimum number of times the loop will be executed.
- **Known maximum trip count.** The maximum number of times the loop will be executed.
- **Known max trip count factor.** Factor that would always evenly divide the loops trip count. This information can be used to possibly unroll the loop.
- **Loop label.** The label you specified for the loop in the linear assembly input file. This field is not present for C/C++ code.
- **Loop carried dependency bound.** The distance of the largest loop carry path. A loop carry path occurs when one iteration of a loop writes a value that must be read in a future iteration. Instructions that are part of the loop carry bound are marked with the ^ symbol.
Optimizing Software Pipelining

- **Initiation interval** (ii). The number of cycles between the initiation of successive iterations of the loop. The smaller the initiation interval, the fewer cycles it takes to execute a loop.
- **Resource bound.** The most used resource constrains the minimum initiation interval. If four instructions require a .D unit, they require at least two cycles to execute (4 instructions/2 parallel .D units).
- **Unpartitioned resource bound.** The best possible resource bound values before the instructions in the loop are partitioned to a particular side.
- **Partitioned resource bound (†).** The resource bound values after the instructions are partitioned.
- **Resource partition.** This table summarizes how the instructions have been partitioned. This information can be used to help assign functional units when writing linear assembly. Each table entry has values for the A-side and B-side registers. An asterisk is used to mark those entries that determine the resource bound value. The table entries represent the following terms:
  - 
  - `.L units` is the total number of instructions that require .L units.
  - `.S units` is the total number of instructions that require .S units.
  - `.D units` is the total number of instructions that require .D units.
  - `.M units` is the total number of instructions that require .M units.
  - `.X cross paths` is the total number of .X cross paths.
  - `.T address paths` is the total number of address paths.
  - `.Long read path` is the total number of long read port paths.
  - `.Long write path` is the total number of long write port paths.
  - Logical ops (.LS) is the total number of instructions that can use either the .L or .S unit.
  - Addition ops (.LSD) is the total number of instructions that can use either the .L or .S or .D unit
- **Bound(.L .S .LS).** The resource bound value as determined by the number of instructions that use the .L and .S units. It is calculated with the following formula:
  \[
  \text{Bound}(L, S, LS) = \text{ceil}(\frac{L + S + LS}{2})
  \]
- **Bound(.L .S .D .LS .LSD).** The resource bound value as determined by the number of instructions that use the .D, .L, and .S units. It is calculated with the following formula:
  \[
  \text{Bound}(L, S, D, LS, LSD) = \text{ceil}(\frac{L + S + D + LS + LSD}{3})
  \]
- **Minimum required memory pad.** The number of bytes that are read if speculative execution is enabled. See Section 3.2.3 for more information.

### 3.2.2.1 Loop Disqualified for Software Pipelining Messages

The following messages appear if the loop is completely disqualified for software pipelining:

- **Bad loop structure.** This error is very rare and can stem from the following:
  - An asm statement inserted in the C code inner loop
  - Parallel instructions being used as input to the Linear Assembly Optimizer
  - Complex control flow such as GOTO statements and breaks
- **Loop contains a call.** Sometimes the compiler may not be able to inline a function call that is in a loop. Because the compiler could not inline the function call, the loop could not be software pipelined.
- **Too many instructions.** There are too many instructions in the loop to software pipeline.
- **Software pipelining disabled.** Software pipelining has been disabled by a command-line option, such as when using the --disable_software_pipelining option, not using the --opt_level=2 (or -O2) or --opt_level=3 (or -O3) option, or using the --opt_for_space=2 or --opt_for_space=3 option.
- **Uninitialized trip counter.** The trip counter may not have been set to an initial value.
- **Suppressed to prevent code expansion.** Software pipelining may be suppressed because of the --opt_for_space=1 option. When the --opt_for_space=1 option is used, software pipelining is disabled in less promising cases to reduce code size. To enable pipelining, use --opt_for_space=0 or omit the --opt_for_space option altogether.
• **Loop carried dependency bound too large.** If the loop has complex loop control, try --speculate_loads according to the recommendations in Section 3.2.3.2.

• **Cannot identify trip counter.** The loop trip counter could not be identified or was used incorrectly in the loop body.

### 3.2.2.2 Pipeline Failure Messages

The following messages can appear when the compiler or assembly optimizer is processing a software pipeline and it fails:

- **Address increment is too large.** An address register’s offset must be adjusted because the offset is out of range of the C6000’s offset addressing mode. You must minimize address register offsets.

- **Cannot allocate machine registers.** A software pipeline schedule was found, but it cannot allocate machine registers for the schedule. Simplification of the loop may help.

The register usage for the schedule found at the given ii is displayed. This information can be used when writing linear assembly to balance register pressure on both sides of the register file. For example:

```plaintext
ii = 11 Cannot allocate machine registers
Regs Live Always : 3/0 (A/B-side)
Max Regs Live : 20/14
Max Condo Regs Live : 2/1
```

- **Regs Live Always.** The number of values that must be assigned a register for the duration of the whole loop body. This means that these values must always be allocated registers for any given schedule found for the loop.

- **Max Regs Live.** Maximum number of values live at any given cycle in the loop that must be allocated to a register. This indicates the maximum number of registers required by the schedule found.

- **Max Cond Regs Live.** Maximum number of registers live at any given cycle in the loop kernel that must be allocated to a condition register.

- **Cycle count too high. Never profitable.** With the schedule that the compiler found for the loop, it is more efficient to use a non-software-pipelined version.

- **Did not find schedule.** The compiler was unable to find a schedule for the software pipeline at the given ii (iteration interval). You should simplify the loop and/or eliminate loop carried dependencies.

- **Iterations in parallel > minimum or maximum trip count.** A software pipeline schedule was found, but the schedule has more iterations in parallel than the minimum or maximum loop trip count. You must enable redundant loops or communicate the trip information.

- **Speculative threshold exceeded.** It would be necessary to speculatively load beyond the threshold currently specified by the --speculate_loads option. You must increase the --speculate_loads threshold as recommended in the software-pipeline feedback located in the assembly file.

- **Register is live too long.** A register must have a value that exists (is live) for more than ii cycles. You may insert MV instructions to split register lifetimes that are too long.

If the assembly optimizer is being used, the .sa file line numbers of the instructions that define and use the registers that are live too long are listed after this failure message. For example:

```plaintext
ii = 9 Register is live too long
[10] -> [17]
```

This means that the instruction that defines the register value is on line 10 and the instruction that uses the register value is on line 17 in the .sa file.

- **Too many predicates live on one side.** The C6000 has predicate, or conditional, registers available for use with conditional instructions. There are five predicate registers on the C6200 and C6700, and six predicate registers on the C6400, C6400+, and C6700+. There are two or three on the A side and three on the B side. Sometimes the particular partition and schedule combination requires more than these available registers.

- **Schedule found with N iterations in parallel.** (This is not a failure message.) A software pipeline schedule was found with N iterations executing in parallel.
3.2.2.2 Register Usage Table Generated by the --debug_software_pipeline Option

The --debug_software_pipeline option places additional software pipeline feedback in the generated assembly file. This information includes a single scheduled iteration view of the software pipelined loop.

If software pipelining succeeds for a given loop, and the --debug_software_pipeline option was used during the compilation process, a register usage table is added to the software pipelining information comment block in the generated assembly code.

The numbers on each row represent the cycle number within the loop kernel.

Each column represents one register on the TMS320C6000. The registers are labeled in the first three rows of the register usage table and should be read columnwise.

An * in a table entry indicates that the register indicated by the column header is live on the kernel execute packet indicated by the cycle number labeling each row.

An example of the register usage table follows:

```
;* Searching for software pipeline schedule at ii = 15 Schedule found with 2 iterations in parallel
;*
;*
;* Register Usage Table:
;* +---------------------------------+
;* |AAAAAAAAAAAAAAAA|BBBBBBBBBBBBBBBB|
;* |0000000000111111|0000000000111111|
;* |0123456789012345|0123456789012345|
;* |----------------+----------------|
;* 0: |*** **** |*** ****** |
;* 1: |**** **** |*** ****** |
;* 2: |**** **** |*** ****** |
;* 3: |** **** |*** ****** |
;* 4: |** **** |*** ****** |
;* 5: |** **** |*** ****** |
;* 6: |** **** |*** ****** |
;* 7: |*** **** |** ******* |
;* 8: |**** **** |*********** |
;* 9: |********** |** ******** |
;* 10: |*********** |** ********* |
;* 11: |*********** |** ********* |
;* 12: |********** |************ |
;* 13: |**** **** |** ******* |
;* 14: |*** **** |*** ****** |
;* +---------------------------------+
```

This example shows that on cycle 0 (first execute packet) of the loop kernel, registers A0, A1, A2, A6, A7, A8, A9, B0, B1, B2, B4, B5, B6, B7, B8, and B9 are all live during this cycle.

3.2.3 Collapsing Prologs and Epilogs for Improved Performance and Code Size

When a loop is software pipelined, a prolog and epilog are generally required. The prolog is used to pipe up the loop and epilog is used to pipe down the loop.

In general, a loop must execute a minimum number of iterations before the software-pipelined version can be safely executed. If the minimum known trip count is too small, either a redundant loop is added or software pipelining is disabled. Collapsing the prolog and epilog of a loop can reduce the minimum trip count necessary to safely execute the pipelined loop.
Collapsing can also substantially reduce code size. Some of this code size growth is due to the redundant loop. The remainder is due to the prolog and epilog.

The prolog and epilog of a software-pipelined loop consists of up to $p-1$ stages of length $ii$, where $p$ is the number of iterations that are executed in parallel during the steady state and $ii$ is the cycle time for the pipelined loop body. During prolog and epilog collapsing the compiler tries to collapse as many stages as possible. However, over-collapsing can have a negative performance impact. Thus, by default, the compiler attempts to collapse as many stages as possible without sacrificing performance. When the --opt_for_space=0 or --opt_for_space=1 options are invoked, the compiler increasingly favors code size over performance.

### 3.2.3.1 Speculative Execution

When prologs and epiloggs are collapsed, instructions might be speculatively executed, thereby causing loads to addresses beyond either end of the range explicitly read within the loop. By default, the compiler cannot speculate loads because this could cause an illegal memory location to be read. Sometimes, the compiler can predicate these loads to prevent over execution. However, this can increase register pressure and might decrease the total amount collapsing which can be performed.

When the --speculate_loads=n option is used, the speculative threshold is increased from the default of 0 to $n$. When the threshold is $n$, the compiler can allow a load to be speculatively executed as the memory location it reads will be no more than $n$ bytes before or after some location explicitly read within the loop. If the $n$ is omitted, the compiler assumes the speculative threshold is unlimited. To specify this in Code Composer Studio, select the Speculate Threshold check box and leave the text box blank in the Build Options dialog box on the Compiler tab, Advanced category.

Collapsing can usually reduce the minimum safe trip count. If the minimum known trip count is less than the minimum safe trip count, a redundant loop is required. Otherwise, pipelining must be suppressed. Both these values can be found in the comment block preceding a software pipelined loop.

```plaintext
;*  Known Minimum Trip Count : 1
....
;*  Minimum safe trip count : 7
```

If the minimum safe trip count is greater than the minimum known trip count, use of --speculate_loads is highly recommended, not only for code size, but for performance.

When using --speculate_loads, you must ensure that potentially speculated loads will not cause illegal reads. This can be done by padding the data sections and/or stack, as needed, by the required memory pad in both directions. The required memory pad for a given software-pipelined loop is also provided in the comment block for that loop.

```plaintext
;*  Minimum required memory pad : 8 bytes
```

### 3.2.3.2 Selecting the Best Threshold Value

When a loop is software pipelined, the comment block preceding the loop provides the following information:

- Required memory pad for this loop
- The minimum value of $n$ needed to achieve this software pipeline schedule and level of collapsing
- Suggestion for a larger value of $n$ to use which might allow additional collapsing

This information shows up in the comment block as follows:

```plaintext
;*  Minimum required memory pad : 5 bytes
;*  Minimum threshold value    : --speculate_loads=7
;*  For further improvement on this loop, try option --speculate_loads=14
```

For safety, the example loop requires that array data referenced within this loop be preceded and followed by a pad of at least 5 bytes. This pad can consist of other program data. The pad will not be modified. In many cases, the threshold value (namely, the minimum value of the argument to --speculate_loads that is needed to achieve a particular schedule and level of collapsing) is the same as the pad. However, when it is not, the comment block will also include the minimum threshold value. In the case of this loop, the threshold value must be at least 7 to achieve this level of collapsing.
Beginning with v7.4.0 of the C6000 Code Generation Tools, the compiler and linker can provide automatic load speculation via the auto argument to the --speculate_loads option (i.e. --speculate_loads=auto or -mh=auto). Use of the auto argument makes it easier to use and benefit from speculative load optimizations. This option can generate speculative loads of up to 256 bytes beyond memory that the compiler can prove to be allocated.

In addition, the compiler communicates information to the linker to help automatically ensure the required pre- and post-padding:

- If the symbol of the speculatively loaded buffer is known during compile time, the linker will ensure the object pointed to by the symbol has the required padding to let the speculative load access legal memory.
- If the symbol information is not known during compile time, the linker will ensure that the placement of data sections will allow legal accessing beyond the boundaries of the data sections. The linker does this by simply padding the start and end of the memory range(s) where the data sections are placed.

However, you can also specify the speculative loads threshold explicitly via the --speculate_loads=n option, where n is at least the minimum required pad (as explained earlier), but you also need to consider whether a larger threshold value would facilitate additional collapsing. This information is also provided, if applicable. For example, in the above comment block, a threshold value of 14 might facilitate further collapsing. If you choose the auto argument to --speculate_loads, the compiler will consider the larger threshold value automatically.

3.3 Redundant Loops

Every loop iterates some number of times before the loop terminates. The number of iterations is called the trip count. The variable used to count each iteration is the trip counter. When the trip counter reaches a limit equal to the trip count, the loop terminates. The C6000 tools use the trip count to determine whether or not a loop can be pipelined. The structure of a software pipelined loop requires the execution of a minimum number of loop iterations (a minimum trip count) in order to fill or prime the pipeline.

The minimum trip count for a software pipelined loop is determined by the number of iterations executing in parallel. In Figure 3-1, the minimum trip count is five. In the following example A, B, and C are instructions in a software pipeline, so the minimum trip count for this single-cycle software pipelined loop is three.

```
A
B
C
```

When the C6000 tools cannot determine the trip count for a loop, then by default two loops and control logic are generated. The first loop is not pipelined, and it executes if the run-time trip count is less than the loop’s minimum trip count. The second loop is the software pipelined loop, and it executes when the run-time trip count is greater than or equal to the minimum trip count. At any given time, one of the loops is a redundant loop. For example:

```
foo(N) /* N is the trip count */
{
    for (I=0; I < N; I++) /* I is the trip counter */
}
```

After finding a software pipeline for the loop, the compiler transforms foo() as below, assuming the minimum trip count for the loop is 3. Two versions of the loop would be generated and the following comparison would be used to determine which version should be executed:

```
foo(N)
{
    if (N < 3)
    {
        for (I=0; I < N; I++) /* Unpipelined version */
    }
```
else
}
for (I=0; I < N; I++) /* Pipelined version */
}
}
foo(50); /* Execute software pipelined loop */
foo(2); /* Execute loop (unpipelined) */

You may be able to help the compiler avoid producing redundant loops with the use of --program_level_compile --opt_level=3 (see Section 3.7) or the use of the MUST_ITERATE pragma (see Section 6.9.20).

---

**Turning Off Redundant Loops**

**NOTE:** Specifying any --opt_for_space option turns off redundant loops.

### 3.4 Utilizing the Loop Buffer Using SPLOOP on C6400+, C6740, and C6600

The C6400+, C6740, and C6600 ISAs have a loop buffer which improves performance and reduces code size for software pipelined loops. The loop buffer provides the following benefits:

- **Code size.** A single iteration of the loop is stored in program memory.
- **Interrupt latency.** Loops executing out of the loop buffer are interruptible.
- **Improves performance.** Loops with unknown trip counts and eliminates redundant loops.
- **Reduces or eliminates the need for speculated loads.**
- **Reduces power usage.**

You can tell that the compiler is using the loop buffer when you find SPLOOP(D/W) at the beginning of a software pipelined loop followed by an SPKERNEL at the end. Refer to the *TMS320C6400/C6400+ CPU and Instruction Set Reference Guide* for information on SPLOOP.

When the --opt_for_space option is not used, the compiler will not use the loop buffer if it can find a faster software pipelined loop without it. When using the --opt_for_space option, the compiler will use the loop buffer when it can.

The compiler does not generate code for the loop buffer (SPLOOP/D/W) when any of the following occur:

- **ii (initiation interval) > 14 cycles**
- **Dynamic length (of a single iteration) > 48 cycles**
- **The optimizer completely unrolls the loop**
- **Code contains elements that disqualify normal software pipelining (call in loop, complex control code in loop, etc.).** See the *TMS320C6000 Programmer's Guide* for more information.

### 3.5 Reducing Code Size (--opt_for_space (or -ms) Option)

When using the --opt_level=n option (or -O), you are telling the compiler to optimize your code. The higher the value of n, the more effort the compiler invests in optimizing your code. However, you might still need to tell the compiler what your optimization priorities are. By default, when --opt_level=2 or --opt_level=3 is specified, the compiler optimizes primarily for performance. (Under lower optimization levels, the priorities are compilation time and debugging ease.) You can adjust the priorities between performance and code size by using the code size flag --opt_for_space=n. The --opt_for_space=0, --opt_for_space=1, --opt_for_space=2 and --opt_for_space=3 options increasingly favor code size over performance.

When you specify --silicon_version=6400+ in conjunction with the --opt_for_space option, the code will be tailored for compression. That is, more instructions are tailored so they will more likely be converted from 32-bit to 16-bit instructions when assembled.
It is recommended that a code size flag not be used with the most performance-critical code. Using --opt_for_space=0 or --opt_for_space=1 is recommended for all but the most performance-critical code. Using --opt_for_space=2 or --opt_for_space=3 is recommended for seldom-executed code. Either --opt_for_space=2 or --opt_for_space=3 should be used if you need minimum code size. It is generally recommended that the code size flags be combined with --opt_level=2 or --opt_level=3.

---

Disabling Code-Size Optimizations or Reducing the Optimization Level

**NOTE:** If you reduce optimization and/or do not use code size flags, you are disabling code-size optimizations and sacrificing performance.

---

The --opt_for_space Option is Equivalent to --opt_for_space=0

**NOTE:** If you use --opt_for_space with no code size level number specified, the option level defaults to --opt_for_space=0.
3.6 Performing File-Level Optimization (--opt_level=3 option)

The --opt_level=3 option (aliased as the -O3 option) instructs the compiler to perform file-level optimization. You can use the --opt_level=3 option alone to perform general file-level optimization, or you can combine it with other options to perform more specific optimizations. The options listed in Table 3-1 work with --opt_level=3 to perform the indicated optimization:

<table>
<thead>
<tr>
<th>If You ...</th>
<th>Use this Option</th>
<th>See</th>
</tr>
</thead>
<tbody>
<tr>
<td>Have files that redeclare standard library functions</td>
<td>--std_lib_func_defined</td>
<td>Section 3.6.1</td>
</tr>
<tr>
<td></td>
<td>--std_lib_func_redefined</td>
<td></td>
</tr>
<tr>
<td>Want to create an optimization information file</td>
<td>--gen_opt_level=n</td>
<td>Section 3.6.2</td>
</tr>
<tr>
<td>Want to compile multiple source files</td>
<td>--program_level_compile</td>
<td>Section 3.7</td>
</tr>
</tbody>
</table>

Do Not Lower the Optimization Level to Control Code Size

NOTE: When trying to reduce code size, do not lower the level of optimization, as you might see an increase in code size. Instead, use the --opt_for_space option to control the code.

3.6.1 Controlling File-Level Optimization (--std_lib_func_def Options)

When you invoke the compiler with the --opt_level=3 option, some of the optimizations use known properties of the standard library functions. If your file redeclares any of these standard library functions, these optimizations become ineffective. Use Table 3-2 to select the appropriate file-level optimization option.

<table>
<thead>
<tr>
<th>If Your Source File...</th>
<th>Use this Option</th>
</tr>
</thead>
<tbody>
<tr>
<td>Declares a function with the same name as a standard library function</td>
<td>--std_lib_func_redefined</td>
</tr>
<tr>
<td>Contains but does not alter functions declared in the standard library</td>
<td>--std_lib_func_defined</td>
</tr>
<tr>
<td>Does not alter standard library functions, but you used the --std_lib_func_redefined or --std_lib_func_defined option in a command file or an environment variable. The --std_lib_func_not_defined option restores the default behavior of the optimizer.</td>
<td>--std_lib_func_not_defined</td>
</tr>
</tbody>
</table>

3.6.2 Creating an Optimization Information File (--gen_opt_info Option)

When you invoke the compiler with the --opt_level=3 option, you can use the --gen_opt_info option to create an optimization information file that you can read. The number following the option denotes the level (0, 1, or 2). The resulting file has an .nfo extension. Use Table 3-3 to select the appropriate level to append to the option.

<table>
<thead>
<tr>
<th>If you...</th>
<th>Use this option</th>
</tr>
</thead>
<tbody>
<tr>
<td>Do not want to produce an information file, but you used the --gen_opt_level=1 or --gen_opt_level=2 option in a command file or an environment variable. The --gen_opt_level=0 option restores the default behavior of the optimizer.</td>
<td>--gen_opt_info=0</td>
</tr>
<tr>
<td>Want to produce an optimization information file</td>
<td>--gen_opt_info=1</td>
</tr>
<tr>
<td>Want to produce a verbose optimization information file</td>
<td>--gen_opt_info=2</td>
</tr>
</tbody>
</table>
## 3.7 Performing Program-Level Optimization (\texttt{--program_level_compile} and \texttt{--opt_level=3} options)

You can specify program-level optimization by using the \texttt{--program_level_compile} option with the \texttt{--opt_level=3} option (aliased as \texttt{-O3}). With program-level optimization, all of your source files are compiled into one intermediate file called a \textit{module}. The module moves to the optimization and code generation passes of the compiler. Because the compiler can see the entire program, it performs several optimizations that are rarely applied during file-level optimization:

- If a particular argument in a function always has the same value, the compiler replaces the argument with the value and passes the value instead of the argument.
- If a return value of a function is never used, the compiler deletes the return code in the function.
- If a function is not called directly or indirectly by \texttt{main()}, the compiler removes the function.

To see which program-level optimizations the compiler is applying, use the \texttt{--gen_opt_level=2} option to generate an information file. See Section 3.6.2 for more information.

In Code Composer Studio, when the \texttt{--program_level_compile} option is used, C and C++ files that have the same options are compiled together. However, if any file has a file-specific option that is not selected as a project-wide option, that file is compiled separately. For example, if every C and C++ file in your project has a different set of file-specific options, each is compiled separately, even though program-level optimization has been specified. To compile all C and C++ files together, make sure the files do not have file-specific options. Be aware that compiling C and C++ files together may not be safe if previously you used a file-specific option.

### Compiling Files With the \texttt{--program_level_compile} and \texttt{--keep_asm} Options

**Note:** If you compile all files with the \texttt{--program_level_compile} and \texttt{--keep_asm} options, the compiler produces only one .asm file, not one for each corresponding source file.

### 3.7.1 Controlling Program-Level Optimization (\texttt{--call_assumptions} Option)

You can control program-level optimization, which you invoke with \texttt{--program_level_compile --opt_level=3}, by using the \texttt{--call_assumptions} option. Specifically, the \texttt{--call_assumptions} option indicates if functions in other modules can call a module's external functions or modify a module's external variables. The number following \texttt{--call_assumptions} indicates the level you set for the module that you are allowing to be called or modified. The \texttt{--opt_level=3} option combines this information with its own file-level analysis to decide whether to treat this module's external function and variable declarations as if they had been declared static. Use Table 3-4 to select the appropriate level to append to the \texttt{--call_assumptions} option.

<table>
<thead>
<tr>
<th>If Your Module ...</th>
<th>Use this Option</th>
</tr>
</thead>
<tbody>
<tr>
<td>Has functions that are called from other modules and global variables that are modified in other modules</td>
<td>\texttt{--call_assumptions=0}</td>
</tr>
<tr>
<td>Does not have functions that are called by other modules but has global variables that are modified in other modules</td>
<td>\texttt{--call_assumptions=1}</td>
</tr>
<tr>
<td>Does not have functions that are called by other modules or global variables that are modified in other modules</td>
<td>\texttt{--call_assumptions=2}</td>
</tr>
<tr>
<td>Has functions that are called from other modules but does not have global variables that are modified in other modules</td>
<td>\texttt{--call_assumptions=3}</td>
</tr>
</tbody>
</table>

In certain circumstances, the compiler reverts to a different \texttt{--call_assumptions} level from the one you specified, or it might disable program-level optimization altogether. Table 3-5 lists the combinations of \texttt{--call_assumptions} levels and conditions that cause the compiler to revert to other \texttt{--call_assumptions} levels.
Performing Program-Level Optimization (--program_level_compile and --opt_level=3 options)

Table 3-5. Special Considerations When Using the --call_assumptions Option

<table>
<thead>
<tr>
<th>If Your Option is...</th>
<th>Under these Conditions...</th>
<th>Then the --call_assumptions Level...</th>
</tr>
</thead>
<tbody>
<tr>
<td>Not specified</td>
<td>The --opt_level=3 optimization level was specified</td>
<td>Defaults to --call_assumptions=2</td>
</tr>
<tr>
<td>Not specified</td>
<td>The compiler sees calls to outside functions under the --opt_level=3 optimization level</td>
<td>Reverts to --call_assumptions=0</td>
</tr>
<tr>
<td>Not specified</td>
<td>Main is not defined</td>
<td>Reverts to --call_assumptions=0</td>
</tr>
<tr>
<td>-call_assumptions=1 or -call_assumptions=2</td>
<td>No function has main defined as an entry point and functions are not identified by the FUNC_EXT_CALLED pragma</td>
<td>Reverts to --call_assumptions=0</td>
</tr>
<tr>
<td>-call_assumptions=1 or -call_assumptions=2</td>
<td>No interrupt function is defined</td>
<td>Reverts to --call_assumptions=0</td>
</tr>
<tr>
<td>-call_assumptions=1 or -call_assumptions=2</td>
<td>Functions are identified by the FUNC_EXT_CALLED pragma</td>
<td>Remains --call_assumptions=1 or --call_assumptions=2</td>
</tr>
<tr>
<td>-call_assumptions=3</td>
<td>Any condition</td>
<td>Remains --call_assumptions=3</td>
</tr>
</tbody>
</table>

In some situations when you use --program_level_compile and --opt_level=3, you must use a --call_assumptions option or the FUNC_EXT_CALLED pragma. See Section 3.7.2 for information about these situations.

3.7.2 Optimization Considerations When Mixing C/C++ and Assembly

If you have any assembly functions in your program, you need to exercise caution when using the --program_level_compile option. The compiler recognizes only the C/C++ source code and not any assembly code that might be present. Because the compiler does not recognize the assembly code calls and variable modifications to C/C++ functions, the --program_level_compile option optimizes out those C/C++ functions. To keep these functions, place the FUNC_EXT_CALLED pragma (see Section 6.9.10) before any declaration or reference to a function that you want to keep.

Another approach you can take when you use assembly functions in your program is to use the --call_assumptions=n option with the --program_level_compile and --opt_level=3 options (see Section 3.7.1).

In general, you achieve the best results through judicious use of the FUNC_EXT_CALLED pragma in combination with --program_level_compile --opt_level=3 and --call_assumptions=1 or --call_assumptions=2.

If any of the following situations apply to your application, use the suggested solution:

**Situation** — Your application consists of C/C++ source code that calls assembly functions. Those assembly functions do not call any C/C++ functions or modify any C/C++ variables.

**Solution** — Compile with --program_level_compile --opt_level=3 --call_assumptions=2 to tell the compiler that outside functions do not call C/C++ functions or modify C/C++ variables. See Section 3.7.1 for information about the --call_assumptions=2 option.

If you compile with the --program_level_compile --opt_level=3 options only, the compiler reverts from the default optimization level (--call_assumptions=2) to --call_assumptions=0. The compiler uses --call_assumptions=0, because it presumes that the calls to the assembly language functions that have a definition in C/C++ may call other C/C++ functions or modify C/C++ variables.

**Situation** — Your application consists of C/C++ source code that calls assembly functions. The assembly language functions do not call C/C++ functions, but they modify C/C++ variables.

**Solution** — Try both of these solutions and choose the one that works best with your code:

- Compile with --program_level_compile --opt_level=3 --call_assumptions=1.
- Add the volatile keyword to those variables that may be modified by the assembly functions and compile with --program_level_compile --opt_level=3 --call_assumptions=2.

See Section 3.7.1 for information about the --call_assumptions=n option.
**Situation** — Your application consists of C/C++ source code and assembly source code. The assembly functions are interrupt service routines that call C/C++ functions; the C/C++ functions that the assembly functions call are never called from C/C++. These C/C++ functions act like main: they function as entry points into C/C++.

**Solution** — Add the volatile keyword to the C/C++ variables that may be modified by the interrupts. Then, you can optimize your code in one of these ways:

- You achieve the best optimization by applying the FUNC_EXT_CALLED pragma to all of the entry-point functions called from the assembly language interrupts, and then compiling with --program_level_compile -opt_level=3 --call_assumptions=2. *Be sure that you use the pragma with all of the entry-point functions.* If you do not, the compiler might remove the entry-point functions that are not preceded by the FUNC_EXT_CALLED pragma.

- Compile with --program_level_compile -opt_level=3 --call_assumptions=3. Because you do not use the FUNC_EXT_CALLED pragma, you must use the --call_assumptions=3 option, which is less aggressive than the --call_assumptions=2 option, and your optimization may not be as effective.

Keep in mind that if you use --program_level_compile -opt_level=3 without additional options, the compiler removes the C functions that the assembly functions call. Use the FUNC_EXT_CALLED pragma to keep these functions.

### 3.8 Using Feedback Directed Optimization

Feedback directed optimization provides a method for finding frequently executed paths in an application using compiler-based instrumentation. This information is fed back to the compiler and is used to perform optimizations. This information is also used to provide you with information about application behavior.

#### 3.8.1 Feedback Directed Optimization

Feedback directed optimization uses run-time feedback to identify and optimize frequently executed program paths. Feedback directed optimization is a two-phase process.

#### 3.8.1.1 Phase 1: Collect Program Profile Information

In this phase the compiler is invoked with the option --gen_profile_info, which instructs the compiler to add instrumentation code to collect profile information. The compiler inserts a minimal amount of instrumentation code to determine control flow frequencies. Memory is allocated to store counter information.

The instrumented application program is executed on the target using representative input data sets. The input data sets should correlate closely with the way the program is expected to be used in the end product environment. When the program completes, a run-time-support function writes the collected information into a profile data file called a PDAT file. Multiple executions of the program using different input data sets can be performed and in such cases, the run-time-support function appends the collected information into the PDAT file. The resulting PDAT file is post-processed using a tool called the Profile Data Decoder or pdd6x. The pdd6x tool consolidates multiple data sets and formats the data into a feedback file (PRF file, see Section 3.8.2) for consumption by phase 2 of feedback directed optimization.

#### 3.8.1.2 Phase 2: Use Application Profile Information for Optimization

In this phase, the compiler is invoked with the --use_profile_info=file.prf option, which reads the specified PRF file generated in phase 1. In phase 2, optimization decisions are made using the data generated during phase 1. The profile feedback file is used to guide program optimization. The compiler optimizes frequently executed program paths more aggressively.

The compiler uses data in the profile feedback file to guide certain optimizations of frequently executed program paths.
3.8.1.3 Generating and Using Profile Information

There are two options that control feedback directed optimization:

--gen_profile_info tells the compiler to add instrumentation code to collect profile information. When the program executes the run-time-support exit() function, the profile data is written to a PDAT file. If the environment variable TI_PROFDATA on the host is set, the data is written into the specified file name. Otherwise, it uses the default filename: pprofout.pdat. The full pathname of the PDAT file (including the directory name) can be specified using the TI_PROFDATA host environment variable. By default, the RTS profile data output routine uses the C I/O mechanism to write data to the PDAT file. You can install a device handler for the PPHNDL device that enables you to re-direct the profile data to a custom device driver routine. Feedback directed optimization requires you to turn on at least skeletal debug information when using the --gen_profile_info option. This enables the compiler to output debug information that allows pdd6x to correlate compiled functions and their associated profile data.

--use_profile_info specifies the profile information file(s) to use for performing phase 2 of feedback directed optimization. More than one profile information file can be specified on the command line; the compiler uses all input data from multiple information files. The syntax for the option is:

```
--use_profile_info=value1[,value2,...,valuen]
```

If no filename is specified, the compiler looks for a file named pprofout.prf in the directory where the compiler is invoked.

3.8.1.4 Example Use of Feedback Directed Optimization

These steps illustrate the creation and use of feedback directed optimization.

1. Generate profile information. (Skeletal debug is on by default.)
   ```
   cl6x -mv6400+ --opt_level=2 --gen_profile_info foo.c --run_linker --output_file=foo.out
   --library=lnk.cmd --library=rts64plus.lib
   ```

2. Execute the application.
   The execution of the application creates a PDAT file named pprofout.pdat in the current (host) directory. The application can be run on a simulator or on target hardware connected to a host machine.

3. Process the profile data.
   After running the application with multiple data-sets, run pdd6x on the PDAT files to create a profile information (PRF) file to be used with --use_profile_info.
   ```
   pdd6x -e foo.out -o pprofout.prf pprofout.pdat
   ```

4. Re-compile using the profile feedback file. Skeletal debug is not required.
   ```
   cl6x -mv6400+ --opt_level=2 --use_profile_info=pprofout.prf foo.c --run_linker
   --output_file=foo.out --library=lnk.cmd --library=rts64plus.lib
   ```

3.8.1.5 The .ppdata Section

The profile information collected in phase 1 is stored in the .ppdata section, which must be allocated into target memory. The .ppdata section contains profiler counters for all functions compiled with --gen_profile_info. The default lnk.cmd file in code generation tools version 6.1 and later has directives to place the .ppdata section in data memory. If the link command file has no section directive for allocating .ppdata section, the link step places the .ppdata section in a writable memory range.

The .ppdata section must be allocated memory in multiples of 32 bytes. Please refer to the linker command file in the distribution for example usage.
3.8.1.6 Feedback Directed Optimization and Code Size Tune

Feedback directed optimization is different from the Code Size Tune feature in Code Composer Studio (CCS). The code size tune feature uses CCS profiling to select specific compilation options for each function in order to minimize code size while still maintaining a specific performance point. Code size tune is coarse-grained, since it is selecting an option set for the whole function. Feedback directed optimization selects different optimization goals along specific regions within a function.

3.8.1.7 Instrumented Program Execution Overhead

During profile collection, the execution time of the application may increase. The amount of increase depends on the size of the application and the number of files in the application compiled for profiling.

The profiling counters increase the code and data size of the application. Consider using the --opt_for_space (-ms) code size options when using profiling to mitigate the code size increase. This has no effect on the accuracy of the profile data being collected. Since profiling only counts execution frequency and not cycle counts, code size optimization flags do not affect profiler measurements.

3.8.1.8 Invalid Profile Data

When recompiling with --use_profile_info, the profile information is invalid in the following cases:

- The source file name changed between the generation of profile information (gen-profile) and the use of the profile information (use-profile).
- The source code was modified since gen-profile. In this case, profile information is invalid for the modified functions.
- Certain compiler options used with gen-profile are different from those with used with use-profile. In particular, options that affect parser behavior could invalidate profile data during use-profile. In general, using different optimization options during use-profile should not affect the validity of profile data.

3.8.2 Profile Data Decoder

The code generation tools include a new tool called the profile data decoder or pdd6x, which is used for post processing profile data (PDAT) files. The pdd6x tool generates a profile feedback (PRF) file. See Section 3.8.1 for a discussion on where pdd6x fits in the profiling flow. The pdd6x tool is invoked with this syntax:

```
pdd6x -e exec.out -o application.prf filename.pdat
```

- **-a** Computes the average of the data values in the data sets instead of accumulating data values.
- **-e exec.out** Specifies `exec.out` is the name of the application executable.
- **-o application.prf** Specifies `application.prf` is the formatted profile feedback file that is used as the argument to --use_profile_info during recompilation. If no output file is specified, the default output filename is pprofout.prf.
- **filename.pdat** Is the name of the profile data file generated by the run-time-support function. This is the default name and it can be overridden by using the host environment variable TI_PROFDATA.
The run-time-support function and pdd6x append to their respective output files and do not overwrite them. This enables collection of data sets from multiple runs of the application.

Profile Data Decoder Requirements

NOTE: Your application must be compiled with at least skeletal (dwarf) debug support to enable feedback directed optimization. When compiling for feedback directed optimization, the pdd6x tool relies on basic debug information about each function in generating the formatted .prf file.

The pprofout.pdat file generated by the run-time support is a raw data file of a fixed format understood only by pdd6x. You should not modify this file in any way.

3.8.3 Feedback Directed Optimization API

There are two user interfaces to the profiler mechanism. You can start and stop profiling in your application by using the following run-time-support calls.

- TI_start_pprof_collection()
  This interface informs the run-time support that you wish to start profiling collection from this point on and causes the run-time support to clear all profiling counters in the application (that is, discard old counter values).

- TI_stop_pprof_collection()
  This interface directs the run-time support to stop profiling collection and output profiling data into the output file (into the default file or one specified by the TI_PROFDATA host environment variable). The run-time support also disables any further output of profile data into the output file during exit(), unless you call TI_start_pprof_collection() again.

3.8.4 Feedback Directed Optimization Summary

Options

- --gen_profile_info
  Adds instrumentation to the compiled code. Execution of the code results in profile data being emitted to a PDAT file.

- --use_profile_info=file.prf
  Uses profile information for optimization and/or generating code coverage information.

- --analyze=codecov
  Generates a code coverage information file and continues with profile-based compilation. Must be used with --use_profile_info.

- --analyze_only
  Generates only a code coverage information file. Must be used with --use_profile_info. You must specify both --analyze=codecov and --analyze_only to do code coverage analysis of the instrumented application.

Host Environment Variables

- TI_PROFDATA
  Writes profile data into the specified file

- TI_COVDIR
  Creates code coverage files in the specified directory

- TI_COVDATA
  Writes code coverage data into the specified file

API

- TI_start_pprof_collection()
  Clears the profile counters to file

- TI_stop_pprof_collection()
  Writes out all profile counters to file

- PPHDNL
  Device driver handle for low-level C I/O based driver for writing out profile data from a target program.
3.9 Using Profile Information to Get Better Program Cache Layout and Analyze Code Coverage

There are two different types of analysis information you can get from the path profiler: code coverage information and call graph information.

The program cache layout tool helps you to develop better program instruction cache efficiency into your applications. Program cache layout is the process of controlling the relative placement of code sections into memory to minimize the occurrence of conflict misses in the program instruction cache.

3.9.1 Background and Motivation

Effective utilization of the program instruction cache is an important part of getting the best performance from a C6000. The dedicated program instruction cache (L1P) provides fast instruction fetches, but a cache miss can be very costly. Some applications (e.g. h264) can spend 30%+ of the processor's time stalling due to L1P cache misses. A cache miss occurs when a fetch fails to read an instruction from L1P and the process is required to access the instruction from the next level of memory. A request to L2 or external memory has a much higher latency than an access from L1P.

Careful placement of code sections can greatly reduce the number of cache misses. The C6000 L1P is especially sensitive to code placement because it is direct-mapped.

Many L1P cache misses are conflict misses. Conflict misses occur when the cache has recently evicted a block of code that is now needed again. In a program instruction cache this often occurs when two frequently executed blocks of code (usually from different functions) interleave their execution and are mapped to the same cache line.

For example, suppose there is a call to function B from inside a loop in function A. Suppose also that the code for function A's loop is mapped to the same cache line as a block of code from function B that is executed every time that B is called. Each time B is called from within this loop, the loop code in function A is evicted from the cache by the code in B that is mapped to the same cache line. Even worse, when B returns to A, the loop code in A evicts the code from function B that is mapped to the same cache line.

Every iteration through the loop will cause two program instruction cache conflict misses. If the loop is heavily traversed, then the number of processor cycles lost to program instruction cache stalls can become quite large.

Many program instruction cache conflict misses can be avoided with more intelligent placement of functions that are active at the same time. Program instruction cache efficiency can be significantly improved using code placement strategies that utilize dynamic profile information that is gathered during the run of an instrumented application.

The program cache layout tool (clt6x) takes dynamic profile information in the form of a weighted call graph and creates a preferred function order command file that can be used as input to the linker to guide the placement of function subsections.

You can use the program cache layout tool to help improve your program locality and reduce the number of L1P cache conflict misses that occur during the run of your application, thereby improving your application's performance.


3.9.2 Code Coverage

The information collected during feedback directed optimization can be used for generating code coverage reports. As with feedback directed optimization, the program must be compiled with the --gen_profile_info option.

Code coverage conveys the execution count of each line of source code in the file being compiled, using data collected during profiling.

3.9.2.1 Phase1: Collect Program Profile Information

In this phase the compiler is invoked with the option --gen_profile_info, which instructs the compiler to add instrumentation code to collect profile information. The compiler inserts a minimal amount of instrumentation code to determine control flow frequencies. Memory is allocated to store counter information.

The instrumented application program is executed on the target using representative input data sets. The input data sets should correlate closely with the way the program is expected to be used in the end product environment. When the program completes, a run-time-support function writes the collected information into a profile data file called a PDAT file. Multiple executions of the program using different input data sets can be performed and in such cases, the run-time-support function appends the collected information into the PDAT file. The resulting PDAT file is post-processed using a tool called the Profile Data Decoder or pdd6x. The pdd6x tool consolidates multiple data sets and formats the data into a feedback file (PRF file, see Section 3.8.2) for consumption by phase 2 of feedback directed optimization.

3.9.2.2 Phase 2: Generate Code Coverage Reports

In this phase, the compiler is invoked with the --use_profile_info=file.prf option, which indicates that the compiler should read the specified PRF file generated in phase 1. The application must also be compiled with either the --codecov or --onlycodecov option; the compiler generates a code-coverage info file. The --codecov option directs the compiler to continue compilation after generating code-coverage information, while the --onlycodecov option stops the compiler after generating code-coverage data. For example:

c6x --opt_level=2 --use_profile_info=pprofout.prf --onlycodecov foo.c

You can specify two environment variables to control the destination of the code-coverage information file.

- The TI_COVDIR environment variable specifies the directory where the code-coverage file should be generated. The default is the directory where the compiler is invoked.
- The TI_COVDATA environment variable specifies the name of the code-coverage data file generated by the compiler. The default is filename.csv where filename is the base-name of the file being compiled. For example, if foo.c is being compiled, the default code-coverage data file name is foo.csv.

If the code-coverage data file already exists, the compiler appends the new dataset at the end of the file.

Code-coverage data is a comma-separated list of data items that can be conveniently handled by data-processing tools and scripting languages. The following is the format of code-coverage data:

"filename-with-full-path","funcname",line#,column#,exec-frequency,"comments"

"filename-with-full-path" Full pathname of the file corresponding to the entry
"funcname" Name of the function
line# Line number of the source line corresponding to frequency data
column# Column number of the source line
exec-frequency Execution frequency of the line
"comments" Intermediate-level representation of the source-code generated by the parser

The full filename, function name, and comments appear within quotation marks (".). For example:

"/some_dir/zlib/c64p/deflate.o",_deflateInit2_",216,5,1,"( strm->zalloc )"

Other tools, such as a spreadsheet program, can be used to format and view the code coverage data.
3.9.3 What Performance Improvements Can You Expect to See?

If your application does not suffer from inefficient usage of the L1P cache, then the program cache layout capability will not have any effect on the performance of your application. Before applying the program cache layout tooling to your application, analyze the L1P cache performance in your application.

3.9.3.1 Evaluating L1P Cache Performance

Evaluating the L1P cache usage efficiency of your application will not only help you determine whether or not your application might benefit from using program cache layout, but it also gives you a rough estimate as to how much performance improvement you can reasonably expect from applying program cache layout.

There are several resources available to help you evaluate L1P cache usage in your application. One way of doing this is to use the Function Profiling capability in Code Composer Studio (CCS). This capability is available in the C6400+ Megamodule Cycle Accurate Simulator target configuration under CCS. You can find further information about using the CCS Function Profiling capabilities at http://tiexpressdsp.com/index.php/Profiler. You can find more information about how to use this capability in conjunction with the program cache layout tool at http://tiexpressdsp.com/index.php/Program_Cache_Layout.

The number of CPU stall cycles that occur due to L1P cache misses gives you a reasonable upper bound estimate of the number of CPU cycles that you may be able to recover with the use of the program cache layout tooling in your application. Please be aware that the performance impact due to program cache layout will tend to vary for the different data sets that are run through your application.

3.9.4 Program Cache Layout Related Features and Capabilities

Version 7.0 of the C6000 code generation tools introduce some features and capabilities that can be used in conjunction with the program cache layout tool, clt6x. The following is a summary:

3.9.4.1 Path Profiler

The C6000 tools include a path profiling utility, pprof6x, that is run from the compiler, cl6x. The pprof6x utility is invoked by the compiler when the --gen_profile or the --use_profile command is used from the compiler command line:

```
cl6x --gen_profile ... file.c
cl6x --use_profile ... file.c
```

For further information about profile-based optimization and a more detailed description of the profiling infrastructure within the C6000, see Section 3.8.

3.9.4.2 Analysis Options

The path profiling utility, pprof6x, appends code coverage or weighted call graph analysis information to existing CSV (comma separated values) files that contain the same type of analysis information.

The utility checks to make sure that an existing CSV file contains analysis information that is consistent with the type of analysis information it is being asked to generate (whether it be code coverage or weighted call graph analysis). Attempts to mix code coverage and weighted call graph analysis information in the same output CSV file will be detected and pprof6x will emit a fatal error and abort.

```
--analyze=callgraph
--analyze=codecov
--analyze_only
```

Instructs the compiler to generate weighted call graph analysis information.

Instructs the compiler to generate code coverage analysis information. This option replaces the previous --codecov option.

Halts compilation after generation of analysis information is completed.
3.9.4.3 Environment Variables

To assist with the management of output CSV analysis files, pprof6x supports two new environment variables:

**TI_WCGDATA**

Allows you to specify a single output CSV file for all weighted call graph analysis information. New information is appended to the CSV file identified by this environment variable, if the file already exists.

**TI_ANALYSIS_DIR**

Specifies the directory in which the output analysis file will be generated. The same environment variable can be used for both code coverage information and weighted call graph information (all analysis files generated by pprof6x will be written to the directory specified by the TI_ANALYSIS_DIR environment variable).

---

**TI_COVDIR Environment Variable**

**NOTE:** The existing TI_COVDIR environment variable is still supported when generating code coverage analysis, but is overridden in the presence of a defined TI_ANALYSIS_DIR environment variable.

---

3.9.4.4 Program Cache Layout Tool, clt6x

The program cache layout tool creates a preferred function order command file from input weighted call graph (WCG) information. The syntax is:

```
clt6x CSV files with WCG info -o forder.cmd
```

3.9.4.5 Linker

The compiler prioritizes the placement of a function relative to others based on the order in which --preferred_order options are encountered during the linker invocation. The syntax is:

```
--preferred_order=function specification
```

3.9.4.6 Linker Command File Operator unordered()

The new linker command file keyword unordered relaxes placement constraints placed on an output section whose specification includes an explicit list of which input sections are contained in the output section. The syntax is:

```
unordered()
```

3.9.5 Program Instruction Cache Layout Development Flow

Once you have determined that your application is experiencing some inefficiencies in its usage of the program instruction cache, you may decide to include the program cache layout tooling in your development to attempt to recover some of the CPU cycles that are being lost to stalls due to program instruction cache conflict misses.

3.9.5.1 Gather Dynamic Profile Information

The program cache layout tool, clt6x, relies on the availability of dynamic profile information in the form of a weighted call graph in order to produce a preferred function order command file that can be used to guide function placement at link-time when your application is re-built.
There are several ways in which this dynamic profile information can be collected. For example, if you are running your application on hardware, you may have the capability to collect a PC discontinuity trace. The discontinuity trace can then be post-processed to construct weighted call graph input information for the clt6x.

The method for collecting dynamic profile information that is presented here relies on the path profiling capabilities in the C6000 code generation tools. Here is how it works:

1. Build an instrumented application using the --gen_profile_info option.

   Using --gen_profile_info instructs the compiler to embed counters into the code along the execution paths of each function.

   To compile only use:

   ```
   cl6x options --gen_profile_info src_file(s)
   ```

   The compile and link use:

   ```
   cl6x options --gen_profile_info src_file(s) -run_linker --library lnk.cmd
   ```

2. Run an instrumented application to generate a .pdat file.

   When the application runs, the counters embedded into the application by --gen_profile_info keep track of how many times a particular execution path through a function is traversed. The data collected in these counters is written out to a profile data file named pprofout.pdat.

   The profile data file is automatically generated. For example, if you are using the C64+ simulator under CCS, you can load and run your instrumented program, and you will see that a new pprofout.pdat file is created in your working directory (where the instrumented application is loaded from).

3. Decode the profile data file.

   Once you have a profile data file, the file is decoded by the profile data decoder tool, pdd6x, as follows:

   ```
   pdd6x -e=instrumented app out file -o=pprofout.prf pprofout.pdat
   ```

   Using pdd6x produces a .prf file which is then fed into the re-compile of the application that uses the profile information to generate weighted call graph input data.

4. Use decoded profile information to generate weighted call graph input.

   The compiler now supports a new option, --analyze, which is used to tell the compiler to generate weighted call graph or code coverage analysis information. Its syntax are as follows:

   ```
   --analyze=callgraph
   --analyze=codecov
   ```

   --analyze=callgraph Instructs the compiler to generate weighted call graph information.

   --analyze=codecov Instructs the compiler to generate code coverage information. This option replaces the previous --codecov option.

   The compiler also supports a new --analyze_only option which instructs the compiler to halt compilation after the generation of analysis information has been completed. This option replaces the previous --onlycodecov option.

   To make use of the dynamic profile information that you gathered, re-compile the source code for your application using the --analyze=callgraph option in combination with the --use_profile_info option:

   ```
   cl6x options -mo --analyze=callgraph --use_profile_info=pprofout.prf src_file(s)
   ```

   The use of -mo instructs the compiler to generate code for each function into its own subsection. This option provides the linker with the means to directly control the placement of the code for a given function.
The compiler generates a CSV file containing weighted call graph information for each source file that is specified on the command line. If such a CSV file already exists, then new call graph analysis information will be appended to the existing CSV file. These CSV files are then input to the cache layout tool (clt6x) to produce a preferred function order command file for your application.

For more details on the content of the CSV files (containing weighted call graph information) generated by the compiler, see Section 3.9.6.

### 3.9.5.2 Generate Preferred Function Order from Dynamic Profile Information

At this point, the compiler has generated a CSV file for each C/C++ source file specified on the command line of the re-compile of the application. Each CSV file contains weighted call graph information about all of the call sites in each function defined in the C/C++ source file.

The program cache layout tool, clt6x, collects all of the weighted call graph information in these CSV files into a single, merged weighted call graph. The weighted call graph is processed to produce a preferred function order command file that is fed into the linker to guide the placement of the functions defined in your application source files. This is the syntax for clt6x:

```
clt6x *.csv -o forder.cmd
```

The output of clt6x is a text file containing a sequence of `--preferred_order= <function specification>` options. By default, the name of the output file is forder.cmd, but you can specify your own file name with the `-o` option. The order in which functions appear in this file is their preferred function order as determined by the clt6x.

In general, the proximity of one function to another in the preferred function order list is a reflection of how often the two functions call each other. If two functions are very close to each other in the list, then the linker interprets this as a suggestion that the two functions should be placed very near to one another. Functions that are placed close together are less likely to create a cache conflict miss at run time when both functions are active at the same time. The overall effect should be an improvement in program instruction cache efficiency and performance.

### 3.9.5.3 Utilize Preferred Function Order in Re-Build of Application

Finally, the preferred function order command file that is produced by the clt6x is fed into the linker during the re-build of the application, as follows:

```
c6x options --run_linker *.obj forder.cmd -l ink.cmd
```

The preferred function order command file, forder.cmd, contains a list of `--preferred_order= <function specification>` options. The linker prioritizes the placement of functions relative to each other in the order that the `--preferred_order` options are encountered during the linker invocation.

Each `--preferred_order` option contains a function specification. A function specification can describe simply the name of the function for a global function, or it can provide the path name and source file name where the function is defined. A function specification that contains path and file name information is used to distinguish one static function from another that has the same function name.

The `--preferred_order` options are interpreted by the linker as suggestions to guide the placement of functions relative to each other. They are not explicit placement instructions. If an object file or input section is explicitly mentioned in a linker command file SECTIONS directive, then the placement instruction specified in the linker command file takes precedence over any suggestion from a `--preferred_order` option that is associated with a function that is defined in that object file or input section.

This precedence can be relaxed by applying the unordered() operator to an output specification as described in Section 3.9.7.
3.9.6 Comma-Separated Values (CSV) Files with Weighted Call Graph (WCG) Information

The format of the CSV files generated by the compiler under the `--analyze=callgraph --use_profile_info` option combination is as follows:

```
"caller","callee","weight" [CR][LF]
caller spec,callee spec,call frequency [CR][LF]
caller spec,callee spec,call frequency [CR][LF]
caller spec,callee spec,call frequency [CR][LF]
...
```

Keep the following points in mind:

- Line 1 of the CSV file is the header line. It specifies the meaning of each field in each line of the remainder of the CSV file. In the case of CSV files that contain weighted call graph information, each line will have a caller function specification, followed by a callee function specification, followed by an unsigned integer that provides the number of times a call was executed during run time.
- There may be instances where the caller and callee function specifications are identical on multiple lines in the CSV file. This will happen when a caller function has multiple call sites to the callee function. In the merged weighted call graph that is created by the clt6x, the weights of each line that has the same caller and callee function specifications will be added together.
- The CSV file that is generated by the compiler using the path profiling instrumentation will not include information about indirect function calls or calls to runtime support helper functions (like _remi or _divi). However, you may be able to gather information about such calls with another method (like the PC discontinuity trace mentioned earlier).
- The format of these CSV files is in compliance with the RFC-4180 specification of Comma-Separated Values (CSV) files. For more details on this specification, please see [http://tools.ietf.org/html/rfc4180](http://tools.ietf.org/html/rfc4180).

3.9.7 Linker Command File Operator - unordered()

A new unordered() operator is now available for use in a linker command file. The effect of this operator is to relax the placement constraints placed on an output section specification in which the content of the output section is explicitly stated.

Consider an example output section specification:

```
SECTIONS
{
  .text:
  {
    file.obj(.text:func_a)
    file.obj(.text:func_b)
    file.obj(.text:func_c)
    file.obj(.text:func_d)
    file.obj(.text:func_e)
    file.obj(.text:func_f)
    file.obj(.text:func_g)
    file.obj(.text:func_h)
    *(.text) > PMEM
  } > PMEM
  ...
}
```

In this SECTIONS directive, the specification of .text explicitly dictates the order in which functions are laid out in the output section. Thus by default, the linker will layout func_a through func_h in exactly the order that they are specified, regardless of any other placement priority criteria (such as a preferred function order list that is enumerated by --preferred_order options).

The unordered() operator can be used to relax this constraint on the placement of the functions in the '.text' output section so that placement can be guided by other placement priority criteria.

The unordered() operator can be applied to an output section as in Example 3-2.
Example 3-2. Output Section for unordered() Operator

```c
SECTIONS
{
  .text: unordered()
  {
    file.obj (.text:func_a)
    file.obj (.text:func_b)
    file.obj (.text:func_c)
    file.obj (.text:func_d)
    file.obj (.text:func_e)
    file.obj (.text:func_f)
    file.obj (.text:func_g)
    file.obj (.text:func_h)
    *(.text)
  } > PMEM
  ...
}
```

So that, given this list of --preferred_order options:
- --preferred_order="func_g"
- --preferred_order="func_b"
- --preferred_order="func_d"
- --preferred_order="func_a"
- --preferred_order="func_c"
- --preferred_order="func_f"
- --preferred_order="func_h"
- --preferred_order="func_e"

The placement of the functions in the .text output section is guided by this preferred function order list. This placement will be reflected in a linker generated map file, as follows:

Example 3-3. Generated Linker Map File for Example 3-2

```
SECTION ALLOCATION MAP

output          section page origin length input sections
--- ----- ------- --------- ----------------
.text 0 00000020 00000120 file.obj (.text:func_g:func_g)
  00000040 00000020 file.obj (.text:func_b:func_b)
  00000060 00000020 file.obj (.text:func_d:func_d)
  00000080 00000020 file.obj (.text:func_a:func_a)
  000000a0 00000020 file.obj (.text:func_c:func_c)
  000000c0 00000020 file.obj (.text:func_f:func_f)
  000000e0 00000020 file.obj (.text:func_h:func_h)
  00000100 00000020 file.obj (.text:func_e:func_e)
```

3.9.7.1 About Dot (.) Expressions in the Presence of unordered()

Another aspect of the unordered() operator that should be taken into consideration is that even though the operator causes the linker to relax constraints imposed by the explicit specification of an output section's contents, the unordered() operator will still respect the position of a dot (.) expression within such a specification.
Consider the output section specification in Example 3-4.

**Example 3-4. Respecting Position of a . Expression**

```c
SECTIONS
{
  .text: unordered()
  {
    file.obj(.text:func_a)
    file.obj(.text:func_b)
    file.obj(.text:func_c)
    file.obj(.text:func_d)
    . += 0x100;
    file.obj(.text:func_e)
    file.obj(.text:func_f)
    file.obj(.text:func_g)
    file.obj(.text:func_h)
  } unordered(),

  *(.text)
}

} > PMEM
...
```

In Example 3-4, a dot (.) expression, ". += 0x100;", separates the explicit specification of two groups of functions in the output section. In this case, the linker will honor the specified position of the dot (.) expression with respect to the functions on either side of the expression. That is, the unordered() operator will allow the preferred function order list to guide the placement of func_a through func_d relative to each other, but none of those functions will be placed after the hole that is created by the dot (.) expression. Likewise, the unordered() operator allows the preferred function order list to influence the placement of func_e through func_h relative to each other, but none of those functions will be placed before the hole that is created by the dot (.) expression.

### 3.9.7.2 GROUPs and UNIONs

The unordered() operator can only be applied to an output section. This includes members of a GROUP or UNION directive.

**Example 3-5. Applying unordered() to GROUPs**

```c
SECTIONS
{
  GROUP
  {
    .grp1:
    {
      file.obj(.grp1:func_a)
      file.obj(.grp1:func_b)
      file.obj(.grp1:func_c)
      file.obj(.grp1:func_d)
    } unordered(),

    .grp2:
    {
      file.obj(.grp2:func_e)
      file.obj(.grp2:func_f)
      file.obj(.grp2:func_g)
      file.obj(.grp2:func_h)
    }
  }
}
```
Example 3-5. Applying unordered() to GROUPs (continued)

```
.text: { *(.text) }
} > PMEM
...
```

The SECTIONS directive in Example 3-5 applies the unordered() operator to the first member of the GROUP. The .grp1 output section layout can then be influenced by other placement priority criteria (like the preferred function order list), whereas the .grp2 output section will be laid out as explicitly specified.

The unordered() operator cannot be applied to an entire GROUP or UNION. Attempts to do so will result in a linker command file syntax error and the link will be aborted.

3.9.8 Things To Be Aware Of

There are some behavioral characteristics and limitations of the program cache layout development flow that you should bear in mind:

• Generation of Path Profiling Data File (.pdat)
  When running an application that has been instrumented to collect path-profiling data (using --gen_profile_info compiler option during build), the application will use functions in the run-time-support library to write out information to the path profiling data file (pprofout.pdat in above tutorial). If there is a path profiling data file already in existence when the application starts to run, then any new path profiling data generated will be appended to the existing file.
  To prevent combining path profiling data from separate runs of an application, you need to either rename the path profiling data file from the previous run of the application or remove it before running the application again.

• Indirect Calls Not Recognized by Path Profiling Mechanisms
  When using available path profiling mechanisms to collect weighted call graph information from the path profiling data, pprof6x does not recognize indirect calls. An indirect call site will not be represented in the CSV output file that is generated by pprof6x.
  You can work around this limitation by introducing your own information about indirect call sites into the relevant CSV file(s). If you take this approach, please be sure to follow the format of the callgraph analysis CSV file ("caller", "callee","call frequency").
  If you are able to get weighted call graph information from a PC trace into a callgraph analysis CSV, this limitation will no longer apply (as the PC trace can always identify the callee of an indirect call).

• Multiple --preferred_order Options Associated With Single Function
  There may be cases in which you might want to input more than one preferred function order command file to the linker during the link of an application. For example, you may have developed or received a separate preferred function order command file for one or more of the object libraries that are used by your application.
  In such cases, it is possible that one function may be specified in multiple preferred function order command files. If this happens, the linker will honor only the first instance of the --preferred_order option in which the function is specified.
Indicating Whether Certain Aliasing Techniques Are Used

Aliasing occurs when you can access a single object in more than one way, such as when two pointers point to the same object or when a pointer points to a named object. Aliasing can disrupt optimization, because any indirect reference can refer to another object. The compiler analyzes the code to determine where aliasing can and cannot occur, then optimizes as much as possible while preserving the correctness of the program. The compiler behaves conservatively.

The following sections describe some aliasing techniques that may be used in your code. These techniques are valid according to the ISO C standard and are accepted by the C6000 compiler; however, they prevent the optimizer from fully optimizing your code.

3.10.1 Use the --aliased_variables Option When Certain Aliases are Used

The compiler, when invoked with optimization, assumes that any variable whose address is passed as an argument to a function is not subsequently modified by an alias set up in the called function. Examples include:

- Returning the address from a function
- Assigning the address to a global variable

If you use aliases like this in your code, you must use the --aliased_variables option when you are optimizing your code. For example, if your code is similar to this, use the --aliased_variables option:

```c
int *glob_ptr;

q()
{
    int x = 1;
    int *p = f(&x);
    *p = 5; // p aliases x
    *glob_ptr = 10; // glob_ptr aliases x
    h(x);
}

int *f(int *arg)
{
    glob_ptr = arg;
    return arg;
}
```

3.10.2 Use the --no_bad_aliases Option to Indicate That These Techniques Are Not Used

The --no_bad_aliases option informs the compiler that it can make certain assumptions about how aliases are used in your code. These assumptions allow the compiler to improve optimization. The --no_bad_aliases option also specifies that loop-invariant counter increments and decrements are non-zero. Loop invariant means the value of an expression does not change within the loop.

- The --no_bad_aliases option indicates that your code does not use the aliasing technique described in Section 3.10.1. If your code uses that technique, do not use the --no_bad_aliases option. You must compile with the --aliased_variables option.
- The --no_bad_aliases option indicates that a pointer to a character type does not alias (point to) an object of another type. That is, the special exception to the general aliasing rule for these types given in section 3.3 of the ISO specification is ignored. If you have code similar to the following example, do not use the --no_bad_aliases option:
Prevent Reordering of Associative Floating-Point Operations

{  
  long l;
  char *p = (char *) &l;
  p[2] = 5;
}

- The --no_bad_aliases option indicates that indirect references on two pointers, P and Q, are not aliases if P and Q are distinct parameters of the same function activated by the same call at run time. If you have code similar to the following example, do not use the --no_bad_aliases option:
  
  ```c
  int a[20];
  f(&a, &a) /* Bad */
  f(&a+42, &a+j) /* Also Bad */
  ```

- The --no_bad_aliases option indicates that each subscript expression in an array reference A[E1]..[En] evaluates to a nonnegative value that is less than the corresponding declared array bound. Do not use --no_bad_aliases if you have code similar to the following example:
  
  ```c
  static int ary[20][20];
  int g()
  {  
    return f(5, -4); /* -4 is a negative index */
    return f(0, 96); /* 96 exceeds 20 as an index */
    return f(4, 16); /* This one is OK */
  }
  ```

  In this example, ary[5][-4], ary[0][96], and ary[4][16] access the same memory location. Only the reference ary[4][16] is acceptable with the --no_bad_aliases option because both of its indices are within the bounds (0..19).

- The --no_bad_aliases option indicates that loop-invariant counter increments and decrements of loop counters are non-zero. Loop invariant means a value of an expression does not change within the loop.

If your code does not contain any of the aliasing techniques described above, you should use the --no_bad_aliases option to improve the optimization of your code. However, you must use discretion with the --no_bad_aliases option; unexpected results may occur if these aliasing techniques appear in your code and the --no_bad_aliases option is used.

### 3.10.3 Using the --no_bad_aliases Option With the Assembly Optimizer

The --no_bad_aliases option allows the assembly optimizer to assume there are no memory aliases in your linear assembly; i.e., no memory references ever depend on each other. However, the assembly optimizer still recognizes any memory dependencies you point out with the .mdep directive. For more information about the .mdep directive, see and Section 4.6.4.

### 3.11 Prevent Reordering of Associative Floating-Point Operations

The compiler freely reorders associative floating-point operations. If you do not wish to have the compiler reorder associative floating point operations, use the --fp_not_associative option. Specifying the --fp_not_associative option may decrease performance.
3.12 Use Caution With asm Statements in Optimized Code

You must be extremely careful when using asm (inline assembly) statements in optimized code. The compiler rearranges code segments, uses registers freely, and can completely remove variables or expressions. Although the compiler never optimizes out an asm statement (except when it is unreachable), the surrounding environment where the assembly code is inserted can differ significantly from the original C/C++ source code.

It is usually safe to use asm statements to manipulate hardware controls such as interrupt masks, but asm statements that attempt to interface with the C/C++ environment or access C/C++ variables can have unexpected results. After compilation, check the assembly output to make sure your asm statements are correct and maintain the integrity of the program.

3.13 Automatic Inline Expansion (--auto_inline Option)

When optimizing with the --opt_level=3 option or --opt_level=2 option (aliased as -O3 and -O2, respectively), the compiler automatically inlines small functions. A command-line option, --auto_inline=size, specifies the size threshold for automatic inlining. This option controls only the inlining of functions that are not explicitly declared as inline.

When the --auto_inline option is not used, the compiler sets the size limit based on the optimization level and the optimization goal (performance versus code size). If the -auto_inline size parameter is set to 0, automatic inline expansion is disabled. If the --auto_inline size parameter is set to a non-zero integer, the compiler automatically inlines any function smaller than size. (This is a change from previous releases, which inlined functions for which the product of the function size and the number of calls to it was less than size. The new scheme is simpler, but will usually lead to more inlining for a given value of size.)

The compiler measures the size of a function in arbitrary units; however the optimizer information file (created with the --gen_opt_info=1 or --gen_opt_info=2 option) reports the size of each function in the same units that the --auto_inline option uses. When --auto_inline is used, the compiler does not attempt to prevent inlining that causes excessive growth in compile time or size; use with care.

When --auto_inline option is not used, the decision to inline a function at a particular call-site is based on an algorithm that attempts to optimize benefit and cost. The compiler inlines eligible functions at call-sites until a limit on size or compilation time is reached.

When deciding what to inline, the compiler collects all eligible call-sites in the module being compiled and sorts them by the estimated benefit over cost. Functions declared static inline are ordered first, then leaf functions, then all others eligible. Functions that are too big are not included.

Inlining behavior varies, depending on which compile-time options are specified:

- The code size limit is smaller when compiling for code size rather than performance. The --auto_inline option overrides this size limit.
- At --opt_level=3, the compiler auto-inlines aggressively if compiling for performance.
- At --opt_level=2, the compiler only automatically inlines small functions.

Some Functions Cannot Be Inlined

NOTE: For a call-site to be considered for inlining, it must be legal to inline the function and inlining must not be disabled in some way. See the inlining restrictions in Section 2.11.5.

Optimization Level 3 or 2 and Inlining

NOTE: In order to turn on automatic inlining, you must use the --opt_level=3 option or --opt_level=2 option. At --opt_level=2, only small functions are auto-inlined. If you desire the --opt_level=3 or 2 optimizations, but not automatic inlining, use --auto_inline=0 with the --opt_level=3 or 2 option.
Using Performance Advice to Optimize your Code

Inlining and Code Size

NOTE: Expanding functions inline increases code size, especially inlining a function that is called in a number of places. Function inlining is optimal for functions that are called only from a small number of places and for small functions. To prevent increases in code size because of inlining, use the --auto_inline=0 and --no_inlining options. These options, used together, cause the compiler to inline intrinsics only.

3.14 Using Performance Advice to Optimize your Code

You can use compiler generated Performance Advice to optimize your code. To get Performance Advice, compile with with the following options:

--advice:performance      Instructs the compiler to emit advice to stdout (default).
--advice:performance_file Instructs the compiler to emit advice into a file.
--advice:performance_dir  Instructs the compiler to emit advice into a file in a specific directory.

If an Advice file is requested, but there is no advice, the advice file will not be created; rather the compiler prints a message to stdout:
"filename.c": advice #27004: No Performance Advice is generated.

Example 3-6. Output Advice to stdout (default)

```
c16x -mv6400 -o2 -k --advice:performance func.c
"func.c", line 10: advice #30006: Loop at line 8 cannot be scheduled efficiently as it contains a function call (_init). Try making _init an inline function.
"func.c", line 12: advice #30000: Loop at line 8 cannot be scheduled efficiently as it contains a function call (_calculate). Try to inline call or consider rewriting loop.
```

Note that Advice to prevent Software Pipeline Disqualification (such as that presented above) will also be printed in the .asm file. So, func.asm will contain:

```
;*----------------------------------------------------------------------------*
;* SOFTWARE PIPELINE INFORMATION
;* Disqualified loop: Loop contains a call
;* Loop at line 8 cannot be scheduled efficiently as it contains a
;* function call (_init). Try making _init an inline function.
;* Disqualified loop: Loop contains non-pipelinable instructions
;* Disqualified loop: Loop contains a call
;* Loop at line 8 cannot be scheduled efficiently as it contains a
;* function call (_calculate). Try to inline call or consider
;* rewriting loop.
;* Disqualified loop: Loop contains non-pipelinable instructions
;*----------------------------------------------------------------------------*
```

Example 3-7. Output Advice to a file filename.advice

```
c16x -mv6400 --advice:performance --advice:performance_file=filename.advice func.c
;*****************************************************************************
;* TMS320C6x C/C++ Codegen      Unix v7.5.0P12047 (a0322878 - Feb 16 2012) *
;* Date/Time created: Thu Feb 16 10:26:02 2012                              *
;*                                                                              *
;* This file contains Performance Advice generated by the compiler under the *
;*                                                                              *
;*----------------------------------------------------------------------------*
```

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Example 3.7. Output Advice to a file filename.advice (continued)

```
/* --advice:performance option. Additional information on the specific piece */
/* of advice can be found at: */
/* or by searching for 'Advice #advice_id'. */
/* Warning: This file is auto generated by the compiler and can be */
/* overwritten during the next compile. */

**************************************************************************
* User Options: --silicon_version=6400

"func.c": advice #27000: Detecting compilation without optimization. Use optimization option -o2 or higher.
```

Example 3.8. Output advice to a specific file "myfile.adv" in directory "mydir"

You can do this by using the --advice:performance_file and --advice:performance_dir option:

```
cl6x -mv6400 -o2 -k --advice:performance_file=myfile.adv --advice:performance_dir=mydir basicloop.c
```

Or by specifying the full path name to the --advice:performance_file option:

```
cl6x -mv6400 -o2 -k --advice:performance_file=mydir/myfile.adv basicloop.c
```

If --advice_dir option and full pathname are specified together, --advice:performance_dir option is ignored, and the advice is generated in the full pathname advice file. Also, note that directory "mydir" must already exist for an advice file to be created in there.

### 3.14.1 Types of Advice

#### 3.14.1.1 Advice #27000

advice #27000: Detecting compilation without optimization. Use optimization option -o2 or higher.

Your compilation is being done without any optimization options (-o0 and above). This prevents the compiler from using its most powerful optimization techniques, since the -o (--opt_level) options are the foundations for most other optimizations. You could get substantially better performance using -o2 (or above) optimization. For C6000, optimization option -o2 is required for the software pipelining loop optimization, which is crucial to getting good performance.

The C/C++ compiler is able to perform various optimizations, but you need to specify optimization options on the command line so that these optimizations are performed. The easiest way to invoke optimization is to specify the --opt_level=n option on the compiler command line. You can use -On to alias the --opt_level option. The n denotes the level of optimization (0, 1, 2, and 3), which controls the type and degree of optimization. See "Invoking Optimization" in Section 3.1 for more information on Optimization Options.

#### 3.14.1.2 Advice #27001: Increase Optimization Level

advice #27001: Detecting compilation with low optimization level.

Use optimization option -o2 or higher.

Your compilation uses low-level optimization options (-o1 and below), which prevents the compiler from using its most powerful optimization techniques.
The C/C++ compiler is able to perform various optimizations, but you can control the level of these optimizations. High-level optimizations are performed in the optimizer and low-level, target-specific optimizations occur in the code generator. You must use high-level optimizations to achieve optimal code. You can invoke optimization by specifying the --opt_level=n option on the compiler command line.

See "Invoking Optimization" in Section 3.1 for more information on Optimization Options. Also see information for Advice #27000 in Section 3.14.1.1.

3.14.1.3 Advice #27002: Do not turn off software pipelining

Advice #27002: Detecting compilation with "-mu" which turns off software pipelining. To optimize, turn off this option.

Your compilation is being done using -mu, which turns off software-pipelining. Software-pipelining is a key optimization for achieving good performance. This Advice is issued to alert you to NOT use compiler option -mu. -mu is a good option for debugging, but it is recommended that this option not be used for production code because of the negative performance implications.

In general, to achieve maximal performance, avoid using the following in production code:

- -g: Support full symbolic debug, and is a good option for debugging. This inhibits code reordering across source line boundaries and limits optimizations around function boundaries. This results in less parallelism, more nops and generally less efficient schedules. Using this option can cause a 30-50% performance degradation for control code, generally somewhat less but still significant degradation for performance critical code.
- -ss: Interlist source code into assembly file. As with -g, this option can negatively impact performance.
- -mu: Turns off software-pipelining, which is a key optimization for achieving good performance. This is a good option for debugging, but is not recommended for use in production code due to negative performance implications.

3.14.1.4 Advice #27003: Avoid compiling with debug options

Advice #27003: Detecting compilation with debug option "-g", which hinders optimization. To optimize, remove -g or compile with --optimize_with_debug_option.

The compiler detects that your compilation is being done using -g, which limits software-pipelining. Software-pipelining is a key optimization for achieving good performance. This Advice is issued to alert you to NOT use compiler option -g. -g is a good option for debugging, but it is recommended that this option not be used for production code because of the negative performance implications. Also see Advice #27002 in Section 3.14.1.3.

3.14.1.5 Advice #27004: No Performance Advice generated

Advice #27004: No Performance Advice is generated.

The compiler detects that your compilation is being done using --advice:performance option, but the compiler has no Advice to report. This Advice is issued to alert you to the fact that no Advice is being emitted, and an Advice file will not be created (if one was requested).

3.14.1.6 Advice #30000: Prevent Loop Disqualification due to call

Advice #30000: Loop at line 10 cannot be scheduled efficiently, as it contains a function call ("function_name"). Try to inline call or consider rewriting loop.

The compiler attempts to perform the software pipeline loop optimization at optimization levels --opt_level=2 (or -O2) and -O3. If there is a call in the loop, the compiler will attempt to completely inline the called function, but sometimes this is not possible. If the compiler cannot inline the called function, software pipelining cannot be performed. This can severely reduce the performance of the loop.

In the testcase below, the call to the function "func2" prevents software pipelining. Inlining function "func2" or rewriting the loop to avoid a function call can avoid pipeline disqualification. If the loop pipelines successfully you may see performance improvement.

```c
void func1(int *p, int *q, int n)
```
{ unsigned int i;
for (i = 0; i < n; i++)
{
    int t = func2(i);
    p[i] = q[i] + t;
}

3.14.1.7 Advice #30001: Prevent Loop Disqualification due to rts-call

advice #30001: Loop at line 18 cannot be scheduled efficiently, as it contains conversion from "type-a" to "type-b". Try to use "suggested" type.

The compiler can insert calls to special functions in the run-time support library (RTS) to support operations that are not natively supported by the ISA. For instance, while C6000 floating-point ISAs support instructions to convert between floating-point and signed integer values, they don't support conversion between floating-point and unsigned integer values. If you use unsigned variables in floating point expressions, the compiler will generate a call to an RTS routine to carry out this function. Such a call will disable software pipelining.

You can change the unsigned variables in your code to signed variables and prevent this from happening. The compiler will then be able to use the native hardware instead of adding the special function call, so you may get better performance.

3.14.1.8 Advice #30002: Prevent Loop Disqualification due to asm statement

advice #30002: Loop at line 8 cannot be scheduled efficiently, as it contains an asm() statement. Try to replace the asm() statement with C or intrinsic statement.

An asm statement inserted in a C code loop will disqualify the loop for software pipelining. Software-pipelining is a key optimization for achieving good performance. You may see reduced performance without software pipelining.

Replace the asm() statement with native C, or an intrinsic function call to prevent this from happening.

3.14.1.9 Advice #30003: Prevent Loop Disqualification due to complex condition

advice #30003: Loop at line 8 cannot be scheduled efficiently, as it contains complex conditional expression. Try to simplify condition.

Your code contains a complex conditional expression, possibly a large "if" clause, within a loop, which is preventing optimization. The C6000 compiler will optimize small "if" statements ("if" statements with "if" and "else" blocks that are short or empty). The compiler will not optimize large "if" statements, and such large if statements within the loop body will disqualify the loop for software pipelining. Software-pipelining is a key optimization; you may see reduced performance without it.

In the examples below, Example 1 will pipeline, but Example 2 won't:

Example 1:
for (i=0; i < N; i++)
{
    if (!flag)
    {
        //statements
    }
    else
    {
        x[i] = y[i];
    }
}
Example 2:
```c
for (i = 0; i < n; i++)
{
    if (!flag)
    {
        //statements
    }
    else
    {
        if (flag == 1) x[i] = y[i];
    }
}
```

Example 1 will have significantly better performance than Example 2 because it pipelines successfully. But Example 2 can be pipelined if the code is modified to eliminate the nested "if" :
```c
for (i = 0; i < n; i++)
{
    if (!flag)
    {
        //statements
    }
    else
    {
        p = (flag == 1);
        x[i] = !p * x[i] + p * y[i];
    }
}
```

3.14.1.10 Advice #30004: Prevent Loop Disqualification due to switch statement

advice #30004: Loop at line 257 cannot be scheduled efficiently, as it contains a switch statement. Try to rewrite loop.

There is a switch statement within the loop. A switch statement in a loop will disqualify the loop for software pipelining. Software-pipelining is a key optimization; you may see reduced performance without it.

Try and rewrite the loop without a switch statement.

3.14.1.11 Advice #30005: Prevent Loop Disqualification due to arithmetic operation

advice #30005: Loop at line 5 cannot be scheduled efficiently, as it contains a "division" operation. Rewrite using simpler operations if possible.

The compiler can insert calls to special functions in the run-time support library (RTS) to support operations that are not natively supported by the ISA. For example, the compiler calls __c6xabi_divi() (_divi() in COFF) function to perform 32-bit integer divide operation. Such functions are called compiler helper functions, and result in a function call within the loop body. In the example below, the compiler will accomplish the division operation by calling the compiler helper function "_divi":
```c
void func(float *p, float n)
{
    int i;

    for (i = 1; i < 1000; i++)
    {
        p[i] /= n;
    }
}
```
However if we modify this loop, like below, the loop pipelines :
```c
void func_adjusted(float *p, float n)
{
    int i;
```
float inv = 1/n;
for (i = 1; i < 1000; i++)
    p[i] *= inv;
}

3.14.1.12 Advice #30006: Prevent Loop Disqualification due to call(2)

advice #30006: Loop at line 22 cannot be scheduled efficiently, as it contains a function call ("function_name"). Try making "function_name" an inline function.

For improved performance, at optimization levels --opt_level=2 (-O2) and --opt_level=3 (-O3), the compiler attempts to software pipeline your loops. Sometimes the compiler may not be able to inline a function call that is in a loop. Because the compiler could not inline the function call, the loop could not be software pipelined, and the loop could not be efficiently scheduled.

For example, in the testcase below, call to function "func2" prevents software pipelining:

```c
void func1(int *p, int *q, int n)
{
    unsigned int i;
    for (i = 0; i < n; i++)
    {
        int t = func2(i);
        ; other operations
    }
}
```

```c
int function func2() { . . . }
```

However if function func2 is inlined, it saves the overhead of a function call. The compiler is free to optimize the function in context with surrounding code. Automatic inlining is controlled by the "inline" keyword; use it to allow inlining of specific functions:

```c
inline int function func2() { . . . }
```

Also see #Advice 30000 in Section 3.14.1.6.

3.14.1.13 Advice #30007: Prevent Loop Disqualification due to rts-call(2)

advice #30007: Attempting to use floating-point operation "__mpyd" on fixed-point device, at line 5 (there may be other instances of this). Such calls reduce loop performance; use fixed point operation if possible.

The compiler inserts calls to special functions in the run-time support library (RTS) to support operations that are not natively supported by the instruction set architecture (ISA). For example, C6000 fixed point ISAs do not support floating-point instructions and the compiler will generate a call to an RTS routine to carry out the floating point operation. In the testcase below, the floating-point multiplication is unavailable for a fixed-point device such as C6200:

```c
void func(float *p, float *q, int n)
{
    unsigned int i;
    for (i = 1; i < n; i++)
    {
        p[i] = (q[i] * 12.4) / p[i - 1];
    }
}
If compiled for C6200 (compiler option -mv6200) the compiler will use an RTS call to carry out the 
operation. Such a call will disable software pipelining. You can rewrite the operation, or use a fixed point 
operation to prevent this.

Also see Advice #30001 in Section 3.14.1.7.

3.14.1.14  Advice #30008: Improve Loop; Qualify with restrict

advice #30008: Consider adding the restrict qualifier to the definition

    of inp1, inp2 if they don't access the same memory location.

To help the compiler determine memory dependencies, you can qualify a pointer, reference, or array with
the restrict keyword. The restrict keyword is a type qualifier that can be applied to pointers, references,
and arrays. Its use represents a guarantee by you, the programmer, that within the scope of the pointer
declaration the object pointed to can be accessed only by that pointer. Any violation of this guarantee
renders the program undefined.

To see more information on using restrict, refer to Section 6.5.5

3.14.1.15  Advice #30009: Improve Loop; Add MUST_ITERATE pragma

advice #30009: If you know that this loop will always execute at a

    multiple of <2> and at least <2> times, try adding

    "#pragma MUST_ITERATE(2, ,2)" just before the loop.

The C6000 architecture is partitioned into two nearly symmetric halves. The resource breakdown
displayed in the software pipelining information in the asm file, is computed after the compiler has
partitioned instructions to either the A-side or the B-side. If the resources are imbalanced (i.e.; some
resources on one side are used more than resources on the other) software pipelining is resource-
bound, and the loop cannot be efficiently scheduled. If the compiler has information about the trip-count
for the loop, it can unroll the loop to balance resource usage, and get better pipelining. You can give loop
trip-count information to the compiler using the "MUST_ITERATE" pragma.

To see more information on using the MUST_ITERATE pragma, refer to Section 6.9.20

3.14.1.16  Advice #30010: Improve Loop; Add MUST_ITERATE pragma(2)

advice #30010: If you know that this loop will always execute atlest

    <2> times, try adding "#pragma MUST_ITERATE(2)" just before the loop.

See Advice #30009 at Section 3.14.1.15.

3.14.1.17  Advice #30011: Improve Loop; Add _nassert()

advice #30011: Consider adding assertions to indicate n-byte alignment

    of variables input1, input2, output if they are actually n-byte

    aligned: _nassert((int)(input1) % 8 == 0).

Most loops have memory access instructions. The compiler attempts to use wider load instructions, and
aligned memory accesses instead of non-aligned memory accesses to reduce/balance out resources used
for the memory access instructions. One of the ways to let the compiler know that it is safe to use "wider"
loads is to use the keyword "_nassert".

To find out more on using the _nassert keyword, see Section 7.5.10.

3.14.2 Using the Interlist Feature With Optimization

You control the output of the interlist feature when compiling with optimization (the --opt_level=n or -On
option) with the --optimizer_interlist and --c_src_interlist options.

• The --optimizer_interlist option interlists compiler comments with assembly source statements.

• The --c_src_interlist option together interlist the compiler comments and the
original C/C++ source with the assembly code.
When you use the --optimizer_interlist option with optimization, the interlist feature does not run as a separate pass. Instead, the compiler inserts comments into the code, indicating how the compiler has rearranged and optimized the code. These comments appear in the assembly language file as comments starting with ;**. The C/C++ source code is not interlisted, unless you use the --c_src_interlist option also.

The interlist feature can affect optimized code because it might prevent some optimization from crossing C/C++ statement boundaries. Optimization makes normal source interlisting impractical, because the compiler extensively rearranges your program. Therefore, when you use the --optimizer_interlist option, the compiler writes reconstructed C/C++ statements.

Example 3-9 shows a function that has been compiled with optimization (--opt_level=2) and the --optimizer_interlist option. The assembly file contains compiler comments interlisted with assembly code.

**Impact on Performance and Code Size**

**NOTE:** The --c_src_interlist option can have a negative effect on performance and code size.

When you use the --c_src_interlist and --optimizer_interlist options with optimization, the compiler inserts its comments and the interlist feature runs before the assembler, merging the original C/C++ source into the assembly file.

Example 3-10 shows the function from Example 3-9 compiled with the optimization (--opt_level=2) and the --c_src_interlist and --optimizer_interlist options. The assembly file contains compiler comments and C source interlisted with assembly code.
Using Performance Advice to Optimize your Code

Example 3-9. The Function From Example 2-4 Compiled With the -O2 and --optimizer_interlist Options

```assembly
_main:
;** 5  ----------------------- printf("Hello, world\n");
;** 6  ----------------------- return 0;

(line 3)
STW .D2 B3,*SP--(12)
B .S1 __printf
NOP 2
MVKL .S1 SL1+0,A0
MVKH .S1 SL1+0,A0
|| MVKL .S2 RL0,B3
STW .D2 A0,**SP(4)
|| MVKH .S2 RL0,B3
RL0: ; CALL OCCURS

(line 4)
ZERO .L1 A4

(line 5)
LDW .D2 *++SP(12),B3
NOP 4
B .S2 B3
NOP 5
; BRANCH OCCURS
```

Example 3-10. The Function From Example 2-4 Compiled with the --opt_level=2, --optimizer_interlist, and --c_src_interlist Options

```assembly
_main:
;** 5  ----------------------- printf("Hello, world\n");
;** 6  ----------------------- return 0;

;------------------------------------------------------------------------------
; 5 | printf("Hello, world\n");
;------------------------------------------------------------------------------

(line 3)
STW .D2 B3,*SP--(12)
B .S1 __printf
NOP 2
MVKL .S1 SL1+0,A0
MVKH .S1 SL1+0,A0
|| MVKL .S2 RL0,B3
STW .D2 A0,**SP(4)
|| MVKH .S2 RL0,B3
RL0: ; CALL OCCURS

;------------------------------------------------------------------------------
; 6 | return 0;
;------------------------------------------------------------------------------

(ZERO .L1 A4
LDW .D2 **SP(12),B3
NOP 4
B .S2 B3
NOP 5
; BRANCH OCCURS
```
3.14.3 Debugging and Profiling Optimized Code

Debugging fully optimized code is not recommended, because the compiler's extensive rearrangement of code and the many-to-many allocation of variables to registers often make it difficult to correlate source code with object code. Profiling code that has been built with the --symdebug:dwarf (aliased as -g) option or the --symdebug:coff option (STABS debug) is not recommended either, because these options can significantly degrade performance. To remedy these problems, you can use the options described in the following sections to optimize your code in such a way that you can still debug or profile the code.

3.14.3.1 Debugging Optimized Code (--symdebug:dwarf, --symdebug:coff, and --opt_level Options)

To debug optimized code, use the --opt_level (aliased as -O) option in conjunction with one of the symbolic debugging options (--symdebug:dwarf or --symdebug:coff). The symbolic debugging options generate directives that are used by the C/C++ source-level debugger, but they disable many compiler optimizations. When you use the --opt_level option (which invokes optimization) with the --symdebug:dwarf or --symdebug:coff option, you turn on the maximum amount of optimization that is compatible with debugging.

If you want to use symbolic debugging and still generate fully optimized code, use the --optimize_with_debug option. This option reenables the optimizations disabled by --symdebug:dwarf or --symdebug:coff. However, if you use the --optimize_with_debug option, portions of the debugger's functionality will be unreliable.

If you are having trouble debugging loops in your code, you can use the --disable_software_pipelining option to turn off software pipelining. See Section 3.2.1 for more information.

Symbolic Debugging Options Affect Performance and Code Size

NOTE: Using the --symdebug:dwarf or --symdebug:coff option can cause a significant performance and code size degradation of your code. Use these options for debugging only. Using --symdebug:dwarf or --symdebug:coff when profiling is not recommended.

C6400+, C6740, and C6600 Support Only DWARF Debugging

NOTE: Since C6400+, C6740, and C6600 produce only DWARF debug information, the --symdebug:coff option is not supported when compiling with -mv6400+, -mv6740, or -mv6600.

3.14.3.2 Profiling Optimized Code

To profile optimized code, use optimization (--opt_level=0 through --opt_level=3) without any debug option. By default, the compiler generates a minimal amount of debug information without affecting optimizations, code size, or performance.

If you have a breakpoint-based profiler, use the --profile:breakpt option with the --opt_level option. The --profile:breakpt option disables optimizations that would cause incorrect behavior when using a breakpoint-based profiler.

If you have a power profiler, use the --profile:power option with the --opt_level option. The --profile:power option produces instrument code for the power profiler.

If you need to profile code at a finer grain that the function level in Code Composer Studio, you can use the --symdebug:dwarf or --symdebug:coff option, although this is not recommended. You might see a significant performance degradation because the compiler cannot use all optimizations with --symdebug:dwarf or --symdebug:coff. It is recommended that outside of Code Composer Studio, you use the clock( ) function.

Profile Points

NOTE: In Code Composer Studio, when symbolic debugging is not used, profile points can only be set at the beginning and end of functions.
3.14.4 Controlling Code Size Versus Speed

The latest mechanism for controlling the goal of optimizations in the compiler is represented by the --opt_for_speed=num option. The num denotes the level of optimization (0-5), which controls the type and degree of code size or code speed optimization:

- **--opt_for_speed=0**
  Enables optimizations geared towards improving the code size with a *high* risk of worsening or impacting performance.

- **--opt_for_speed=1**
  Enables optimizations geared towards improving the code size with a *medium* risk of worsening or impacting performance.

- **--opt_for_speed=2**
  Enables optimizations geared towards improving the code size with a *low* risk of worsening or impacting performance.

- **--opt_for_speed=3**
  Enables optimizations geared towards improving the code performance/speed with a *low* risk of worsening or impacting code size.

- **--opt_for_speed=4**
  Enables optimizations geared towards improving the code performance/speed with a *medium* risk of worsening or impacting code size.

- **--opt_for_speed=5**
  Enables optimizations geared towards improving the code performance/speed with a *high* risk of worsening or impacting code size.

If you specify the option without a parameter, the default setting is --opt_for_speed=4.

The initial mechanism for controlling code space, the --opt_for_space option, has the following equivalences with the --opt_for_speed option:

<table>
<thead>
<tr>
<th>--opt_for_space</th>
<th>--opt_for_speed</th>
</tr>
</thead>
<tbody>
<tr>
<td>none</td>
<td>=4</td>
</tr>
<tr>
<td>=0</td>
<td>=3</td>
</tr>
<tr>
<td>=1</td>
<td>=2</td>
</tr>
<tr>
<td>=2</td>
<td>=1</td>
</tr>
<tr>
<td>=3</td>
<td>=0</td>
</tr>
</tbody>
</table>
3.14.5 What Kind of Optimization Is Being Performed?

The TMS320C6000 C/C++ compiler uses a variety of optimization techniques to improve the execution speed of your C/C++ programs and to reduce their size.

Following are some of the optimizations performed by the compiler:

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<td>Alias disambiguation</td>
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<td>Branch optimizations and control-flow simplification</td>
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<td>Induction variable optimizations and strength reduction</td>
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<tr>
<td>Loop-invariant code motion</td>
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<td>Instruction scheduling</td>
<td>Section 3.14.5.11</td>
</tr>
</tbody>
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<table>
<thead>
<tr>
<th>C6000-Specific Optimization</th>
<th>See</th>
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<tbody>
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</tr>
<tr>
<td>Register tracking/targeting</td>
<td>Section 3.14.5.13</td>
</tr>
<tr>
<td>Software pipelining</td>
<td>Section 3.14.5.14</td>
</tr>
</tbody>
</table>

3.14.5.1 Cost-Based Register Allocation

The compiler, when optimization is enabled, allocates registers to user variables and compiler temporary values according to their type, use, and frequency. Variables used within loops are weighted to have priority over others, and those variables whose uses do not overlap can be allocated to the same register.

Induction variable elimination and loop test replacement allow the compiler to recognize the loop as a simple counting loop and software pipeline, unroll, or eliminate the loop. Strength reduction turns the array references into efficient pointer references with autoincrements.

3.14.5.2 Alias Disambiguation

C and C++ programs generally use many pointer variables. Frequently, compilers are unable to determine whether or not two or more I values (lowercase L: symbols, pointer references, or structure references) refer to the same memory location. This aliasing of memory locations often prevents the compiler from retaining values in registers because it cannot be sure that the register and memory continue to hold the same values over time.

Alias disambiguation is a technique that determines when two pointer expressions cannot point to the same location, allowing the compiler to freely optimize such expressions.
3.14.5.3 Branch Optimizations and Control-Flow Simplification

The compiler analyzes the branching behavior of a program and rearranges the linear sequences of operations (basic blocks) to remove branches or redundant conditions. Unreachable code is deleted, branches to branches are bypassed, and conditional branches over unconditional branches are simplified to a single conditional branch.

When the value of a condition is determined at compile time (through copy propagation or other data flow analysis), the compiler can delete a conditional branch. Switch case lists are analyzed in the same way as conditional branches and are sometimes eliminated entirely. Some simple control flow constructs are reduced to conditional instructions, totally eliminating the need for branches.

3.14.5.4 Data Flow Optimizations

Collectively, the following data flow optimizations replace expressions with less costly ones, detect and remove unnecessary assignments, and avoid operations that produce values that are already computed. The compiler with optimization enabled performs these data flow optimizations both locally (within basic blocks) and globally (across entire functions).

- **Copy propagation.** Following an assignment to a variable, the compiler replaces references to the variable with its value. The value can be another variable, a constant, or a common subexpression. This can result in increased opportunities for constant folding, common subexpression elimination, or even total elimination of the variable.

- **Common subexpression elimination.** When two or more expressions produce the same value, the compiler computes the value once, saves it, and reuses it.

- **Redundant assignment elimination.** Often, copy propagation and common subexpression elimination optimizations result in unnecessary assignments to variables (variables with no subsequent reference before another assignment or before the end of the function). The compiler removes these dead assignments.

3.14.5.5 Expression Simplification

For optimal evaluation, the compiler simplifies expressions into equivalent forms, requiring fewer instructions or registers. Operations between constants are folded into single constants. For example, \( a = (b + 4) - (c + 1) \) becomes \( a = b - c + 3 \).

3.14.5.6 Inline Expansion of Functions

The compiler replaces calls to small functions with inline code, saving the overhead associated with a function call as well as providing increased opportunities to apply other optimizations.

3.14.5.7 Function Symbol Aliasing

The compiler recognizes a function whose definition contains only a call to another function. If the two functions have the same signature (same return value and same number of parameters with the same type, in the same order), then the compiler can make the calling function an alias of the called function.

For example, consider the following:

```c
int bbb(int arg1, char *arg2);

int aaa(int n, char *str)
{
    return bbb(n, str);
}
```

For this example, the compiler makes `aaa` an alias of `bbb`, so that at link time all calls to function `aaa` should be redirected to `bbb`. If the linker can successfully redirect all references to `aaa`, then the body of function `aaa` can be removed and the symbol `aaa` is defined at the same address as `bbb`. 
3.14.5.8 Induction Variables and Strength Reduction

Induction variables are variables whose value within a loop is directly related to the number of executions of the loop. Array indices and control variables for loops are often induction variables.

Strength reduction is the process of replacing inefficient expressions involving induction variables with more efficient expressions. For example, code that indexes into a sequence of array elements is replaced with code that increments a pointer through the array.

Induction variable analysis and strength reduction together often remove all references to your loop-control variable, allowing its elimination.

3.14.5.9 Loop-Invariant Code Motion

This optimization identifies expressions within loops that always compute to the same value. The computation is moved in front of the loop, and each occurrence of the expression in the loop is replaced by a reference to the precomputed value.

3.14.5.10 Loop Rotation

The compiler evaluates loop conditionals at the bottom of loops, saving an extra branch out of the loop. In many cases, the initial entry conditional check and the branch are optimized out.

3.14.5.11 Instruction Scheduling

The compiler performs instruction scheduling, which is the rearranging of machine instructions in such a way that improves performance while maintaining the semantics of the original order. Instruction scheduling is used to improve instruction parallelism and hide pipeline latencies. It can also be used to reduce code size.

3.14.5.12 Register Variables

The compiler helps maximize the use of registers for storing local variables, parameters, and temporary values. Accessing variables stored in registers is more efficient than accessing variables in memory. Register variables are particularly effective for pointers.

3.14.5.13 Register Tracking/Targeting

The compiler tracks the contents of registers to avoid reloading values if they are used again soon. Variables, constants, and structure references such as (a.b) are tracked through straight-line code. Register targeting also computes expressions directly into specific registers when required, as in the case of assigning to register variables or returning values from functions.

3.14.5.14 Software Pipelining

Software pipelining is a technique used to schedule from a loop so that multiple iterations of a loop execute in parallel. See Section 3.2 for more information.
Using the Assembly Optimizer

The assembly optimizer allows you to write assembly code without being concerned with the pipeline structure of the C6000 or assigning registers. It accepts linear assembly code, which is assembly code that may have had register-allocation performed and is unscheduled. The assembly optimizer assigns registers and uses loop optimizations to turn linear assembly into highly parallel assembly.

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</table>
4.1 Code Development Flow to Increase Performance

You can achieve the best performance from your C6000 code if you follow this flow when you are writing and debugging your code:

There are three phases of code development for the C6000:

- **Phase 1: write in C**
  
  You can develop your C/C++ code for phase 1 without any knowledge of the C6000. Use a simulator after compiling with the --opt_level=3 option without any --debug option to identify any inefficient areas in your C/C++ code. See Section 3.14.3 for more information about debugging and profiling optimized code. To improve the performance of your code, proceed to phase 2.
• **Phase 2: refine your C/C++ code**
  In phase 2, use the intrinsics and compiler options that are described in this book to improve your C/C++ code. Use a simulator to check the performance of your altered code. Refer to the *TMS320C6000 Programmer's Guide* for hints on refining C/C++ code. If your code is still not as efficient as you would like it to be, proceed to phase 3.

• **Phase 3: write linear assembly**
  In this phase, you extract the time-critical areas from your C/C++ code and rewrite the code in linear assembly. You can use the assembly optimizer to optimize this code. When you are writing your first pass of linear assembly, you should not be concerned with the pipeline structure or with assigning registers. Later, when you are refining your linear assembly code, you might want to add more details to your code, such as partitioning registers.

  Improving performance in this stage takes more time than in phase 2, so try to refine your code as much as possible before using phase 3. Then, you should have smaller sections of code to work on in this phase.

### 4.2 About the Assembly Optimizer

If you are not satisfied with the performance of your C/C++ code after you have used all of the C/C++ optimizations that are available, you can use the assembly optimizer to make it easier to write assembly code for the C6000.

The assembly optimizer performs several tasks including the following:

- Optionally, partitions instructions and/or registers
- Schedules instructions to maximize performance using the instruction-level parallelism of the C6000
- Ensures that the instructions conform to the C6000 latency requirements
- Optionally, allocates registers for your source code

Like the C/C++ compiler, the assembly optimizer performs software pipelining. *Software pipelining* is a technique used to schedule instructions from a loop so that multiple iterations of the loop execute in parallel. The code generation tools attempt to software pipeline your code with inputs from you and with information that it gathers from your program. For more information, see Section 3.2.

To invoke the assembly optimizer, use the compiler program (cl6x). The assembly optimizer is automatically invoked by the compiler program if one of your input files has a .sa extension. You can specify C/C++ source files along with your linear assembly files. For more information about the compiler program, see Chapter 2.
4.3 What You Need to Know to Write Linear Assembly

By using the C6000 profiling tools, you can identify the time-critical sections of your code that need to be rewritten as linear assembly. The source code that you write for the assembly optimizer is similar to assembly source code. However, linear assembly code does not need to be partitioned, scheduled, or register allocated. The intention is for you to let the assembly optimizer determine this information for you. When you are writing linear assembly code, you need to know about these items:

• Assembly optimizer directives

Your linear assembly file can be a combination of linear assembly code segments and regular assembly source. Use the assembly optimizer directives to differentiate the assembly optimizer code from the regular assembly code and to provide the assembly optimizer with additional information about your code. The assembly optimizer directives are described in Section 4.4.

• Options that affect what the assembly optimizer does

The compiler options in Table 4-1 affect the behavior of the assembly optimizer.

<table>
<thead>
<tr>
<th>Option</th>
<th>Effect</th>
<th>See</th>
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<td>Changes the default extension for assembly optimizer source files</td>
<td>Section 2.3.9</td>
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<tr>
<td>--ap_file</td>
<td>Changes how assembly optimizer source files are identified</td>
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<tr>
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<td>Turns off software pipelining</td>
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<tr>
<td>--debug_software_pipeline</td>
<td>Generates verbose software pipelining information</td>
<td>Section 3.2.2</td>
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<tr>
<td>--interrupt_threshold=n</td>
<td>Specifies an interrupt threshold value</td>
<td>Section 2.12</td>
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<td>--keep_asm</td>
<td>Keeps the assembly language (.asm) file</td>
<td>Section 2.3.1</td>
</tr>
<tr>
<td>--no_bad_aliases</td>
<td>Presumes no memory aliasing</td>
<td>Section 3.10.3</td>
</tr>
<tr>
<td>--opt_for_space=n</td>
<td>Controls code size on four levels (n=0, 1, 2, or 3)</td>
<td>Section 3.5</td>
</tr>
<tr>
<td>--opt_level=n</td>
<td>Increases level of optimization (n=0, 1, 2, or 3)</td>
<td>Section 3.1</td>
</tr>
<tr>
<td>--quiet</td>
<td>Suppresses progress messages</td>
<td>Section 2.3.1</td>
</tr>
<tr>
<td>--silicon_version=n</td>
<td>Select target version</td>
<td>Section 2.3.4</td>
</tr>
<tr>
<td>--skip_assembler</td>
<td>Compiles or assembly optimizes only (does not assemble)</td>
<td>Section 2.3.1</td>
</tr>
<tr>
<td>--speculate_loads=n</td>
<td>Allows speculative execution of loads with bounded address ranges</td>
<td>Section 3.2.3</td>
</tr>
</tbody>
</table>

• TMS320C6000 instructions

When you are writing your linear assembly, your code does not need to indicate the following:

– Pipeline latency
– Register usage
– Which unit is being used

As with other code generation tools, you might need to modify your linear assembly code until you are satisfied with its performance. When you do this, you will probably want to add more detail to your linear assembly. For example, you might want to partition or assign some registers.

Do Not Use Scheduled Assembly Code as Source

NOTE: The assembly optimizer assumes that the instructions in the input file are placed in the logical order in which you would like them to occur (that is, linear assembly code). Parallel instructions are illegal.

If the compiler cannot make your instructions linear (non-parallel), it produces an error message. The compiler assumes instructions occur in the order the instructions appear in the file. Scheduled code is illegal (even non-parallel scheduled code). Scheduled code may not be detected by the compiler but the resulting output may not be what you intended.

• Linear assembly source statement syntax

The linear assembly source programs consist of source statements that can contain assembly optimizer directives, assembly language instructions, and comments. See Section 4.3.1 for more information on the elements of a source statement.
What You Need to Know to Write Linear Assembly

- **Specifying registers or register sides**
  Registers can be assigned explicitly to user symbols. Alternatively, symbols can be assigned to the A-side or B-side leaving the compiler to do the actual register allocation. See Section 4.3.2 for information on specifying registers.

- **Specifying the functional unit**
  The functional unit specifier is optional in linear assembly code. Data path information is respected; unit information is ignored.

- **Source comments**
  The assembly optimizer attaches the comments on instructions from the input linear assembly to the output file. It attaches the 2-tuple \(<x, y>\) to the comments to specify which iteration and cycle of the loop an instruction is on in the software pipeline. The zero-based number \(x\) represents the iteration the instruction is on during the first execution of the kernel. The zero-based number \(y\) represents the cycle the instruction is scheduled on within a single iteration of the loop. See Section 4.3.4, for an illustration of the use of source comments and the resulting assembly optimizer output.

### 4.3.1 Linear Assembly Source Statement Format

A source statement can contain five ordered fields (label, mnemonic, unit specifier, operand list, and comment). The general syntax for source statements is as follows:

- **label**: Labels are optional for all assembly language instructions and for most (but not all) assembly optimizer directives. When used, a label must begin in column 1 of a source statement. A label can be followed by a colon.

- **[ register ]**: Square brackets ([ ]) enclose conditional instructions. The machine-instruction mnemonic is executed based on the value of the register within the brackets; valid register names are A0 for C6400, C6400+, C6740, and C6600 only; A1, A2, B0, B1, B2, or symbolic.

- **mnemonic**: The mnemonic is a machine-instruction (such as ADDK, MVKH, B) or assembly optimizer directive (such as .proc, .trip).

- **unit specifier**: The optional unit specifier enables you to specify the functional unit operand. Only the specified unit side is used; other specifications are ignored. The preferred method is specifying register sides.

- **operand list**: The operand list is not required for all instructions or directives. The operands can be symbols, constants, or expressions and must be separated by commas.

- **comment**: Comments are optional. Comments that begin in column 1 must begin with a semicolon or an asterisk; comments that begin in any other column must begin with a semicolon.

The C6000 assembly optimizer reads up to 200 characters per line. Any characters beyond 200 are truncated. Keep the operational part of your source statements (that is, everything other than comments) less than 200 characters in length for correct assembly. Your comments can extend beyond the character limit, but the truncated portion is not included in the .asm file.

Follow these guidelines in writing linear assembly code:

- All statements must begin with a label, a blank, an asterisk, or a semicolon.
- Labels are optional; if used, they must begin in column 1.
- One or more blanks must separate each field. Tab characters are interpreted as blanks. You must separate the operand list from the preceding field with a blank.
- Comments are optional. Comments that begin in column 1 can begin with an asterisk or a semicolon (* or ;) but comments that begin in any other column must begin with a semicolon.
- If you set up a conditional instruction, the register must be surrounded by square brackets.
- A mnemonic cannot begin in column 1 or it is interpreted as a label.

Refer to the *TMS320C6000 Assembly Language Tools User’s Guide* for information on the syntax of C6000 instructions, including conditional instructions, labels, and operands.
4.3.2 Register Specification for Linear Assembly

There are only two cross paths in the C6000. This limits the C6000 to one source read from each data path's opposite register file per cycle. The compiler must select a side for each instruction; this is called partitioning.

It is recommended that you do not initially partition the linear assembly source code by hand. This allows the compiler more freedom to partition and optimize your code. If the compiler does not find an optimal partition in a software pipelined loop, then you can partition enough instructions by hand to force optimal partitioning by partitioning registers.

The assembly optimizer chooses a register for you such that its use agrees with the functional units chosen for the instructions that operate on the value.

Registers can be directly partitioned through two directives. The .rega directive is used to constrain a symbolic name to A-side registers. The .regb directive is used to constrain a symbolic name to B-side registers. See the .rega/.regb topic for further details on these directives. The .reg directive allows you to use descriptive names for values that are stored in registers. See the .reg topic for further details and examples of the .reg directive.

Example 4-1 is a hand-coded linear assembly program that computes a dot product; compare to Example 4-2, which illustrates C code.

Example 4-1. Linear Assembly Code for Computing a Dot Product

```
_dotp: .cproc a_0, b_0
  .rega a_4, tmp0, sum0, prod1, prod2
  .regb b_4, tmp1, sum1, prod3, prod4
  .reg cnt, sum
  .reg val0, val1
  ADD 4, a_0, a_4
  ADD 4, b_0, b_4
  MVK 100, cnt
  ZERO sum0
  ZERO sum1
  loop: .trip 25
    LDW *a_0++[2], val0 ; load a[0-1]
    LDW *b_0++[2], val1 ; load b[0-1]
    MPY val0, val1, prod1 ; a[0] * b[0]
    MPYH val0, val1, prod2 ; a[1] * b[1]
    ADD prod1, prod2, tmp0 ; sum0 += (a[0] * b[0]) +
    ADD tmp0, sum0, sum0 ; (a[1] * b[1])
    LDW *a_4++[2], val0 ; load a[2-3]
    LDW *b_4++[2], val1 ; load b[2-3]
    MPY val0, val1, prod3 ; a[2] * b[2]
    MPYH val0, val1, prod4 ; a[3] * b[3]
    ADD prod3, prod4, tmp1 ; sum1 += (a[2] * b[2]) +
    ADD tmp1, sum1, sum1 ; (a[3] * b[3])
  [cnt] SUB cnt, 4, cnt ; cnt -= 4
  [cnt] B loop ; if (cnt!=0) goto loop
  ADD sum0, sum1, sum ; compute final result
 .return sum
.endproc
```

Example 4-2 is refined C code for computing a dot product.
Example 4-2. C Code for Computing a Dot Product

```c
int dotp(short a[], short b[]) {
    int sum0 = 0;
    int sum1 = 0;
    int sum, i;
    for (i = 0; i < 100/4; i += 4) {
        sum0 += a[i] * b[i];
        sum0 += a[i+1] * b[i+1];
        sum1 += a[i+2] * b[i+2];
        sum1 += a[i+3] * b[i+3];
    }
    return sum0 + sum1;
}
```

The old method of partitioning registers indirectly by partitioning instructions can still be used. Side and functional unit specifiers can still be used on instructions. However, functional unit specifiers (.L/.S/.D/.M) are ignored. Side specifiers are translated into partitioning constraints on the corresponding symbolic names, if any. For example:

```c
MV .1 x, y ; translated to .REGA y
LDW .D2T2 *u, v:w ; translated to .REGB u, v, w
```

In the linear assembler, you can also specify register pairs using the .cproc and/or .reg directive as in Example 4-3:

Example 4-3. Specifying a Register Pair

```assembly
.global foopair
foopair: .cproc q1:q0, s0
.reg r1:r0
ADD q1:q0, s0, r1:r0
.return r1:r0
.endproc
```

In Example 4-3, the expression "q1:q0" means that the first argument into the linear assembly function is a register pair. By the C calling conventions, the pair "q1:q0" symbols are mapped to register pair "a5:a4". When a register pair syntax is used as the argument to a .reg directive (as shown), it means that the two register symbols are constrained to be an aligned register pair when the compiler processes the linear assembler source and allocates actual registers that the register pair symbols map to "r1:r0" as shown.

The 7.2. Beta compiler supports a register quad syntax (C6600 only), in order to specify 128-bit operands of 128-bit capable instructions in linear assembly and assembly source code. Example 4-4 illustrates how you can specify register quads:

Example 4-4. Specifying a Register Quad (C6600 Only)

```assembly
.global fooquad
fooquad: .cproc q3:q2:q1:q0, s3:s2:s1:s0
.reg r3:r2:r1:r0
QMPY32 s3:s2:s1:s0, q3:q2:q1:q0, r3:r2:r1:r0
.return r3:r2:r1:r0
.endproc
```

In Example 4-4, the expression "q3:q2:q1:q0" means that the first argument into the linear assembly function is a register quad. By the C calling conventions, the pair "q3:q2:q1:q0" symbols are mapped to register quad "a15:a14:a4.a3".
In Example 4-4, the expression "q3:q2:q1:q0" means that the first argument into the linear assembly function is a register quad. By the C calling conventions, the quad "q3:q2:q1:q0" symbols are mapped to register quad "a7:a6:a5:a4". When a register quad syntax is used as the argument to a .reg directive (as shown), it means that the four register symbols are constrained to be an aligned register quad when the compiler processes the linear assembler source and allocates actual registers that the register quad symbols map to "r3:r2:r1:r0" as shown.

### 4.3.3 Functional Unit Specification for Linear Assembly

Specifying functional units has been deprecated by the ability to partition registers directly. (See Section 4.3.2 for details.) While you can use the unit specifier field in linear assembly, only the register side information is used by the compiler.

You specify a functional unit by following the assembler instruction with a period (.) and a functional unit specifier. One instruction can be assigned to each functional unit in a single instruction cycle. There are eight functional units, two of each functional type, and two address paths. The two of each functional type are differentiated by the data path each uses, A or B.

- **.D1** and **.D2** Data/addition/subtraction operations
- **.L1** and **.L2** Arithmetic logic unit (ALU)/compares/long data arithmetic
- **.M1** and **.M2** Multiply operations
- **.S1** and **.S2** Shift/ALU/branch/field operations
- **.T1** and **.T2** Address paths

There are several ways to enter the unit specifier filed in linear assembly. Of these, only the specific register side information is recognized and used:

- You can specify the particular functional unit (for example, .D1).
- You can specify the .D1 or .D2 functional unit followed by T1 or T2 to specify that the nonmemory operand is on a specific register side. T1 specifies side A and T2 specifies side B. For example:
  ```assembly
  LDW .D1T2 *A3[A4], B3
  LDW .D1T2 *src, dst
  ```

- You can specify only the data path (for example, .1), and the assembly optimizer assigns the functional type (for example, .L1).

For more information on functional units refer to the *TMS320C6000 CPU and Instruction Set Reference Guide*.

### 4.3.4 Using Linear Assembly Source Comments

Your comments in linear assembly can begin in any column and extend to the end of the source line. A comment can contain any ASCII character, including blanks. Your comments are printed in the linear assembly source listing, but they do not affect the linear assembly.

A source statement that contains only a comment is valid. If it begins in column 1, it can start with a semicolon (;) or an asterisk (*). Comments that begin anywhere else on the line must begin with a semicolon. The asterisk identifies a comment only if it appears in column 1.

The assembly optimizer schedules instructions; that is, it rearranges instructions. Stand-alone comments are moved to the top of a block of instructions. Comments at the end of an instruction statement remain in place with the instruction.

Example 4-5 shows code for a function called Lmac that contains comments.
Example 4-5. Lmac Function Code Showing Comments

Lmac: .cproc A4,B4
    .reg t0,t1,p,i,sh:sl
    MVK 100,i
    ZERO sh
    ZERO sl
loop: .trip 100
    LDH *a4++, t0 ; t0 = a[i]
    LDH *b4++, t1 ; t1 = b[i]
    MPY t0,t1,p ; prod = t0 * t1
    [I] ADD p,sh:sl,sh:sl ; sum += prod
    [I] ADD -1,i,i ; --i
    [I] B loop ; if (I) goto loop
    .return sh:sl
.endproc

4.3.5 Assembly File Retains Your Symbolic Register Names

In the output assembly file, register operands contain your symbolic name. This aids you in debugging your linear assembly files and in gluing snippets of linear assembly output into assembly files.

A .map directive (see the .map topic) at the beginning of an assembly function associates the symbolic name with the actual register. In other words, the symbolic name becomes an alias for the actual register. The .map directive can be used in assembly and linear assembly code.

When the compiler splits a user symbol into two symbols and each is mapped to distinct machine register, a suffix is appended to instances of the symbolic name to generate unique names so that each unique name is associated with one machine register.

For example, if the compiler associated the symbolic name y with A5 in some instructions and B6 in some others, the output assembly code might look like:

```
  .MAP y/A5
  .MAP y'/B6
    ADD .S2X y, 4, y' ; Equivalent to add A5, 4, B6
```

To disable this format with symbolic names and display assembly instructions with actual registers instead, compile with the --machine_REGS option.
Assembly Optimizer Directives

Assembly optimizer directives supply data for and control the assembly optimization process. The assembly optimizer optimizes linear assembly code that is contained within procedures; that is, code within the .proc and .endproc directives or within the .cproc and .endproc directives. If you do not use .cproc/.proc directives in your linear assembly file, your code will not be optimized by the assembly optimizer. This section describes these directives and others that you can use with the assembly optimizer.

Table 4-2 summarizes the assembly optimizer directives. It provides the syntax for each directive, a description of each directive, and any restrictions that you should keep in mind. See the specific directive topic for more detail.

In Table 4-2 and the detailed directive topics, the following terms for parameters are used:

- **argument**— Symbolic variable name or machine register
- **memref**— Symbol used for a memory reference (not a register)
- **register**— Machine (hardware) register
- **symbol**— Symbolic user name or symbolic register name
- **variable**— Symbolic variable name or machine register

**Table 4-2. Assembly Optimizer Directives Summary**

<table>
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<tr>
<th>Syntax</th>
<th>Description</th>
<th>Restrictions</th>
</tr>
</thead>
<tbody>
<tr>
<td>.call [ret_reg =] func_name (argument1, argument2, ...)</td>
<td>Calls a function</td>
<td>Valid only within procedures</td>
</tr>
<tr>
<td>.circ symbol1 / register1 [, symbol2 / register2]</td>
<td>Declares circular addressing</td>
<td>Must manually insert setup/teardown code for circular addressing. Valid only within procedures</td>
</tr>
<tr>
<td>label .cproc [argument1 [, argument2, ...]]</td>
<td>Start a C/C++ callable procedure</td>
<td>Must use with .endproc</td>
</tr>
<tr>
<td>.endproc</td>
<td>End a C/C++ callable procedure</td>
<td>Must use with .cproc</td>
</tr>
<tr>
<td>.endproc [variable1 [, variable2, ...]]</td>
<td>End a procedure</td>
<td>Must use with .proc</td>
</tr>
<tr>
<td>.map symbol1 / register1 [, symbol2 / register2]</td>
<td>Assigns a symbol to a register</td>
<td>Must use an actual machine register</td>
</tr>
<tr>
<td>.mdep [memref1 [, memref2]]</td>
<td>Indicates a memory dependence</td>
<td>Valid only within procedures</td>
</tr>
<tr>
<td>.mptr [variable1,memref, base [+ offset] [, stride]]</td>
<td>Avoid memory bank conflicts</td>
<td>Valid only within procedures</td>
</tr>
<tr>
<td>.no_mdep</td>
<td>No memory aliases in the function</td>
<td>Valid only within procedures</td>
</tr>
<tr>
<td>label .proc [variable1 [, variable2, ...]]</td>
<td>Start a procedure</td>
<td>Must use with .endproc</td>
</tr>
<tr>
<td>.reg symbol1 [, symbol2, ...]</td>
<td>Declare variables</td>
<td>Valid only within procedures</td>
</tr>
<tr>
<td>.rega symbol1 [, symbol2, ...]</td>
<td>Partition symbol to A-side register</td>
<td>Valid only within procedures</td>
</tr>
<tr>
<td>.regb symbol1 [, symbol2, ...]</td>
<td>Partition symbol to B-side register</td>
<td>Valid only within procedures</td>
</tr>
<tr>
<td>.reserve [register1 [, register2, ...]]</td>
<td>Prevents the compiler from allocating a register</td>
<td>Valid only within procedures</td>
</tr>
<tr>
<td>.return [argument]</td>
<td>Return a value to a procedure</td>
<td>Valid only within .cproc procedures</td>
</tr>
<tr>
<td>label .trip min</td>
<td>Specify trip count value</td>
<td>Valid only within procedures</td>
</tr>
<tr>
<td>.volatile memref1 [, memref2, ...]</td>
<td>Designate memory reference volatile</td>
<td>Use --interrupt_threshold=1 if reference may be modified during an interrupt</td>
</tr>
</tbody>
</table>
.call — Calls a Function

Syntax

```
.call [ret_reg] func_name ([argument1, argument2,...])
```

Description

Use the .call directive to call a function. Optionally, you can specify a register that is assigned the result of the call. The register can be a symbolic or machine register. The .call directive adheres to the same register and function calling conventions as the C/C++ compiler. For information, see Section 7.3 and Section 7.4. There is no support for alternative register or function calling conventions.

You cannot call a function that has a variable number of arguments, such as printf. No error checking is performed to ensure the correct number and/or type of arguments is passed. You cannot pass or return structures through the .call directive.

Following is a description of the .call directive parameters:

- **ret_reg** (Optional) Symbolic/machine register that is assigned the result of the call. If not specified, the assembly optimizer presumes the call overwrites the registers A5 and A4 with a result.
- **func_name** The name of the function to call, or the name of the symbolic/ machine register for indirect calls. A register pair is not allowed. The label of the called function must be defined in the file. If the code for the function is not in the file, the label must be defined with the .global or .ref directive (refer to the TMS320C6000 Assembly Language Tools User's Guide for details). If you are calling a C/C++ function, you must use the appropriate linkname of that function. See Section 6.12 for more information.
- **arguments** (Optional) Symbolic/machine registers passed as an argument. The arguments are passed in this order and cannot be a constant, memory reference, or other expression.

By default, the compiler generates near calls and the linker utilizes trampolines if the near call will not reach its destination. To force a far call, you must explicitly load the address of the function into a register, and then issue an indirect call. For example:

```
MVK func,reg
MVKH func,reg
.call reg(op1) ; forcing a far call
```

If you want to use * for indirection, you must abide by C/C++ syntax rules, and use the following alternate syntax:

```
.call [ret_reg =] (* ireg)(arg1, arg2,...)
```

For example:

```
.call (*driver)(op1, op2) ; indirect call
.reg driver
.call driver(op1, op2) ; also an indirect call
```

Here are other valid examples that use the .call syntax.

```
.call fir(x, h, y) ; void function
.call minimal() ; no arguments
.call sum = vecsum(a, b) ; returns an int
.call hi:lo = _atol(string) ; returns a long
```

Since you can use machine register names anywhere you can use symbolic registers, it may appear you can change the function calling convention. For example:

```
.call A6 = compute()
```
It appears that the result is returned in A6 instead of A4. This is incorrect. Using machine registers does not override the calling convention. After returning from the `compute` function with the returned result in A4, a MV instruction transfers the result to A6.

Example

Here is a complete `.call` example:

```
.global _main
.global _puts, _rand, _ltoa
.sect ".const"
string1: .string "The random value returned is ", 0
string2: .string ", 0 ; '10' == newline
.bss charbuf, 20
.text
_main: .cproc
.reg random_value, bufptr, ran_val_hi:ran_val_lo
.call random_value = _rand() ; get a random value
MVKL string1, bufptr ; load address of string1
MVKH string1, bufptr
.call _.puts(bufptr) ; print out string1
MV ran_val_lo
SHR ran_val_lo, 31, ran_val_hi ; sign extend random value
.call _ltoa(ran_val_hi:ran_val_lo, bufptr) ; convert it to a string
.call _puts(bufptr) ; print out the random value
MVKL string2, bufptr
MVKH string2, bufptr
.call _puts(bufptr) ; load address of string2
.endproc
```

### .circ — Declare Circular Registers

#### Syntax

```
.circ symbol1/register1 [, symbol2/register2, ...]
```

#### Description

The `.circ` directive assigns a symbolic register name to a machine register and declares the symbolic register as available for circular addressing. The compiler then assigns the variable to the register and ensures that all code transformations are safe in this situation. You must insert setup/teardown code for circular addressing.

- **symbol**
  A valid symbol name to be assigned to the register. The variable is up to 128 characters long and must begin with a letter. Remaining characters of the variable can be a combination of alphanumeric characters, the underscore (_), and the dollar sign ($).

- **register**
  Name of the actual register to be assigned a variable.

The compiler assumes that it is safe to speculate any load using an explicitly declared circular addressing variable as the address pointer and may exploit this assumption to perform optimizations.

When a symbol is declared with the `.circ` directive, it is not necessary to declare that symbol with the `.reg` directive.

The `.circ` directive is equivalent to using `.map` with a circular declaration.

#### Example

Here the symbolic name Ri is assigned to actual machine register Mi and Ri is declared as potentially being used for circular addressing.

```
.CIRC R1/M1, R2/M2 ...
```
Define a C Callable Procedure

Syntax

```
label .cproc [argument1, argument2, ...]
.endproc
```

Description

Use the `.cproc/.endproc` directive pair to delimit a section of your code that you want the assembly optimizer to optimize and treat as a C/C++ callable function. This section is called a procedure. The `.cproc` directive is similar to the `.proc` directive in that you use `.cproc` at the beginning of a section and `.endproc` at the end of a section. In this way, you can set off sections of your assembly code that you want to be optimized, like functions. The directives must be used in pairs; do not use `.cproc` without the corresponding `.endproc`. Specify a label with the `.cproc` directive. You can have multiple procedures in a linear assembly file.

The `.cproc` directive differs from the `.proc` directive in that the compiler treats the `.cproc` region as a C/C++ callable function. The assembly optimizer performs some operations automatically in a `.cproc` region in order to make the function conform to the C/C++ calling conventions and to C/C++ register usage conventions.

These operations include the following:

- When you use save-on-entry registers (A10 to A15 and B10 to B15), the assembly optimizer saves the registers on the stack and restores their original values at the end of the procedure.
- If the compiler cannot allocate machine registers to symbolic register names specified with the `.reg` directive (see the `.reg` topic) it uses local temporary stack variables. With `.cproc`, the compiler manages the stack pointer and ensures that space is allocated on the stack for these variables.

For more information, see Section 7.3 and Section 7.4.

Use the optional `argument` to represent function parameters. The argument entries are very similar to parameters declared in a C/C++ function. The arguments to the `.cproc` directive can be of the following types:

- **Machine-register names.** If you specify a machine-register name, its position in the argument list must correspond to the argument passing conventions for C (see Section 7.4). For example, the C/C++ compiler passes the first argument to a function in register A4. This means that the first argument in a `.cproc` directive must be A4 or a symbolic name. Up to ten arguments can be used with the `.cproc` directive.

- **Variable names.** If you specify a variable name, then the assembly optimizer ensures that either the variable name is allocated to the appropriate argument passing register or the argument passing register is copied to the register allocated for the variable name. For example, the first argument in a C/C++ call is passed in register A4, so if you specify the following `.cproc` directive:

  ```
  frame .cproc arg1
  ```

  The assembly optimizer either allocates `arg1` to A4, or `arg1` is allocated to a different register (such as B7) and an MV A4, B7 is automatically generated.

- **Register pairs.** A register pair is specified as `arghi:arglo` and represents a 40-bit argument or a 64-bit type double argument.

For example, the `.cproc` defined as follows:

```
._fcn: .cproc arg1, arg2hi:arg2lo, arg3, B6, arg5, B9:B8
...
.return res
...
.endproc
```

Corresponds to a C function declared as:

```c
int fcn(int arg1, long arg2, int arg3, int arg4, int arg5, long arg6);
```
In this example, the fourth argument of .cproc is register B6. This is allowed since the fourth argument in the C/C++ calling conventions is passed in B6. The sixth argument of .cproc is the actual register pair B9:B8. This is allowed since the sixth argument in the C/C++ calling conventions is passed in B8 or B9:B8 for longs.

- **Register quads** (C6600 only). A register quad is specified as r3:r2:r1:r0 and represents a 128-bit type, __x128_t. See Example 4-4.

If you are calling a procedure from C++ source, you must use the appropriate linkname for the procedure label. Otherwise, you can force C naming conventions by using the extern C declaration. See Section 6.12 and Section 7.5 for more information.

When .endproc is used with a .cproc directive, it cannot have arguments. The live out set for a .cproc region is determined by any .return directives that appear in the .cproc region. (A value is live out if it has been defined before or within the procedure and is used as an output from the procedure.) Returning a value from a .cproc region is handled by the .return directive. The return branch is automatically generated in a .cproc region. See the .return topic for more information.

Only code within procedures is optimized. The assembly optimizer copies any code that is outside of procedures to the output file and does not modify it. See Section 4.4.1 for a list of instruction types that cannot appear in a .cproc region.

**Example**

Here is an example in which .cproc and .endproc are used:

```
.if_then: .cproc a, cword, mask, theta
    .reg    cond, if, ai, sum, cntr
    MVK    32, cntr    ; cntr = 32
    ZERO   sum        ; sum = 0
    LOOP:
        [cond] AND cword, mask, cond    ; cond = codeword & mask
        MVK 1, cond                   ; !!(cond))
        CMPEQ theta, cond, if        ; (theta == !!(cond))
        LDH *a++, ai                  ; a[i]
        [if] ADD sum, ai, sum         ; sum += a[i]
        [!if] SUB sum, ai, sum         ; sum -= a[i]
        SHL mask, 1, mask             ; mask = mask << 1
        [cntr] ADD -1, cntr, cntr     ; decrement counter
        [cntr] B LOOP                  ; for LOOP
    .return sum
.endproc
```
**.map — Assign a Variable to a Register**

### Syntax

```
.map symbol, / register, [, symbol, / register, ...]
```

### Description

The `.map` directive assigns symbol names to machine registers. Symbols are stored in the substitution symbol table. The association between symbolic names and actual registers is wiped out at the beginning and end of each linear assembly function. The `.map` directive can be used in assembly and linear assembly files.

- **variable**: A valid symbol name to be assigned to the register. The substitution symbol is up to 128 characters long and must begin with a letter. Remaining characters of the variable can be a combination of alphanumeric characters, the underscore (_), and the dollar sign ($).
- **register**: Name of the actual register to be assigned a variable.

When a symbol is declared with the `.map` directive, it is not necessary to declare that symbol with the `.reg` directive.

### Example

Here the `.map` directive is used to assign x to register A6 and y to register B7. The symbols are used with a move statement.

```
.map x/A6, y/B7
MV x, y ; equivalent to MV A6, B7
```

**.mdep — Indicates a Memory Dependence**

### Syntax

```
.mdep memref1, memref2
```

### Description

The `.mdep` directive identifies a specific memory dependence.

Following is a description of the `.mdep` directive parameters:

- **memref**: The symbol parameter is the name of the memory reference.

The symbol used to name a memory reference has the same syntax restrictions as any assembly symbol. (For more information about symbols, refer to the *TMS320C6000 Assembly Language Tools User’s Guide.*) It is in the same space as the symbolic registers. You cannot use the same name for a symbolic register and annotating a memory reference.

The `.mdep` directive tells the assembly optimizer that there is a dependence between two memory references.

The `.mdep` directive is valid only within procedures; that is, within occurrences of the `.proc` and `.endproc` directive pair or the `.cproc` and `.endcproc` directive pair.

### Example

Here is an example in which `.mdep` is used to indicate a dependence between two memory references.

```
.mdep ld1, st1
LDW *p1++{ld1}, inp1 ; memory reference "ld1"
; other code ...
STW outp2, *p2++{st1} ; memory reference "st1"
```
The `.mptr` directive associates a register with the information that allows the assembly optimizer to determine automatically whether two memory operations have a memory bank conflict. If the assembly optimizer determines that two memory operations have a memory bank conflict, then it does not schedule them in parallel.

A memory bank conflict occurs when two accesses to a single memory bank in a given cycle result in a memory stall that halts all pipeline operation for one cycle while the second value is read from memory. For more information on memory bank conflicts, including how to use the `.mptr` directive to prevent them, see Section 4.5.

Following are descriptions of the `.mptr` directive parameters:

- **variable** | **memref**: The name of the register symbol or memory reference used to identify a load or store involved in a dependence.
- **base**: A symbolic address that associates related memory accesses.
- **offset**: The offset in bytes from the starting base symbol. The offset is an optional parameter and defaults to 0.
- **stride**: The register loop increment in bytes. The stride is an optional parameter and defaults to 0.

The `.mptr` directive tells the assembly optimizer that when the **symbol or memref** is used as a memory pointer in an LD(B/BU)(H/HU)(W) or ST(B/H/W) instruction, it is initialized to point to **base + offset** and is incremented by **stride** each time through the loop.

The `.mptr` directive is valid within procedures only; that is, within occurrences of the `.proc` and `.endproc` directive pair or the `.cproc` and `.endproc` directive pair.

The **symbolic addresses** used for base symbol names are in a name space separate from all other labels. This means that a symbolic register or assembly label can have the same name as a memory bank base name. For example:

```assembly
.mptr Darray,Darray
```

**Example**

Here is an example in which `.mptr` is used to avoid memory bank conflicts.

```assembly
_blkcp: .cproc I
  .reg ptr1, ptr2, tmp1, tmp2
  MVK 0x0, ptr1 ; ptr1 = address 0
  MVK 0x8, ptr2 ; ptr2 = address 8
loop: .trip 50
  .mptr ptr1, a+0, 4
  .mptr foo, a+8, 4 ; potential conflict
  LDW *ptr1++, tmp1 ; load *0, bank 0
  STW tmp1, *ptr2++(foo) ; store *8, bank 0
[I] ADD -1,i,i ; I--
[I] B loop ; if (!0) goto loop
.endproc
```
.no_mdep — No Memory Aliases in the Function

Syntax
.no_mdep

Description
The .no_mdep directive tells the assembly optimizer that no memory dependencies occur within that function, with the exception of any dependencies pointed to with the .mdep directive.

Example
Here is an example in which .no_mdep is used.

```assembly
fn: .cproc dst, src, cnt
   .no_mdep ; no memory aliasing in this function
   ...
.endproc
```

.pref — Assign a Variable to a Register in a Set

Syntax
.pref symbol / register, [/register2...]

Description
The .pref directive communicates a preference to assign a variable to one of a list of registers. The preference is used only in the .cproc or .proc region the .pref directive is declared in and is valid only until the end of the region.

- **symbol**: A valid symbol name to be assigned to the register. The substitution symbol is up to 128 characters long and must begin with a letter. Remaining characters of the symbol can be a combination of alphanumeric characters, the underscore (_), and the dollar sign ($).

- **register**: List of actual registers to be assigned a variable.

There is no guarantee that the symbol will be assigned to any register in the specified group. The compiler may ignore the preference.

When a symbol is declared with the .pref directive, it is not necessary to declare that variable with the .reg directive.

Example
Here x is given a preference to be assigned to either A6 or B7. However, it would be correct for the compiler to assign x to B3 (for example) instead.

```assembly
.PREF x/A6/B7 ; Preference to assign x to either A6 or B7
```

.proc/.endproc — Define a Procedure

Syntax
label .proc [variable, [variable2, ...]]
.endproc [register1, [register2, ...]]

Description
Use the .proc/.endproc directive pair to delimit a section of your code that you want the assembly optimizer to optimize. This section is called a procedure. Use .proc at the beginning of the section and .endproc at the end of the section. In this way, you can set off sections of unscheduled assembly instructions that you want optimized by the compiler. The directives must be used in pairs; do not use .proc without the corresponding .endproc. Specify a label with the .proc directive. You can have multiple procedures in a linear assembly file.

Use the optional variable parameter in the .proc directive to indicate which registers are live in, and use the optional register parameter of the .endproc directive to indicate which registers are live out for each procedure. The variable can be an actual register or a symbolic name. For example:

```assembly
.PROC x, A5, y, B7
...
.ENDPROC y
```
A value is *live in* if it has been defined before the procedure and is used as an input to the procedure. A value is *live out* if it has been defined before or within the procedure and is used as an output from the procedure. If you do not specify any registers with the .endproc directive, it is assumed that no registers are live out.

Only code within procedures is optimized. The assembly optimizer copies any code that is outside of procedures to the output file and does not modify it.

See Section 4.4.1 for a list of instruction types that cannot appear in a .proc region.

**Example**

Here is a block move example in which .proc and .endproc are used:

```assembly
move .proc A4, B4, B0
.no_mdep
loop:
  LDW *B4++, A1
  MV A1, B1
  STW B1, *A4++
  ADD -4, B0, B0
[B0] B loop
.endproc
```

**.reg — Declare Symbolic Registers**

**Syntax**

```
.reg symbol1 [, symbol2, ...]
```

**Description**

The .reg directive allows you to use descriptive names for values that are stored in registers. The assembly optimizer chooses a register for you such that its use agrees with the functional units chosen for the instructions that operate on the value.

The .reg directive is valid within procedures only; that is, within occurrences of the .proc and .endproc directive pair or the .cproc and .endproc directive pair.

Declaring register pairs (or register quads for C6600) explicitly is optional. Doing so is only necessary if the registers should be allocated as a pair, but they are not used that way. It is a best practice to declare register pairs and register quads with the pair/quad syntax. Here is an example of declaring a register pair:

```
.reg A7:A6
```

**Example 1**

This example uses the same code as the block move example shown for .proc/.endproc but the .reg directive is used:

```assembly
move .cproc dst, src, cnt
.reg tmp1, tmp2
loop:
  LDW *src++, tmp1
  MV tmp1, tmp2
  STW tmp2, *dst++
  ADD -4, cnt, cnt
[cnt] B loop
.endproc
```

Notice how this example differs from the .proc example: symbolic registers declared with .reg are allocated as machine registers.

**Example 2**

The code in the following example is invalid, because a variable defined by the .reg directive cannot be used outside of the defined procedure:

```assembly
.move A4
.reg tmp
  LDW *A4++, top
  MV top, B5
.endproc
MV top, B6 ; WRONG: top is invalid outside of the procedure
```
.rega/.regb — Partition Registers Directly

Syntax

- .rega symbol, symbol, ...
- .regb symbol, symbol, ...

Description

Registers can be directly partitioned through two directives. The .rega directive is used to constrain a symbol name to A-side registers. The .regb directive is used to constrain a symbol name to B-side registers. For example:

```
.REGA y
.REGB u, v, w
MV x, y
LDW *u, v:w
```

The .rega and .regb directives are valid within procedures only; that is, within occurrences of the .proc and .endproc directive pair or the .cproc and .endproc directive pair.

When a symbol is declared with the .rega or .regb directive, it is not necessary to declare that symbol with the .reg directive.

The old method of partitioning registers indirectly by partitioning instructions can still be used. Side and functional unit specifiers can still be used on instructions. However, functional unit specifiers (.L/.S/.D/.M) and crosspath information are ignored. Side specifiers are translated into partitioning constraints on the corresponding symbol names, if any. For example:

```
MV .1X z, y ; translated to .REGA y
LDW .D2T2 *u, v:w ; translated to .REGB u, v, w
```

.reserve — Reserve a Register

Syntax

- .reserve register, register, ...

Description

The .reserve directive prevents the assembly optimizer from using the specified register in a .proc or .cproc region.

If a .reserved register is explicitly assigned in a .proc or .cproc region, then the assembly optimizer can also use that register. For example, the variable tmp1 can be allocated to register A7, even though it is in the .reserve list, since A7 was explicitly defined in the ADD instruction:

```
.cproc
 .reserve a7
 .reg tmp1
 ....
 ADD a6, b4, a7
 ....
.endproc
```

Reserving Registers A4 and A5

NOTE: When inside of a .cproc region that contains a .call statement, A4 and A5 cannot be specified in a .reserve statement. The calling convention mandates that A4 and A5 are used as the return registers for a .call statement.
The .reserve in this example guarantees that the assembly optimizer does not use A10 to A13 or B10 to B13 for the variables tmp1 to tmp5:

```assembly
.test .proc a4, b4
  .reg tmp1, tmp2, tmp3, tmp4, tmp5
  .reserve a10, a11, a12, a13, b10, b11, b12, b13
  ....
.endproc a4
```

Example 2

The assembly optimizer may generate less efficient code if the available register pool is overly restricted. In addition, it is possible that the available register pool is constrained such that allocation is not possible and an error message is generated. For example, the following code generates an error since all of the conditional registers have been reserved, but a conditional register is required for the variable tmp:

```assembly
.cproc ...
  .reserve a1, a2, b0, b1, b2
  .reg tmp
  ....
  [tmp] ....
  ....
.endproc
```

### .return — Return a Value to a C callable Procedure

**Syntax**

```
.return [argument]
```

**Description**

The .return directive function is equivalent to the return statement in C/C++ code. It places the optional argument in the appropriate register for a return value as per the C/C++ calling conventions (see Section 7.4).

The optional **argument** can have the following meanings:

- Zero arguments implies a .cproc region that has no return value, similar to a void function in C/C++ code.
- An argument implies a .cproc region that has a 32-bit return value, similar to an int function in C/C++ code.
- A register pair of the format hi:lo implies a .cproc region that has a 40-bit long, a 64-bit long long, or a 64-bit type double return value; similar to a long/long long/double function in C/C++ code.

Arguments to the .return directive can be either symbolic register names or machine-register names.

All return statements in a .cproc region must be consistent in the type of the return value. It is not legal to mix a .return arg with a .return hi:lo in the same .cproc region.

The .return directive is unconditional. To perform a conditional .return, simply use a conditional branch around a .return. The assembly optimizer removes the branch and generates the appropriate conditional code. For example, to return if condition cc is true, code the return as:

```
[!cc] B around
.return
around:
```

**Example**

This example uses a symbolic register, tmp, and a machine-register, A5, as .return arguments:

```assembly
cproc ...
.reg tmp
....
.return tmp = legal symbolic name
....
.return a5 = legal actual name
```
### .trip — Specify Trip Count Values

#### Syntax

```
label .trip minimum value [, maximum value[, factor]]
```

#### Description

The `.trip` directive specifies the value of the trip count. The trip count indicates how many times a loop iterates. The `.trip` directive is valid within procedures only. Following are descriptions of the `.trip` directive parameters:

- **label**: The label represents the beginning of the loop. This is a required parameter.
- **minimum value**: The minimum number of times that the loop can iterate. This is a required parameter. The default is 1.
- **maximum value**: The maximum number of times that the loop can iterate. The maximum value is an optional parameter.
- **factor**: The factor used, along with `minimum value` and `maximum value`, to determine the number of times that the loop can iterate. In the following example, the loop executes some multiple of 8, between 8 and 48, times:
  ```plaintext
  loop: .trip 8, 48, 8
  ```
  A factor of 2 states that your loop always executes an even number of times allowing the compiler to unroll once; this can result in a performance increase. The factor is optional when the maximum value is specified.

If the assembly optimizer cannot ensure that the trip count is large enough to pipeline a loop for maximum performance, a pipelined version and an unpipelined version of the same loop are generated. This makes one of the loops a redundant loop. The pipelined or the unpipelined loop is executed based on a comparison between the trip count and the number of iterations of the loop that can execute in parallel. If the trip count is greater or equal to the number of parallel iterations, the pipelined loop is executed; otherwise, the unpipelined loop is executed. For more information about redundant loops, see Section 3.3.

You are not required to specify a `.trip` directive with every loop; however, you should use `.trip` if you know that a loop iterates some number of times. This generally means that redundant loops are not generated (unless the minimum value is really small) saving code size and execution time.

If you know that a loop always executes the same number of times whenever it is called, define maximum value (where maximum value equals minimum value) as well. The compiler may now be able to unroll your loop thereby increasing performance.

When you are compiling with the interrupt flexibility option (`--interrupt_threshold=n`), using a `.trip` maximum value allows the compiler to determine the maximum number of cycles that the loop can execute. Then, the compiler compares that value to the threshold value given by the `--interrupt_threshold` option. See Section 2.12 for more information.
.volatile — Declare Memory References as Volatile

Example

The .trip directive states that the loop will execute 16, 24, 32, 40 or 48 times when the \texttt{w\_vecsum} routine is called.

\begin{verbatim}
w\_vecsum: .cproc ptr\_a, ptr\_b, ptr\_c, weight, cnt
 .reg ai, bi, prod, scaled\_prod, ci
 .no_mdep

loop: .trip 16, 48, 8
 ldh *ptr\_a++, ai
 ldh *ptr\_b++, bi
 mpy weight, ai, prod
 shr prod, 15, scaled\_prod
 add scaled\_prod, bi, ci
 sth ci, *ptr\_c++
 [cnt] sub cnt, 1, cnt
 [cnt] b loop
 .endproc
\end{verbatim}

.stw W, *X\text{\text{st}} ; volatile store
.stw U, *V
.ldw *Y{ld}, Z ; volatile load

.Syntax

\texttt{.volatile memref\_1[, memref\_2, ...]}

.Description

The .\texttt{volatile} directive allows you to designate memory references as volatile. Volatile loads and stores are not deleted. Volatile loads and stores are not reordered with respect to other volatile loads and stores.

If the .\texttt{volatile} directive references a memory location that may be modified during an interrupt, compile with the \texttt{--interrupt\_threshold=1} option to ensure all code referencing the volatile memory location can be interrupted.

.Example

The st and ld memory references are designated as volatile.

\begin{verbatim}
 .volatile st, ld
 STW W, *X\text{\text{st}} ; volatile store
 STW U, *V
 LDW *Y{ld}, Z ; volatile load
\end{verbatim}
4.4.1 Instructions That Are Not Allowed in Procedures

These types of instructions are not allowed in .cproc or .proc topic regions:

- The stack pointer (register B15) can be read, but it cannot be written to. Instructions that write to B15 are not allowed in a .proc or .cproc region. Stack space can be allocated by the assembly optimizer in a .proc or .cproc region for storage of temporary values. To allocate this storage area, the stack pointer is decremented on entry to the region and incremented on exit from the region. Since the stack pointer can change value on entry to the region, the assembly optimizer does not allow code that changes the stack pointer register.

- Indirect branches are not allowed in a .proc or .cproc region so that the .proc or .cproc region exit protocols cannot be bypassed. Here is an example of an indirect branch:

```assembly
B B4  <= illegal
```

- Direct branches to labels not defined in the .proc or .cproc region are not allowed so that the .proc or .cproc region exit protocols cannot be bypassed. Here is an example of a direct branch outside of a .proc region:

```assembly
.proc...
B outside  = illegal
.endproc
outside:
```

- Direct branches to the label associated with a .proc directive are not allowed. If you require a branch back to the start of the linear assembly function, then use the .call directive. Here is an example of a direct branch to the label of a .proc directive:

```assembly
_func: .proc...
B _func  <= illegal...
.endproc
```

- An .if/.endif loop must be entirely inside or outside of a proc or .cproc region. It is not allowed to have part of an .if/.endif loop inside of a .proc or .cproc region and the other part of the .if/.endif loop outside of the .proc or .cproc region. Here are two examples of legal .if/.endif loops. The first loop is outside a .cproc region, the second loop is inside a .proc region:

```assembly
.if .cproc...
.endproc
.if...
.endif
```

Here are two examples of .if/.endif loops that are partly inside and partly outside of a .cproc or .proc region:

```assembly
.if .cproc .endif .endproc
.if...
.endif
```

- The following assembly instructions cannot be used from linear assembly:
  - EFI
  - SPLOOP, SPLOOPD and SPLOOPW and all other loop-buffer related instructions
4.5 Avoiding Memory Bank Conflicts With the Assembly Optimizer

The internal memory of the C6000 family varies from device to device. See the appropriate device data sheet to determine the memory spaces in your particular device. This section discusses how to write code to avoid memory bank conflicts.

Most C6000 devices use an interleaved memory bank scheme, as shown in Figure 4-1. Each number in the diagram represents a byte address. A load byte (LDB) instruction from address 0 loads byte 0 in bank 0. A load halfword (LDH) from address 0 loads the halfword value in bytes 0 and 1, which are also in bank 0. A load word (LDW) from address 0 loads bytes 0 through 3 in banks 0 and 1.

Because each bank is single-ported memory, only one access to each bank is allowed per cycle. Two accesses to a single bank in a given cycle result in a memory stall that halts all pipeline operation for one cycle while the second value is read from memory. Two memory operations per cycle are allowed without any stall, as long as they do not access the same bank.

**Figure 4-1. 4-Bank Interleaved Memory**

<table>
<thead>
<tr>
<th>Bank 0</th>
<th>Bank 1</th>
<th>Bank 2</th>
<th>Bank 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 1</td>
<td>2 3</td>
<td>4 5</td>
<td>6 7</td>
</tr>
<tr>
<td>8 9</td>
<td>10 11</td>
<td>12 13</td>
<td>14 15</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8N</td>
<td>8N + 1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8N + 2</td>
<td>8N + 3</td>
<td>8N + 4</td>
<td>8N + 5</td>
</tr>
<tr>
<td>8N + 6</td>
<td>8N + 7</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

For devices that have more than one memory space (Figure 4-2), an access to bank 0 in one memory space does not interfere with an access to bank 0 in another memory space, and no pipeline stall occurs.

**Figure 4-2. 4-Bank Interleaved Memory With Two Memory Spaces**

<table>
<thead>
<tr>
<th>Memory space 0</th>
<th>Memory space 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 1</td>
<td>8M 8M + 1</td>
</tr>
<tr>
<td>8 9</td>
<td>8M + 1</td>
</tr>
<tr>
<td></td>
<td>8M + 2</td>
</tr>
<tr>
<td></td>
<td>8M + 3</td>
</tr>
<tr>
<td></td>
<td>8M + 4</td>
</tr>
<tr>
<td></td>
<td>8M + 5</td>
</tr>
<tr>
<td></td>
<td>8M + 6</td>
</tr>
<tr>
<td></td>
<td>8M + 7</td>
</tr>
</tbody>
</table>

Bank 0 | Bank 1 | Bank 2 | Bank 3
4.5.1 Preventing Memory Bank Conflicts

The assembly optimizer uses the assumptions that memory operations do not have bank conflicts. If it determines that two memory operations have a bank conflict on any loop iteration it does not schedule the operations in parallel. The assembly optimizer checks for memory bank conflicts only for those loops that it is trying to software pipeline.

The information required for memory bank analysis indicates a base, an offset, a stride, a width, and an iteration delta. The width is implicitly determined by the type of memory access (byte, halfword, word, or double word for the C6400 and C6700). The iteration delta is determined by the assembly optimizer as it constructs the schedule for the software pipeline. The base, offset, and stride are supplied by the load and store instructions and/or by the .mptr directive.

An LD(B/BU)(H/HU)(W) or ST(B/H/W) operation in linear assembly can have memory bank information associated with it implicitly, by using the .mptr directive. The .mptr directive associates a register with the information that allows the assembly optimizer to determine automatically whether two memory operations have a bank conflict. If the assembly optimizer determines that two memory operations have a memory bank conflict, then it does not schedule them in parallel within a software pipelined loop. The syntax is:

```
.mptr variable, base + offset, stride
```

For example:

```
.mptr a_0,a+0,16
.mptr a_4,a+4,16
LDW *a_0++[4], val1 ; base=a, offset=0, stride=16
LDW *a_4++[4], val2 ; base=a, offset=4, stride=16
.mptr dptr,D+0,8
LDH *dptr++, d0 ; base=D, offset=0, stride=8
LDH *dptr++, d1 ; base=D, offset=2, stride=8
LDH *dptr++, d2 ; base=D, offset=4, stride=8
LDH *dptr++, d3 ; base=D, offset=6, stride=8
```

In this example, the offset for dptr is updated after every memory access. The offset is updated only when the pointer is modified by a constant. This occurs for the pre/post increment/decrement addressing modes.

See the .mptr topic for more information.

Example 4-6 shows loads and stores extracted from a loop that is being software pipelined.

Example 4-6. Load and Store Instructions That Specify Memory Bank Information

```
.mptr Ain,IN,-16
.mptr Bin,IN-4,-16
.mptr Aco,COEF,16
.mptr Bco,COEF+4,16
.mptr Aout,optr+0,4
.mptr Bout,optr+2,4
LDW *Ain--[2],Ain12 ; IN(k-I) & IN(k-I+1)
LDW *Bin--[2],Bin23 ; IN(k-I-2) & IN(k-I-1)
LDW *Ain--[2],Ain34 ; IN(k-I-4) & IN(k-I-3)
LDW *Bin--[2],Bin56 ; IN(k-I-6) & IN(k-I-5)
LDW *Bco++[2],Bco12 ; COEF(I) & COEF(I+1)
LDW *Aco++[2],Aco23 ; COEF(I+2) & COEF(I+3)
LDW *Bco++[2],Bcin34 ; COEF(I+4) & COEF(I+5)
LDW *Aco++[2],Ain56 ; COEF(I+6) & COEF(I+7)
STH Assum,*Aout++[2] ; *oPtr++ = (r >> 15)
STH Bssum,*Bout++[2] ; *oPtr++ = (I >> 15)
```
4.5.2 A Dot Product Example That Avoids Memory Bank Conflicts

The C code in Example 4-7 implements a dot product function. The inner loop is unrolled once to take advantage of the C6000’s ability to operate on two 16-bit data items in a single 32-bit register. LDW instructions are used to load two consecutive short values. The linear assembly instructions in Example 4-8 implement the dotp loop kernel. Example 4-9 shows the loop kernel determined by the assembly optimizer.

For this loop kernel, there are two restrictions associated with the arrays a[ ] and b[ ]:

- Because LDW is being used, the arrays must be aligned to start on word boundaries.
- To avoid a memory bank conflict, one array must start in bank 0 and the other array in bank 2. If they start in the same bank, then a memory bank conflict occurs every cycle and the loop computes a result every two cycles instead of every cycle, due to a memory bank stall. For example:

  Bank conflict:
  
  MVK 0, A0
  || MVK 8, B0
  LDW *A0, A1

  No bank conflict:
  
  MVK 0, A0
  || MVK 4, B0
  LDW *A0, A1
  || LDW *B0, B1

Example 4-7. C Code for Dot Product

```c
int dot(short a[], short b[])
{
    int sum0 = 0, sum1 = 0, sum, i;

    for (I = 0; I < 100/2; I+= 2)
    {
        sum0 += a[i] * b[i];
        sum1 += a[i + 1] * b[i + 1];
    }
    return sum0 + sum1;
}
```
Example 4-8. Linear Assembly for Dot Product

```
_dot: .cproc a, b
.reg sum0, sum1, I
.reg val1, val2, prod1, prod2
MK 50,i ; i = 100/2
ZERO sum0 ; multiply result = 0
ZERO sum1 ; multiply result = 0
loop: .trip 50
LDW *a++,val1 ; load a[0-1] bank0
LDW *b++,val2 ; load b[0-1] bank2
MPY val1,val2,prod1 ; a[0] * b[0]
MPYH val1,val2,prod2 ; a[1] * b[1]
ADD prod1,sum0,sum0 ; sum0 += a[0] * b[0]
ADD prod2,sum1,sum1 ; sum1 += a[1] * b[1]
[I] ADD -1,i,i ; i--
[B] B loop ; if (!I) goto loop
ADD sum0,sum1,A4 ; compute final result
.return A4
.endproc
```

Example 4-9. Dot Product Software-Pipelined Kernel

```
L2: ; PIPED LOOP KERNEL
    ADD .L2 B7,B4,B4 ; 14 <0,7> sum0 += a[0]*b[0]
    ADD .L1 A5,A0,A0 ; 15 <0,7> sum1 += a[1]*b[1]
    MPY .M2X B6,A4,B7 ; 12 <2,5> a[0] * b[0]
    MPYH .M1X B6,A4,A5 ; 13 <2,5> a[1] * b[1]
    [B0] B .S1 L2 ; 18 <5,2> if (!I) goto loop
    [B0] ADD .S2 0xffffffff,B0,B0 ; 17 <6,1> i--
    LDW .D2T2 *B5++,B6 ; 10 <7,0> load a[0-1] bank0
    LDW .D1T1 *A3++,A4 ; 11 <7,0> load b[0-1] bank2
    LDW *B0, B1
```

It is not always possible to control fully how arrays and other memory objects are aligned. This is especially true when a pointer is passed into a function and that pointer may have different alignments each time the function is called. A solution to this problem is to write a dot product routine that cannot have memory hits. This would eliminate the need for the arrays to use different memory banks.

If the dot product loop kernel is unrolled once, then four LDW instructions execute in the loop kernel. Assuming that nothing is known about the bank alignment of arrays a and b (except that they are word aligned), the only safe assumptions that can be made about the array accesses are that a[0-1] cannot conflict with a[2-3] and that b[0-1] cannot conflict with b[2-3]. Example 4-10 shows the unrolled loop kernel.
Example 4-10. Dot Product From Example 4-8 Unrolled to Prevent Memory Bank Conflicts

```assembly
_dotp2: .cproc a_0, b_0
  .reg a_4, b_4, sum0, sum1, I
  .reg val1, val2, prod1, prod2
  ADD 4,a_0,a_4
  ADD 4,b_0,b_4
  MVC 25,i ; I = 100/4
  ZERO sum0 ; multiply result = 0
  ZERO sum1 ; multiply result = 0
  .mptr a_0,a+0,8
  .mptr a_4,a+4,8
  .mptr b_0,b+0,8
  .mptr b_4,b+4,8

loop: .trip 25
  LDW *a_0++[2],val1 ; load a[0-1] bankx
  LDW *b_0++[2],val2 ; load b[0-1] banky
  MPY val1,val2,prod1 ; a[0] * b[0]
  MPYH val1,val2,prod2 ; a[1] * b[1]
  ADD prod1,sum0,sum0 ; sum0 += a[0] * b[0]
  ADD prod2,sum1,sum1 ; sum1 += a[1] * b[1]
  LDW *a_4++[2],val1 ; load a[2-3] bankx+2
  LDW *b_4++[2],val2 ; load b[2-3] banky+2
  MPY val1,val2,prod1 ; a[2] * b[2]
  MPYH val1,val2,prod2 ; a[3] * b[3]
  ADD prod1,sum0,sum0 ; sum0 += a[2] * b[2]
  ADD prod2,sum1,sum1 ; sum1 += a[3] * b[3]

[I] ADD -1,i,i ; I--
[I] B loop ; if (!0) goto loop
  ADD sum0,sum1,A4 ; compute final result
.return A4
.endproc
```
The goal is to find a software pipeline in which the following instructions are in parallel:

```
LDW *a0++[2],val1 ; load a[0-1] bankx
|| LDW *a2++[2],val2 ; load a[2-3] bankx+2
LDW *b0++[2],val1 ; load b[0-1] banky
|| LDW *b2++[2],val2 ; load b[2-3] banky+2
```

**Example 4-11. Unrolled Dot Product Kernel From Example 4-9**

```
L2: ; PIPED LOOP KERNEL
  [ B1] SUB .S2 B1,1,B1 ; <0,8>
  || ADD .L2 B9,B5,B9 ; [21] <0,8> ^ sum0 += a[0] * b[0]
  || ADD .L1 A6,A0,A0 ; [22] <0,8> ^ sum1 += a[1] * b[1]
  || MPY .M2X B8,A4,B9 ; [19] <1,6> a[0] * b[0]
  || [ B0] B .S1 L2 ; [32] <2,4> if (!I) goto loop
  || [ A1] LDW .D2T2 *B8++(8),B8 ; [17] <4,0> load a[0-1] bankx
  [ A1] SUB .S1 A1,1,A1 ; <0,9>
  || ADD .L2 B5,B9,B5 ; [28] <0,9> ^ sum0 += a[2] * b[2]
  || ADD .L1 A6,A0,A0 ; [29] <0,9> ^ sum1 += a[3] * b[3]
  || [ B0] ADD .S2 -1,B0,B0 ; [31] <3,3> I--
  || [ A1] LDW .D1T1 *A5++(8),A4 ; [18] <4,1> load b[0-1] banky
```

Without the .mptr directives in Example 4-10, the loads of a[0-1] and b[0-1] are scheduled in parallel, and the loads of a[2-3] and b[2-3] might be scheduled in parallel. This results in a 50% chance that a memory conflict will occur on every cycle. However, the loop kernel shown in Example 4-11 can never have a memory bank conflict.

In Example 4-10, if .mptr directives had been used to specify that a and b point to different bases, then the assembly optimizer would never find a schedule for a 1-cycle loop kernel, because there would always be a memory bank conflict. However, it would find a schedule for a 2-cycle loop kernel.

### 4.5.3 Memory Bank Conflicts for Indexed Pointers

When determining memory bank conflicts for indexed memory accesses, it is sometimes necessary to specify that a pair of memory accesses always conflict, or that they never conflict. This can be accomplished by using the .mptr directive with a stride of 0.

A stride of 0 indicates that there is a constant relation between the memory accesses regardless of the iteration delta. Essentially, only the base, offset, and width are used by the assembly optimizer to determine a memory bank conflict. Recall that the stride is optional and defaults to 0.

In Example 4-12, the .mptr directive is used to specify which memory accesses conflict and which never conflict.

**Example 4-12. Using .mptr for Indexed Pointers**

```python
.mptr a,RS
.mptr b,RS
.mptr c,XY
.mptr d,XY+2
LDW *a++[i0a],A0 ; a and b always conflict with each other
LDW *b++[i0b],B0 ;
STH A1,*c++[i1a] ; c and d never conflict with each other
STH B2,*d++[i1b] ;
```
4.5.4 Memory Bank Conflict Algorithm

The assembly optimizer uses the following process to determine if two memory access instructions might have a memory bank conflict:

1. If either access does not have memory bank information, then they do not conflict.
2. If both accesses do not have the same base, then they conflict.
3. The offset, stride, access width, and iteration delta are used to determine if a memory bank conflict will occur. The assembly optimizer uses a straightforward analysis of the access patterns and determines if they ever access the same relative bank. The stride and offset values are always expressed in bytes.

The iteration delta is the difference in the loop iterations of the memory references being scheduled in the software pipeline. For example, given three instructions A, B, C and a software pipeline with a single-cycle kernel, then A and C have an iteration delta of 2:

```
A
B A
C B A
C
```

4.6 Memory Alias Disambiguation

Memory aliasing occurs when two instructions can access the same memory location. Such memory references are called ambiguous. Memory alias disambiguation is the process of determining when such ambiguity is not possible. When you cannot determine whether two memory references are ambiguous, you presume they are ambiguous. This is the same as saying the two instructions have a memory dependence between them.

Dependencies between instructions constrain the instruction schedule, including the software pipeline schedule. In general, the fewer the Dependencies, the greater freedom you have in choosing a schedule and the better the final schedule performs.

4.6.1 How the Assembly Optimizer Handles Memory References (Default)

The assembly optimizer assumes memory references are aliased, unless it can prove otherwise. Because alias analysis is very limited in the assembly optimizer, this presumption is often overly conservative. In such cases, the extra instruction Dependencies, due to the presumed memory aliases, can cause the assembly optimizer to emit instruction schedules that have less parallelism and do not perform well. To handle these cases, the assembly optimizer provides one option and two directives.

4.6.2 Using the --no_bad_aliases Option to Handle Memory References

In the assembly optimizer, the --no_bad_aliases option means no memory references ever depend on each other. The --no_bad_aliases option does not mean the same thing to the C/C++ compiler. The C/C++ compiler interprets the --no_bad_aliases switch to indicate several specific cases of memory aliasing are guaranteed not to occur. For more information about using the --no_bad_aliases option, see Section 3.10.2.

4.6.3 Using the .no_mdep Directive

You can specify the .no_mdep directive anywhere in a .(c)proc function. Whenever it is used, you guarantee that no memory Dependencies occur within that function.

---

**Memory Dependency Exception**

**NOTE:** For both of these methods, --no_bad_aliases and .no_mdep, the assembly optimizer recognizes any memory Dependencies you point out with the .mdep directive.
4.6.4 Using the .mdep Directive to Identify Specific Memory Dependencies

You can use the .mdep directive to identify specific memory Dependencies by annotating each memory reference with a name, and using those names with the .mdep directive to indicate the actual dependence. Annotating a memory reference requires adding information right next to the memory reference in the assembly stream. Include the following immediately after a memory reference:

{ memref }

The memref has the same syntax restrictions as any assembly symbol. (For more information about symbols, refer to the TMS320C6000 Assembly Language Tools User’s Guide.) It is in the same name space as the symbolic registers. You cannot use the same name for a symbolic register and annotating a memory reference.

Example 4-13. Annotating a Memory Reference

```
LDW *p1++ {ld1}, inp1 ;name memory reference "ld1"
;other code ...
STW outp2, *p2++ {st1} ;name memory reference "st1"
```

The directive to indicate a specific memory dependence in the previous example is as follows:

```.mdep ld1, st1```

This means that whenever ld1 accesses memory at location X, some later time in code execution, st1 may also access location X. This is equivalent to adding a dependence between these two instructions. In terms of the software pipeline, these two instructions must remain in the same order. The ld1 reference must always occur before the st1 reference; the instructions cannot even be scheduled in parallel.

It is important to note the directional sense of the directive from ld1 to st1. The opposite, from st1 to ld1, is not implied. In terms of the software pipeline, while every ld1 must occur before every st1, it is still legal to schedule the ld1 from iteration n+1 before the st1 from iteration n.

Example 4-14 is a picture of the software pipeline with the instructions from two different iterations in different columns. In the actual instruction sequence, instructions on the same horizontal line are in parallel.

Example 4-14. Software Pipeline Using .mdep ld1, st1

```
iteration n               iteration n+1
------------------------  ------------------------
LDW { ld1 }               LDW { ld1 }
...                       ...
STW { st1 }               STW { st1 }

*<If that schedule...>
.mdep st1, ld1
```

If that schedule does not work because the iteration n st1 might write a value the iteration n+1 ld1 should read, then you must note a dependence relationship from st1 to ld1.

```.mdep st1, ld1```

Both directives together force the software pipeline shown in Example 4-15.
Example 4-15. Software Pipeline Using .mdep st1, ld1 and .mdep ld1, st1

```
iteration n           iteration n+1
---------------------           ---------------------
LDW { ld1 }
...
STW { st1 }

LDW { ld1 }
...
STW { st1 }

indexed addressing,...>
```

Indexed addressing, *+base[index], is a good example of an addressing mode where you typically do not know anything about the relative sequence of the memory accesses, except they sometimes access the same location. To correctly model this case, you need to note the dependence relation in both directions, and you need to use both directives.

```
.mdep ld1, st1  .mdep st1, ld1
```

4.6.5 Memory Alias Examples

Following are memory alias examples that use the .mdep and .no_mdep directives.

- **Example 1**
  The .mdep r1, r2 directive declares that LDW must be before STW. In this case, src and dst might point to the same array.
  ```
  fn: .cproc dst, src, cnt
  .reg tmp
  .no_mdep
  .mdep r1, r2
  LDW *src{r1}, tmp
  STW cnt, *dst{r2}
  .return tmp
  .endproc
  ```

- **Example 2**
  Here, .mdep r2, r1 indicates that STW must occur before LDW. Since STW is after LDW in the code, the dependence relation is across loop iterations. The STW instruction writes a value that may be read by the LDW instruction on the next iteration. In this case, a 6-cycle recurrence is created.
  ```
  fn: .cproc dst, src, cnt
  .reg tmp
  .no_mdep
  .mdep r2, r1
  LOOP: .trip 100
  LDW *src++{r1}, tmp
  STW tmp, *dst++{r2}
  [cnt] SUB cnt, 1, cnt
  [cnt] B LOOP
  .endproc
  ```
Memory Alias Disambiguation

Memory Dependence/Bank Conflict

**NOTE:** Do not confuse memory alias disambiguation with the handling of memory bank conflicts. These may seem similar because they each deal with memory references and the effect of those memory references on the instruction schedule. Alias disambiguation is a correctness issue, bank conflicts are a performance issue. A memory dependence has a much broader impact on the instruction schedule than a bank conflict. It is best to keep these two topics separate.

Volatile References

**NOTE:** For volatile references, use .volatile rather than .mdep.
The C/C++ compiler and assembly language tools provide two methods for linking your programs:

- You can compile individual modules and link them together. This method is especially useful when you have multiple source files.
- You can compile and link in one step. This method is useful when you have a single source module.

This chapter describes how to invoke the linker with each method. It also discusses special requirements of linking C/C++ code, including the run-time-support libraries, specifying the type of initialization, and allocating the program into memory. For a complete description of the linker, see the *TMS320C6000 Assembly Language Tools User's Guide*.

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5.1 Invoking the Linker Through the Compiler (-z Option)

This section explains how to invoke the linker after you have compiled and assembled your programs: as a separate step or as part of the compile step.

5.1.1 Invoking the Linker Separately

This is the general syntax for linking C/C++ programs as a separate step:

```
cl6x --run_linker (--rom_model | --ram_model) filenames
  [options] [--output_file= name.out] --library= library [lnk.cmd]
```

- **cl6x --run_linker** The command that invokes the linker.
- **--rom_model** | **--ram_model** Options that tell the linker to use special conventions defined by the C/C++ environment. When you use cl6x --run_linker, you must use **--rom_model** or **--ram_model**. The **--rom_model** option uses automatic variable initialization at run time; the **--ram_model** option uses variable initialization at load time.
- **filenames** Names of object files, linker command files, or archive libraries. The default extension for all input files is .obj; any other extension must be explicitly specified. The linker can determine whether the input file is an object or ASCII file that contains linker commands. The default output filename is a.out, unless you use the **--output_file** option to name the output file.
- **options** Options affect how the linker handles your object files. Linker options can only appear after the **--run_linker** option on the command line, but otherwise may be in any order. (Options are discussed in detail in the TMS320C6000 Assembly Language Tools User’s Guide.)
- **--output_file= name.out** Names the output file.
- **--library= library** Identifies the appropriate archive library containing C/C++ run-time-support and floating-point math functions, or linker command files. If you are linking C/C++ code, you must use a run-time-support library. You can use the libraries included with the compiler, or you can create your own run-time-support library. If you have specified a run-time-support library in a linker command file, you do not need this parameter. The **--library** option’s short form is -l.
- **lnk.cmd** Contains options, filenames, directives, or commands for the linker.

When you specify a library as linker input, the linker includes and links only those library members that resolve undefined references. The linker uses a default allocation algorithm to allocate your program into memory. You can use the MEMORY and SECTIONS directives in the linker command file to customize the allocation process. For information, see the TMS320C6000 Assembly Language Tools User’s Guide.

You can link a C/C++ program consisting of object files prog1.obj, prog2.obj, and prog3.obj, with an executable object file filename of prog.out with the command:

```
cl6x --run_linker --rom_model prog1 prog2 prog3 --output_file=prog.out
  --library=rts6200.lib
```
5.1.2 Invoking the Linker as Part of the Compile Step

This is the general syntax for linking C/C++ programs as part of the compile step:

```
cl6x filenames [options] --run_linker {--rom_model | --ram_model} filenames
    [options] [--output_file= name.out] --library= library [link.cmd]
```

The `--run_linker` option divides the command line into the compiler options (the options before `--run_linker`) and the linker options (the options following `--run_linker`). The `--run_linker` option must follow all source files and compiler options on the command line.

All arguments that follow `--run_linker` on the command line are passed to the linker. These arguments can be linker command files, additional object files, linker options, or libraries. These arguments are the same as described in Section 5.1.1.

All arguments that precede `--run_linker` on the command line are compiler arguments. These arguments can be C/C++ source files, assembly files, linear assembly files, or compiler options. These arguments are described in Section 2.2.

You can compile and link a C/C++ program consisting of object files prog1.c, prog2.c, and prog3.c, with an executable object file filename of prog.out with the command:

```
cl6x prog1.c prog2.c prog3.c --run_linker --rom_model --output_file=prog.out --library=rts6200.lib
```

---

**NOTE:** Order of Processing Arguments in the Linker

The order in which the linker processes arguments is important. The compiler passes arguments to the linker in the following order:

1. Object filenames from the command line
2. Arguments following the `--run_linker` option on the command line
3. Arguments following the `--run_linker` option from the C6X_C_OPTION environment variable

---

5.1.3 Disabling the Linker (--compile_only Compiler Option)

You can override the `--run_linker` option by using the `--compile_only` compiler option. The `--run_linker` option's short form is `-z` and the `--compile_only` option's short form is `-c`.

The `--compile_only` option is especially helpful if you specify the `--run_linker` option in the C6X_C_OPTION environment variable and want to selectively disable linking with the `--compile_only` option on the command line.
5.2 Linker Code Optimizations

5.2.1 Generating Function Subsections (--gen_func_subsections Compiler Option)

When the linker places code into an executable file, it allocates all the functions in a single source file as a group. This means that if any function in a file needs to be linked into an executable, then all the functions in the file are linked in. This can be undesirable if a file contains many functions and only a few are required for an executable.

This situation may exist in libraries where a single file contains multiple functions, but the application only needs a subset of those functions. An example is a library .obj file that contains a signed divide routine and an unsigned divide routine. If the application requires only signed division, then only the signed divide routine is required for linking. By default, both the signed and unsigned routines are linked in since they exist in the same .obj file.

The --gen_func_subsections compiler option remedies this problem by placing each function in a file in its own subsection. Thus, only the functions that are referenced in the application are linked into the final executable. This can result in an overall code size reduction.

However, be aware that using the --gen_func_subsections compiler option can result in overall code size growth if all or nearly all functions are being referenced. This is because any section containing code must be aligned to a 32-byte boundary to support the C6000 branching mechanism. When the --gen_func_subsections option is not used, all functions in a source file are usually placed in a common section which is aligned. When --gen_func_subsections is used, each function defined in a source file is placed in a unique section. Each of the unique sections requires alignment. If all the functions in the file are required for linking, code size may increase due to the additional alignment padding for the individual subsections.

Thus, the --gen_func_subsections compiler option is advantageous for use with libraries where normally only a limited number of the functions in a file are used in any one executable.

The alternative to the --gen_func_subsections option is to place each function in its own file.

5.2.2 Conditional Linking

The conditional linking paradigm is different under COFF compared to ELF. In COFF, you must mark a section with the .clink directive to make it eligible for removal during conditional linking. In ELF, all sections are considered eligible for removal through conditional linking. Sections are not removed if they are referenced or if they are marked with the .retain directive.

Under COFF, when you compile with the -gen_func_subsections option, in addition to placing each function in a separate subsection, the compiler also annotates that subsection with the conditional linking directive, .clink. This directive marks the section as a candidate to be removed if it is not referenced by any other section in the program. The compiler does not place a .clink directive in a subsection for a trap or interrupt function, as these may be needed by a program even though there is no symbolic reference to them anywhere in the program.

Under COFF, if a section that has been marked for conditional linking is never referenced by any other section in the program, that section is removed from the program. Under ELF, a section that is never referenced by any other section in the program is removed from the program automatically, unless it is marked with .retain. Conditional linking is disabled when performing a partial link or when relocation information is kept with the output of the link. Conditional linking can also be disabled with the --disable_clink linker option.
5.3 Controlling the Linking Process

Regardless of the method you choose for invoking the linker, special requirements apply when linking C/C++ programs. You must:

- Include the compiler’s run-time-support library
- Specify the type of boot-time initialization
- Determine how you want to allocate your program into memory

This section discusses how these factors are controlled and provides an example of the standard default linker command file.

For more information about how to operate the linker, see the linker description in the TMS320C6000 Assembly Language Tools User’s Guide

5.3.1 Including the Run-Time-Support Library

You must link all C/C++ programs with a run-time-support library. The library contains standard C/C++ functions as well as functions used by the compiler to manage the C/C++ environment. The following sections describe two methods for including the run-time-support library.

5.3.1.1 Automatic Run-Time-Support Library Selection

If the --rom_model or --ram_model option is specified during the linker and the entry point for the program (normally c_int00) is not resolved by any specified object file or library, the linker attempts to automatically include the best compatible run-time-support library for your program. The chosen run-time-support library is linked in after any other libraries specified with the --library option on the command line. Alternatively, you can force the linker to choose an appropriate run-time-support library by specifying "libc.a" as an argument to the --library option, or when specifying the run-time-support library name explicitly in a linker command file.

The automatic selection of a run-time-support library can be disabled with the --disable_auto_rts option.

If the --issue_remarks option is specified before the --run_linker option during the linker, a remark is generated indicating which run-time support library was linked in. If a different run-time-support library is desired, you must specify the name of the desired run-time-support library using the --library option and in your linker command files when necessary.

Example 5-1. Using the --issue_remarks Option

```sh
cl6x --silicon_version=6400+ --issue_remarks main.c --run_linker --rom_model

<Linking>
remark: linking in "libc.a"
remark: linking in "rts64plus.lib" in place of "libc.a"
```

5.3.1.2 Manual Run-Time-Support Library Selection

You should use the --library linker option to specify which C6000 run-time-support library to use. The --library option also tells the linker to look at the --search_path options and then the C6X_C_DIR environment variable to find an archive path or object file. To use the --library linker option, type on the command line:

```sh
cl6x --run_linker (--rom_model | --ram_model) filenames --library= libraryname
```
5.3.1.3 Library Order for Searching for Symbols

Generally, you should specify the run-time-support library as the last name on the command line because the linker searches libraries for unresolved references in the order that files are specified on the command line. If any object files follow a library, references from those object files to that library are not resolved. You can use the --reread_libs option to force the linker to reread all libraries until references are resolved. Whenever you specify a library as linker input, the linker includes and links only those library members that resolve undefined references.

By default, if a library introduces an unresolved reference and multiple libraries have a definition for it, then the definition from the same library that introduced the unresolved reference is used. Use the --priority option if you want the linker to use the definition from the first library on the command line that contains the definition.

5.3.2 Run-Time Initialization

C/C++ programs require initialization of the run-time environment before execution of the program itself may begin. This initialization is performed by a bootstrap routine. This routine is responsible for creating the stack, initializing global variables, and calling the function main. The bootstrap routine should be the entry point for the program, and it typically should be the RESET interrupt handler. The bootstrap routine is responsible for the following tasks:
1. Set up the stack by initializing SP
2. Set up the data page pointer DP (for architectures that have one)
3. Set configuration registers
4. Process the .cinit table to autoinitialize global variables (when using the --rom_model option)
5. Process the .pinit table to construct global C++ objects.
6. Call the function main with appropriate arguments
7. Call exit when main returns

When you compile a C program and use --rom_model or --ram_model, the linker looks for a bootstrap routine named _c_int00. The run-time support library provides a sample _c_int00 in boot.obj, which performs the required tasks. If you use the run-time support's bootstrap routine, you should set _c_int00 as the entry point.

A sample bootstrap routine is _c_int00, provided in boot.obj in the run-time support object libraries. The entry point is usually set to the starting address of the bootstrap routine.

NOTE: The _c_int00 Symbol
If you use the --ram_model or --rom_model link option, _c_int00 is automatically defined as the entry point for the program.

5.3.3 Global Object Constructors

Global C++ variables that have constructors and destructors require their constructors to be called during program initialization and their destructors to be called during program termination. The C++ compiler produces a table of constructors to be called at startup.

Constructors for global objects from a single module are invoked in the order declared in the source code, but the relative order of objects from different object files is unspecified.

Global constructors are called after initialization of other global variables and before the function main is called. Global destructors are invoked during the function exit, similar to functions registered through atexit.

Section 7.8.1.3 discusses the format of the global constructor table for COFFABI mode and Section 7.8.1.3 for EABI mode..
5.3.4 Specifying the Type of Global Variable Initialization

The C/C++ compiler produces data tables for initializing global variables. Section 7.8.3 discusses the format of these initialization tables for COFFABI. Section 7.8.2.4 discusses the format of these initialization tables for EABI. The initialization tables are used in one of the following ways:

- Global variables are initialized at run time. Use the --rom_model linker option (see Section 7.8.1.1).
- Global variables are initialized at load time. Use the --ram_model linker option (see Section 7.8.1.2).

When you link a C/C++ program, you must use either the --rom_model or --ram_model option. These options tell the linker to select initialization at run time or load time.

When you compile and link programs, the --rom_model option is the default. If used, the --rom_model option must follow the --run_linker option (see Section 5.1). The following list outlines the linking conventions for COFFABI used with --rom_model or --ram_model:

- The symbol _c_int00 is defined as the program entry point; it identifies the beginning of the C/C++ boot routine in boot.obj. When you use --rom_model or --ram_model, _c_int00 is automatically referenced, ensuring that boot.obj is automatically linked in from the run-time-support library.
- The initialization output section is padded with a termination record so that the loader (load-time initialization) or the boot routine (run-time initialization) knows when to stop reading the initialization tables.
- When initializing at load time (the --ram_model option), the following occur:
  - The linker sets the initialization table symbol to -1. This indicates that the initialization tables are not in memory, so no initialization is performed at run time.
  - The STYP_COPY flag is set in the initialization table section header. STYP_COPY is the special attribute that tells the loader to perform autoinitialization directly and not to load the initialization table into memory. The linker does not allocate space in memory for the initialization table.
- When autoinitializing at run time (--rom_model option), the linker defines the initialization table symbol as the starting address of the initialization table. The boot routine uses this symbol as the starting point for autoinitialization.

For details on linking conventions for EABI used with --rom_model and --ram_model, see Section 7.8.2.3 and Section 7.8.2.5, respectively.

5.3.5 Specifying Where to Allocate Sections in Memory

The compiler produces relocatable blocks of code and data. These blocks, called sections, are allocated in memory in a variety of ways to conform to a variety of system configurations.

The compiler creates two basic kinds of sections: initialized and uninitialized. Table 5-1 summarizes the initialized sections created under the COFF ABI mode. Table 5-2 summarizes the initialized sections created under the EABI mode. Table 5-3 summarizes the uninitialized sections. Be aware that the COFF ABI .cinit and .pinit (.init_array in EABI) tables have different formats in EABI.

<table>
<thead>
<tr>
<th>Name</th>
<th>Contents</th>
</tr>
</thead>
<tbody>
<tr>
<td>.args</td>
<td>Command argument for host-based loader; read-only (see the --arg_size option)</td>
</tr>
<tr>
<td>.cinit</td>
<td>Tables for explicitly initialized global and static variables</td>
</tr>
<tr>
<td>.const</td>
<td>Global and static const variables that are explicitly initialized and contain string literals</td>
</tr>
<tr>
<td>.pinit</td>
<td>Table of constructors to be called at startup</td>
</tr>
<tr>
<td>.ppdata</td>
<td>Data tables for compiler-based profiling (see the --gen_profile_info option)</td>
</tr>
<tr>
<td>.ppinfo</td>
<td>Correlation tables for compiler-based profiling (see the --gen_profile_info option)</td>
</tr>
<tr>
<td>.switch</td>
<td>Jump tables for large switch statements</td>
</tr>
<tr>
<td>.text</td>
<td>Executable code and constants</td>
</tr>
</tbody>
</table>
Table 5-2. Initialized Sections Created by the Compiler for EABI

<table>
<thead>
<tr>
<th>Name</th>
<th>Contents</th>
</tr>
</thead>
<tbody>
<tr>
<td>.args</td>
<td>Command argument for host-based loader; read-only (see the --arg_size option)</td>
</tr>
<tr>
<td>.binit</td>
<td>Boot time copy tables (See the TMS320C6000 Assembly Language Tools User's Guide for information on BINIT in linker command files.)</td>
</tr>
<tr>
<td>.cinit</td>
<td>In EABI mode, the compiler does not generate a .cinit section. However, when the --rom_mode linker option is specified, the linker creates this section, which contains tables for explicitly initialized global and static variables.</td>
</tr>
<tr>
<td>.const</td>
<td>Far, const global and static variables, and string constants</td>
</tr>
<tr>
<td>.c6xabi.exidx</td>
<td>Index table for exception handling; read-only (see --exceptions option)</td>
</tr>
<tr>
<td>.c6xabi.extab</td>
<td>Unwinded instructions for exception handling; read-only (see --exceptions option)</td>
</tr>
<tr>
<td>.fardata</td>
<td>Far non-const global and static variables that are explicitly initialized</td>
</tr>
<tr>
<td>.init_array</td>
<td>Table of constructors to be called at startup</td>
</tr>
<tr>
<td>.name.load</td>
<td>Compressed image of section name; read-only (See the TMS320C6000 Assembly Language Tools User's Guide for information on copy tables.)</td>
</tr>
<tr>
<td>.neardata</td>
<td>Near non-const global and static variables that are explicitly initialized</td>
</tr>
<tr>
<td>.ppdata</td>
<td>Data tables for compiler-based profiling (see the --gen_profile_info option)</td>
</tr>
<tr>
<td>.ppinfo</td>
<td>Correlation tables for compiler-based profiling (see the --gen_profile_info option)</td>
</tr>
<tr>
<td>.rodata</td>
<td>Global and static variables that have near and const qualifiers</td>
</tr>
<tr>
<td>.switch</td>
<td>Jump tables for large switch statements</td>
</tr>
<tr>
<td>.text</td>
<td>Executable code and constants</td>
</tr>
</tbody>
</table>

Table 5-3. Uninitialized Sections Created by the Compiler for Both ABIs

<table>
<thead>
<tr>
<th>Name</th>
<th>Contents</th>
</tr>
</thead>
<tbody>
<tr>
<td>.bss</td>
<td>Global and static variables</td>
</tr>
<tr>
<td>.far</td>
<td>Global and static variables declared far</td>
</tr>
<tr>
<td>.stack</td>
<td>Stack</td>
</tr>
<tr>
<td>.sysmem</td>
<td>Memory for malloc functions (heap)</td>
</tr>
</tbody>
</table>

When you link your program, you must specify where to allocate the sections in memory. In general, initialized sections are linked into ROM or RAM; uninitialized sections are linked into RAM. With the exception of code sections, the initialized and uninitialized sections created by the compiler cannot be allocated into internal program memory. See Section 7.1.1 for a complete description of how the compiler uses these sections.

The linker provides MEMORY and SECTIONS directives for allocating sections. For more information about allocating sections into memory, see the TMS320C6000 Assembly Language Tools User's Guide.
5.3.6 A Sample Linker Command File

Example 5-2 shows a typical linker command file that links a C program. The command file in this example is named lnk.cmd and lists several linker options:

- --rom_model Tells the linker to use autoinitialization at run time.
- --heap_size Tells the linker to set the C heap size at 0x2000 bytes.
- --stack_size Tells the linker to set the stack size to 0x0100 bytes.
- --library Tells the linker to use an archive library file, rts6200.lib, for input.

To link the program, use the following syntax:

```
cl6x --run_linker object_file(s) --output_file= outfile --map_file= mapfile lnk.cmd
```

The MEMORY and possibly the SECTIONS directives, might require modification to work with your system. See the TMS320C6000 Assembly Language Tools User's Guide for more information on these directives.

**Example 5-2. Linker Command File**

```plaintext
--rom_model
--heap_size=0x2000
--stack_size=0x0100
--library=rts6200.lib

MEMORY
{
    VECTS:    o = 0x00000000  l = 0x000000400 /* reset & interrupt vectors */
    PMEM:     o = 0x000000400  l = 0x00000FFC00 /* intended for initialization */
    BMEM:     o = 0x80000000  l = 0x0000010000 /* .bss, .sysmem, .stack, .cinit */
}

SECTIONS
{
    vectors > VECTS
    .text > PMEM
    .data > BMEM
    .stack > BMEM
    .bss > BMEM
    .sysmem > BMEM
    .cinit > BMEM
    .const > BMEM
    .cio > BMEM
    .far > BMEM
}```
The C/C++ compiler supports the C/C++ language standard that was developed by a committee of the American National Standards Institute (ANSI) and subsequently adopted by the International Standards Organization (ISO).

The C++ language supported by the C6000 is defined by the ANSI/ISO/IEC 14882:1998 standard with certain exceptions.

---

**Chapter 6**

**TMS320C6000C/C++ Language Implementation**

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<th>Page</th>
</tr>
</thead>
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</tr>
</tbody>
</table>
6.1 Characteristics of TMS320C6000 C

The compiler supports the C language as defined by ISO/IEC 9899:1990, which is equivalent to American National Standard for Information Systems-Programming Language C X3.159-1989 standard, commonly referred to as C89, published by the American National Standards Institute. The compiler can also accept many of the language extensions found in the GNU C compiler (see Section 6.15). The compiler does not support C99.

The ANSI/ISO standard identifies some features of the C language that are affected by characteristics of the target processor, run-time environment, or host environment. For reasons of efficiency or practicality, this set of features can differ among standard compilers.

Unsupported features of the C library are:

- The run-time library has minimal support for wide and multi-byte characters. The type wchar_t is implemented as int. The wide character set is equivalent to the set of values of type char. The library includes the header files <wchar.h> and <wctype.h>, but does not include all the functions specified in the standard. So-called multi-byte characters are limited to single characters. There are no shift states. The mapping between multi-byte characters and wide characters is simple equivalence; that is, each wide character maps to and from exactly a single multi-byte character having the same value.
- The run-time library includes the header file <locale.h>, but with a minimal implementation. The only supported locale is the C locale. That is, library behavior that is specified to vary by locale is hard-coded to the behavior of the C locale, and attempting to install a different locale by way of a call to setlocale() will return NULL.

6.2 Characteristics of TMS320C6000 C++

The C6000 compiler supports C++ as defined in the ANSI/ISO/IEC 14882:1998 standard, including these features:

- Complete C++ standard library support, with exceptions noted below.
- Templates
- Exceptions, which are enabled with the --exceptions option; see Section 6.6.
- Run-time type information (RTTI), which can be enabled with the --rtti compiler option.

The exceptions to the standard are as follows:

- The compiler does not support embedded C++ run-time-support libraries.
- The library supports wide chars (wchar_t), in that template functions and classes that are defined for char are also available for wchar_t. For example, wide char stream classes wios, wiostream, wstreambuf and so on (corresponding to char classes ios, iostream, streambuf) are implemented. However, there is no low-level file I/O for wide chars. Also, the C library interface to wide char support (through the C++ headers <cwchar> and <cwctype>) is limited as described above in the C library.
- For COFF ABI only: If the definition of an inline function contains a static variable, and it appears in multiple compilation units (usually because it’s a member function of a class defined in a header file), the compiler generates multiple copies of the static variable rather than resolving them to a single definition. The compiler emits a warning (#1369) in such cases.
- No support for bad_cast or bad_type_id is included in the typeinfo header.
- Two-phase name binding in templates, as described in [tesp.res] and [temp.dep] of the standard, is not implemented.
- The export keyword for templates is not implemented.
- A typedef of a function type cannot include member function cv-qualifiers.
- A partial specialization of a class member template cannot be added outside of the class definition.
6.3 Using MISRA-C:2004

You can alter your code to work with the MISRA-C:2004 rules. The following enable/disable the rules:

- The --check_misra option enables checking of the specified MISRA-C:2004 rules.
- The CHECK_MISRA pragma enables/disables MISRA-C:2004 rules at the source level. This pragma is equivalent to using the --check_misra option. See Section 6.9.1.
- The RESET_MISRA pragma resets the specified MISRA-C:2004 rules to the state they were before any CHECK_MISRA pragmas were processed. See Section 6.9.25.

The syntax of the option and pragmas is:

```
--check_misra={all|required|advisory|none|rulespec}
#pragma CHECK_MISRA ("{all|required|advisory|none|rulespec}");
#pragma RESET_MISRA ("{all|required|advisory|rulespec}");
```

The `rulespec` parameter is a comma-separated list of these specifiers:

- [-]X    Enable (or disable) all rules in topic X.
- [-]X-Z  Enable (or disable) all rules in topics X through Z.
- [-]X.A  Enable (or disable) rule A in topic X.
- [-]X.A-C Enable (or disable) rules A through C in topic X.

Example: --check_misra=1-5,-1.1,7.2-4
- Checks topics 1 through 5
- Disables rule 1.1 (all other rules from topic 1 remain enabled)
- Checks rules 2 through 4 in topic 7

Two options control the severity of certain MISRA-C:2004 rules:

- The --misra_required option sets the diagnostic severity for required MISRA-C:2004 rules.
- The --misra_advisory option sets the diagnostic severity for advisory MISRA-C:2004 rules.

The syntax for these options is:

```
--misra_advisory={error|warning|remark|suppress}
--misra_required={error|warning|remark|suppress}
```
6.4 Data Types

Table 6-1 lists the size, representation, and range of each scalar data type for the C6000 compiler for COFF ABI. See Table 6-2 for the EABI data types. Many of the range values are available as standard macros in the header file limits.h.

Table 6-1. TMS320C6000 C/C++ COFF ABI Data Types

<table>
<thead>
<tr>
<th>Type</th>
<th>Size</th>
<th>Representation</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>char, signed char</td>
<td>8 bits</td>
<td>ASCII</td>
<td>-128</td>
<td>127</td>
</tr>
<tr>
<td>unsigned char</td>
<td>8 bits</td>
<td>ASCII</td>
<td>0</td>
<td>255</td>
</tr>
<tr>
<td>short</td>
<td>16 bits</td>
<td>2s complement</td>
<td>-32 768</td>
<td>32 767</td>
</tr>
<tr>
<td>unsigned short</td>
<td>16 bits</td>
<td>Binary</td>
<td>0</td>
<td>65 535</td>
</tr>
<tr>
<td>int, signed int</td>
<td>32 bits</td>
<td>2s complement</td>
<td>-2 147 483 648</td>
<td>2 147 483 647</td>
</tr>
<tr>
<td>unsigned int</td>
<td>32 bits</td>
<td>Binary</td>
<td>0</td>
<td>4 294 967 295</td>
</tr>
<tr>
<td>long, signed long</td>
<td>40 bits</td>
<td>2s complement</td>
<td>-549 755 813 888</td>
<td>549 755 813 887</td>
</tr>
<tr>
<td>unsigned long</td>
<td>40 bits</td>
<td>Binary</td>
<td>0</td>
<td>1 099 511 627 775</td>
</tr>
<tr>
<td>__int40_t</td>
<td>40 bits</td>
<td>2s complement</td>
<td>-549 755 813 888</td>
<td>549 755 813 887</td>
</tr>
<tr>
<td>unsigned __int40_t</td>
<td>40 bits</td>
<td>Binary</td>
<td>0</td>
<td>1 099 511 627 775</td>
</tr>
<tr>
<td>long long, signed long long</td>
<td>64 bits</td>
<td>2s complement</td>
<td>-9 223 372 036 854 775 808</td>
<td>9 223 372 036 854 775 807</td>
</tr>
<tr>
<td>unsigned long long</td>
<td>64 bits</td>
<td>Binary</td>
<td>0</td>
<td>18 446 744 073 709 551 615</td>
</tr>
<tr>
<td>enum</td>
<td>32 bits</td>
<td>2s complement</td>
<td>-2 147 483 648</td>
<td>2 147 483 647</td>
</tr>
<tr>
<td>float</td>
<td>32 bits</td>
<td>IEEE 32-bit</td>
<td>1.175 494e-38 (1)</td>
<td>3.40 282 346e+38</td>
</tr>
<tr>
<td>double</td>
<td>64 bits</td>
<td>IEEE 64-bit</td>
<td>2.22 507 385e-308 (1)</td>
<td>1.79 769 313e+308</td>
</tr>
<tr>
<td>long double</td>
<td>64 bits</td>
<td>IEEE 64-bit</td>
<td>2.22 507 385e-308 (1)</td>
<td>1.79 769 313e+308</td>
</tr>
<tr>
<td>pointers, references, pointer to data members</td>
<td>32 bits</td>
<td>Binary</td>
<td>0</td>
<td>0xFFFFFFFF</td>
</tr>
</tbody>
</table>

(1) Figures are minimum precision.

Table 6-2. TMS320C6000 C/C++ EABI Data Types

<table>
<thead>
<tr>
<th>Type</th>
<th>Size</th>
<th>Representation</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>char, signed char</td>
<td>8 bits</td>
<td>ASCII</td>
<td>-128</td>
<td>127</td>
</tr>
<tr>
<td>unsigned char</td>
<td>8 bits</td>
<td>ASCII</td>
<td>0</td>
<td>255</td>
</tr>
<tr>
<td>short</td>
<td>16 bits</td>
<td>2s complement</td>
<td>-32 768</td>
<td>32 767</td>
</tr>
<tr>
<td>unsigned short</td>
<td>16 bits</td>
<td>Binary</td>
<td>0</td>
<td>65 535</td>
</tr>
<tr>
<td>int, signed int</td>
<td>32 bits</td>
<td>2s complement</td>
<td>-2 147 483 648</td>
<td>2 147 483 647</td>
</tr>
<tr>
<td>unsigned int</td>
<td>32 bits</td>
<td>Binary</td>
<td>0</td>
<td>4 294 967 295</td>
</tr>
<tr>
<td>long, signed long</td>
<td>32 bits</td>
<td>2s complement</td>
<td>-2 147 483 648</td>
<td>2 147 483 647</td>
</tr>
<tr>
<td>unsigned long</td>
<td>32 bits</td>
<td>Binary</td>
<td>0</td>
<td>4 294 967 295</td>
</tr>
<tr>
<td>__int40_t</td>
<td>40 bits</td>
<td>2s complement</td>
<td>-549 755 813 888</td>
<td>549 755 813 887</td>
</tr>
<tr>
<td>unsigned __int40_t</td>
<td>40 bits</td>
<td>Binary</td>
<td>0</td>
<td>1 099 511 627 775</td>
</tr>
<tr>
<td>long long, signed long long</td>
<td>64 bits</td>
<td>2s complement</td>
<td>-9 223 372 036 854 775 808</td>
<td>9 223 372 036 854 775 807</td>
</tr>
<tr>
<td>unsigned long long</td>
<td>64 bits</td>
<td>Binary</td>
<td>0</td>
<td>18 446 744 073 709 551 615</td>
</tr>
<tr>
<td>enum</td>
<td>32 bits</td>
<td>2s complement</td>
<td>-2 147 483 648</td>
<td>2 147 483 647</td>
</tr>
<tr>
<td>float</td>
<td>32 bits</td>
<td>IEEE 32-bit</td>
<td>1.175 494e-38 (1)</td>
<td>3.40 282 346e+38</td>
</tr>
<tr>
<td>double</td>
<td>64 bits</td>
<td>IEEE 64-bit</td>
<td>2.22 507 385e-308 (1)</td>
<td>1.79 769 313e+308</td>
</tr>
<tr>
<td>long double</td>
<td>64 bits</td>
<td>IEEE 64-bit</td>
<td>2.22 507 385e-308 (1)</td>
<td>1.79 769 313e+308</td>
</tr>
<tr>
<td>pointers, references, pointer to data members</td>
<td>32 bits</td>
<td>Binary</td>
<td>0</td>
<td>0xFFFFFFFF</td>
</tr>
</tbody>
</table>

(1) Figures are minimum precision.
6.5 Keywords

The C6000 C/C++ compiler supports the standard const, register, restrict, and volatile keywords. In addition, the C/C++ compiler extends the C/C++ language through the support of the cregister, interrupt, near, and far keywords.

6.5.1 The const Keyword

The C/C++ compiler supports the ANSI/ISO standard keyword `const`. This keyword gives you greater optimization and control over allocation of storage for certain data objects. You can apply the const qualifier to the definition of any variable or array to ensure that its value is not altered.

If you define an object as far const, the .const section allocates storage for the object. The const data storage allocation rule has two exceptions:

- If the keyword volatile is also specified in the definition of an object (for example, volatile const int x).
  Volatile keywords are assumed to be allocated to RAM. (The program does not modify a const volatile object, but something external to the program might.)
- If the object has automatic storage (allocated on the stack).

In both cases, the storage for the object is the same as if the const keyword were not used.

The placement of the const keyword within a definition is important. For example, the first statement below defines a constant pointer p to a variable int. The second statement defines a variable pointer q to a constant int:

```c
int * const p = &x;
const int * q = &x;
```

Using the const keyword, you can define large constant tables and allocate them into system ROM. For example, to allocate a ROM table, you could use the following definition:

```c
far const int digits[] = {0,1,2,3,4,5,6,7,8,9};
```

6.5.2 The cregister Keyword

The compiler extends the C/C++ language by adding the cregister keyword to allow high level language access to control registers.

When you use the cregister keyword on an object, the compiler compares the name of the object to a list of standard control registers for the C6000 (see Table 6-3). If the name matches, the compiler generates the code to reference the control register. If the name does not match, the compiler issues an error.

```
<table>
<thead>
<tr>
<th>Register</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>AMR</td>
<td>Addressing mode register</td>
</tr>
<tr>
<td>CSR</td>
<td>Control status register</td>
</tr>
<tr>
<td>DESR</td>
<td>(C6700+ only) dMAX event status register</td>
</tr>
<tr>
<td>DETR</td>
<td>(C6700+ only) dMAX event trigger register</td>
</tr>
<tr>
<td>DNUM</td>
<td>(C6400+ only) DSP core number register</td>
</tr>
<tr>
<td>ECR</td>
<td>(C6400+ only) Exception clear register</td>
</tr>
<tr>
<td>EFR</td>
<td>(C6400+ only) Exception flag register</td>
</tr>
<tr>
<td>FADCR</td>
<td>(C6700 only) Floating-point adder configuration register</td>
</tr>
<tr>
<td>FAUCR</td>
<td>(C6700 only) Floating-point auxiliary configuration register</td>
</tr>
<tr>
<td>FMCR</td>
<td>(C6700 only) Floating-point multiplier configuration register</td>
</tr>
<tr>
<td>GFPGFR</td>
<td>(C6400 only) Galois field polynomial generator function register</td>
</tr>
<tr>
<td>GPLYA</td>
<td>(C6400+ only) GMPY A-side polynomial register</td>
</tr>
<tr>
<td>CPLYB</td>
<td>(C6400+ only) GMPY B-side polynomial register</td>
</tr>
<tr>
<td>ICR</td>
<td>Interrupt clear register</td>
</tr>
<tr>
<td>IER</td>
<td>Interrupt enable register</td>
</tr>
<tr>
<td>IERR</td>
<td>(C6400+ only) Internal exception report register</td>
</tr>
</tbody>
</table>
```
Table 6-3. Valid Control Registers (continued)

<table>
<thead>
<tr>
<th>Register</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>IFR</td>
<td>Interrupt flag register. (IFR is read only.)</td>
</tr>
<tr>
<td>ILC</td>
<td>(C6400+ only) Inner loop count register</td>
</tr>
<tr>
<td>IRP</td>
<td>Interrupt return pointer</td>
</tr>
<tr>
<td>ISR</td>
<td>Interrupt set register</td>
</tr>
<tr>
<td>ISTP</td>
<td>Interrupt service table pointer</td>
</tr>
<tr>
<td>ITSRR</td>
<td>(C6400+ only) Interrupt task state register</td>
</tr>
<tr>
<td>NRP</td>
<td>Nonmaskable interrupt return pointer</td>
</tr>
<tr>
<td>NTSR</td>
<td>(C6400+ only) NMI/exception task state register</td>
</tr>
<tr>
<td>REP</td>
<td>(C6400+ only) Restricted entry point address register</td>
</tr>
<tr>
<td>RILC</td>
<td>(C6400+ only) Reload inner loop count register</td>
</tr>
<tr>
<td>SSR</td>
<td>(C6400+ only) Saturation status register</td>
</tr>
<tr>
<td>TSCH</td>
<td>(C6400+ only) Time-stamp counter (high 32) register</td>
</tr>
<tr>
<td>TSSL</td>
<td>(C6400+ only) Time-stamp counter (low 32) register</td>
</tr>
<tr>
<td>TSR</td>
<td>(C6400+ only) Task state register</td>
</tr>
</tbody>
</table>

The cregister keyword can be used only in file scope. The cregister keyword is not allowed on any declaration within the boundaries of a function. It can only be used on objects of type integer or pointer. The cregister keyword is not allowed on objects of any floating-point type or on any structure or union objects.

The cregister keyword does not imply that the object is volatile. If the control register being referenced is volatile (that is, can be modified by some external control), then the object must be declared with the volatile keyword also.

To use the control registers in Table 6-3, you must declare each register as follows. The c6x.h include file defines all the control registers through this syntax:

```c
extern cregister volatile unsigned int register;
```

Once you have declared the register, you can use the register name directly. See the TMS320C62x DSP CPU and Instruction Set Reference Guide, TMS320C64x/C64x+ DSP CPU and Instruction Set Reference Guide, the TMS320C67x/C67x+ DSP CPU and Instruction Set Reference Guide, or TMS320C66x+ DSP CPU and Instruction Set Reference Guide for detailed information on the control registers.

See Example 6-1 for an example that declares and uses control registers.

**Example 6-1. Define and Use Control Registers**

```c
extern cregister volatile unsigned int AMR;
extern cregister volatile unsigned int CSR;
extern cregister volatile unsigned int IFR;
extern cregister volatile unsigned int ISR;
extern cregister volatile unsigned int ICR;
extern cregister volatile unsigned int IER;
extern cregister volatile unsigned int FADCR;
extern cregister volatile unsigned int FAUCR;
extern cregister volatile unsigned int FMCR;
main()
{
    printf("AMR = %x\n", AMR);
}
```
6.5.3 The interrupt Keyword

The compiler extends the C/C++ language by adding the interrupt keyword, which specifies that a function
is treated as an interrupt function.

Functions that handle interrupts follow special register-saving rules and a special return sequence. The
implementation stresses safety. The interrupt routine does not assume that the C run-time conventions for
the various CPU register and status bits are in effect; instead, it re-establishes any values assumed by the
run-time environment. When C/C++ code is interrupted, the interrupt routine must preserve the contents of
all machine registers that are used by the routine or by any function called by the routine. When you use
the interrupt keyword with the definition of the function, the compiler generates register saves based on
the rules for interrupt functions and the special return sequence for interrupts.

You can only use the interrupt keyword with a function that is defined to return void and that has no
parameters. The body of the interrupt function can have local variables and is free to use the stack or
global variables. For example:

```c
interrupt void int_handler()
{
    unsigned int flags;
    ...
}
```

The name c_int00 is the C/C++ entry point. This name is reserved for the system reset interrupt. This
special interrupt routine initializes the system and calls the function main. Because it has no caller, c_int00
does not save any registers.

Use the alternate keyword, __interrupt, if you are writing code for strict ANSI/ISO mode (using the --
strict_ansi compiler option).

6.5.4 The near and far Keywords

The C6000 C/C++ compiler extends the C/C++ language with the near and far keywords to specify how
global and static variables are accessed and how functions are called.

Syntactically, the near and far keywords are treated as storage class modifiers. They can appear before,
after, or in between the storage class specifiers and types. With the exception of near and far, two storage
class modifiers cannot be used together in a single declaration. The following examples are legal
combinations of near and far with other storage class modifiers:

```c
far static int x;
static near int x;
static int far x;
far int foo();
static far int foo();
```

6.5.4.1 near and far Data Objects

Global and static data objects can be accessed in the following two ways:

- **near keyword**: The compiler assumes that the data item can be accessed relative to the data page
pointed. For example:

  ```c
  LDW *(dp(_address)),a0
  ```

- **far keyword**: The compiler cannot access the data item via the DP. This can be required if the
  total amount of program data is larger than the offset allowed (32K) from the DP. For example:

  ```c
  MVKL _address, a1
  MVKH _address, a1
  LDW *a1,a0
  ```
Once a variable has been defined to be far, all external references to this variable in other C files or headers must also contain the far keyword. This is also true of the near keyword. However, you will get compiler or linker errors when the far keyword is not used everywhere. Not using the near keyword everywhere only leads to slower data access times.

If you use the DATA_SECTION pragma, the object is indicated as a far variable, and this cannot be overridden. If you reference this object in another file, then you need to use extern far when declaring this object in the other source file. This ensures access to the variable, since the variable might not be in the .bss section. For details, see Section 6.9.6.

NOTE: Defining Global Variables in Assembly Code

If you also define a global variable in assembly code with the .usect directive (where the variable is not assigned in the .bss section) or you allocate a variable into separate section using a #pragma DATA_SECTION directive; and you want to reference that variable in C code, you must declare the variable as extern far. This ensures the compiler does not try to generate an illegal access of the variable by way of the data page pointer.

When data objects do not have the near or far keyword specified, the compiler will use far accesses to aggregate data and near accesses to non-aggregate data. For more information on the data memory model and ways to control accesses to data, see Section 7.1.5.1.

6.5.4.2 Near and far Function Calls

Function calls can be invoked in one of two ways:

<table>
<thead>
<tr>
<th>near keyword</th>
<th>The compiler assumes that destination of the call is within ± 1 M word of the caller. Here the compiler uses the PC-relative branch instruction.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>B _func</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>far keyword</th>
<th>The compiler is told by you that the call is not within ± 1 M word.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>MVKL _func, al                                                                  MVKH _func, al                                                                  B _func</td>
</tr>
</tbody>
</table>

By default, the compiler generates small-memory model code, which means that every function call is handled as if it were declared near, unless it is actually declared far.

For more information on function calls, see Section 7.1.6.

6.5.5 The restrict Keyword

To help the compiler determine memory dependencies, you can qualify a pointer, reference, or array with the restrict keyword. The restrict keyword is a type qualifier that can be applied to pointers, references, and arrays. Its use represents a guarantee by you, the programmer, that within the scope of the pointer declaration the object pointed to can be accessed only by that pointer. Any violation of this guarantee renders the program undefined. This practice helps the compiler optimize certain sections of code because aliasing information can be more easily determined.

In Example 6-2, the restrict keyword is used to tell the compiler that the function func1 is never called with the pointers a and b pointing to objects that overlap in memory. You are promising that accesses through a and b will never conflict; therefore, a write through one pointer cannot affect a read from any other pointers. The precise semantics of the restrict keyword are described in the 1999 version of the ANSI/ISO C Standard.
Example 6-2. Use of the restrict Type Qualifier With Pointers

```c
void func1(int * restrict a, int * restrict b)
{
    /* func1's code here */
}
```

Example 6-3 illustrates using the restrict keyword when passing arrays to a function. Here, the arrays `c` and `d` should not overlap, nor should `c` and `d` point to the same array.

Example 6-3. Use of the restrict Type Qualifier With Arrays

```c
void func2(int c[restrict], int d[restrict])
{
    int i;
    for(i = 0; i < 64; i++)
    {
        c[i] += d[i];
        d[i] += 1;
    }
}
```

6.5.6 The volatile Keyword

The compiler eliminates redundant memory accesses whenever possible, using data flow analysis to figure out when it is legal. However, some memory accesses may be special in some way that the compiler cannot see, and in such cases you must use the volatile keyword to prevent the compiler from optimizing away something important. The compiler does not optimize out any accesses to variables declared volatile. The number and order of accesses of a volatile variable are exactly as they appear in the C/C++ code, no more and no less.

There are different ways to understand how volatile works, but fundamentally it is a hint to the compiler that something it cannot understand is going on, and so the compiler should not try to be over-clever.

Any variable which might be modified by something external to the obvious control flow of the program (such as an interrupt service routine) must be declared volatile. This tells the compiler that an interrupt function might modify the value at any time, so the compiler should not perform optimizations which will change the number or order of accesses of that variable. This is the primary purpose of the volatile keyword.

In the following example, the loop intends to wait for a location to be read as 0xFF:

```c
unsigned int *ctrl;
while (*ctrl != 0xFF);
```

However, in this example, `*ctrl` is a loop-invariant expression, so the loop is optimized down to a single-memory read. To get the desired result, define `ctrl` as:

```c
volatile unsigned int *ctrl;
```

Here the `*ctrl` pointer is intended to reference a hardware location, such as an interrupt flag.

Volatile must also be used when accessing memory locations that represent memory-mapped peripheral devices. Such memory locations might change value in ways that the compiler cannot predict. These locations might change if accessed, or when some other memory location is accessed, or when some signal occurs.

Volatile must also be used for local variables in a function which calls setjmp, if the value of the local variables needs to remain valid if a longjmp occurs.
Example 6-4. Volatile for Local Variables With setjmp

```c
#include <stdlib.h>
jmp_buf context;
void function()
{
    volatile int x = 3;
    switch(setjmp(context))
    {
        case 0: setup(); break;
        default:
        {
            printf("x == %d\n", x); /* We can only reach here if longjmp
                has occurred; because x's lifetime
                begins before the setjmp and lasts
                through the longjmp, the C standard
                requires x be declared "volatile" */
                break;
        }
    }
}
```

The --interrupt_threshold=1 option should be used when compiling with volatiles.

6.6 C++ Exception Handling

The compiler supports all the C++ exception handling features as defined by the ANSI/ISO 14882 C++ Standard. More details are discussed in The C++ Programming Language, Third Edition by Bjarne Stroustrup.

The compiler --exceptions option enables exception handling. The compiler’s default is no exception handling support.

For exceptions to work correctly, all C++ files in the application must be compiled with the --exceptions option, regardless of whether exceptions occur in a particular file. Mixing exception-enabled object files and libraries with object files and libraries that do not have exceptions enabled can lead to undefined behavior.

Exception handling requires support in the run-time-support library, which come in exception-enabled and exception-disabled forms; you must link with the correct form. When using automatic library selection (the default), the linker automatically selects the correct library Section 5.3.1.1. If you select the library manually, you must use run-time-support libraries whose name contains _eh if you enable exceptions.

Using --exceptions causes the compiler to insert exception handling code. This code will increase the code size of the program, particularly for COFF ABI. In addition, COFF ABI will increase the execution time, even if an exception is never thrown. EABI will not increase code size as much, and has a minimal execution time cost if exceptions are never thrown, but will slightly increase the data size for the exception-handling tables.

See Section 8.1 for details on the run-time libraries.

6.7 Register Variables and Parameters

The C/C++ compiler treats register variables (variables defined with the register keyword) differently, depending on whether you use the --opt_level (-O) option.

• Compiling with optimization
  The compiler ignores any register definitions and allocates registers to variables and temporary values by using an algorithm that makes the most efficient use of registers.

• Compiling without optimization
  If you use the register keyword, you can suggest variables as candidates for allocation into registers. The compiler uses the same set of registers for allocating temporary expression results as it uses for
allocating register variables.

The compiler attempts to honor all register definitions. If the compiler runs out of appropriate registers, it frees a register by moving its contents to memory. If you define too many objects as register variables, you limit the number of registers the compiler has for temporary expression results. This limit causes excessive movement of register contents to memory.

Any object with a scalar type (integral, floating point, or pointer) can be defined as a register variable. The register designator is ignored for objects of other types, such as arrays.

The register storage class is meaningful for parameters as well as local variables. Normally, in a function, some of the parameters are copied to a location on the stack where they are referenced during the function body. The compiler copies a register parameter to a register instead of the stack, which speeds access to the parameter within the function.

For more information about register conventions, see Section 7.3.

6.8 The asm Statement

The C/C++ compiler can embed assembly language instructions or directives directly into the assembly language output of the compiler. This capability is an extension to the C/C++ language—the \texttt{asm} statement. The \texttt{asm} (or \texttt{__asm}) statement provides access to hardware features that C/C++ cannot provide. The \texttt{asm} statement is syntactically like a call to a function named \texttt{asm}, with one string constant argument:

\begin{verbatim}
asm(" assembler text ");
\end{verbatim}

The compiler copies the argument string directly into your output file. The assembler text must be enclosed in double quotes. All the usual character string escape codes retain their definitions. For example, you can insert a .byte directive that contains quotes as follows:

\begin{verbatim}
asm("STR: .byte "abc"");
\end{verbatim}

The inserted code must be a legal assembly language statement. Like all assembly language statements, the line of code inside the quotes must begin with a label, a blank, a tab, or a comment (asterisk or semicolon). The compiler performs no checking on the string; if there is an error, the assembler detects it. For more information about the assembly language statements, see the \emph{TMS320C6000 Assembly Language Tools User's Guide}.

The \texttt{asm} statements do not follow the syntactic restrictions of normal C/C++ statements. Each can appear as a statement or a declaration, even outside of blocks. This is useful for inserting directives at the very beginning of a compiled module.

Use the alternate statement \texttt{__asm("assembler text")} if you are writing code for strict ANSI/ISO C mode (using the --strict_ansi option).

\begin{center}
\textbf{NOTE: \quad Avoid Disrupting the C/C++ Environment With \texttt{asm} Statements}
\end{center}

Be careful not to disrupt the C/C++ environment with \texttt{asm} statements. The compiler does not check the inserted instructions. Inserting jumps and labels into C/C++ code can cause unpredictable results in variables manipulated in or around the inserted code. Directives that change sections or otherwise affect the assembly environment can also be troublesome.

Be especially careful when you use optimization with \texttt{asm} statements. Although the compiler cannot remove \texttt{asm} statements, it can significantly rearrange the code order near them and cause undesired results.
Pragma Directives

Pragma directives tell the compiler how to treat a certain function, object, or section of code. The C6000 C/C++ compiler supports the following pragmas:

- CHECK_MISRA (See Section 6.9.1)
- CLINK (See Section 6.9.2)
- CODE_SECTION (See Section 6.9.3)
- DATA_ALIGN (See Section 6.9.4)
- DATA_MEM_BANK (See Section 6.9.5)
- DATA_SECTION (See Section 6.9.6)
- DIAG_SUPPRESS, DIAG_REMARK, DIAG_WARNING, DIAG_ERROR, and DIAG_DEFAULT (See Section 6.9.7)
- FUNC_ALWAYS_INLINE (See Section 6.9.8)
- FUNC_CANNOT_INLINE (See Section 6.9.9)
- FUNC_EXT_CALLED (See Section 6.9.10)
- FUNC_INTERRUPT_THRESHOLD (See Section 6.9.11)
- FUNC_IS_PURE (See Section 6.9.12)
- FUNC_IS_SYSTEM (See Section 6.9.13)
- FUNC_NEVER_RETURNS (See Section 6.9.14)
- FUNC_NO_GLOBAL_ASG (See Section 6.9.15)
- FUNC_NO_IND_ASG (See Section 6.9.16)
- FUNCTION_OPTIONS (See Section 6.9.17)
- INTERRUPT (See Section 6.9.18)
- LOCATION (See Section 6.9.19)
- MUST_ITERATE (See Section 6.9.20)
- NMI_INTERRUPT (See Section 6.9.21)
- NOINIT (See Section 6.9.22)
- NO_HOOKS (See Section 6.9.23)
- PERSISTENT (See Section 6.9.22)
- PROB_ITERATE (See Section 6.9.24)
- RESET_MISRA (See Section 6.9.25)
- RETAIN (See Section 6.9.26)
- SET_CODE_SECTION (See Section 6.9.27)
- SET_DATA_SECTION (See Section 6.9.27)
- STRUCT_ALIGN (See Section 6.9.28)
- UNROLL (See Section 6.9.29)

Most of these pragmas apply to functions. Except for the DATA_MEM_BANK pragma, the arguments `func` and `symbol` cannot be defined or declared inside the body of a function. You must specify the pragma outside the body of a function; and the pragma specification must occur before any declaration, definition, or reference to the `func` or `symbol` argument. If you do not follow these rules, the compiler issues a warning and may ignore the pragma.

For the pragmas that apply to functions or symbols (except CLINK and RETAIN), the syntax for the pragmas differs between C and C++. In C, you must supply the name of the object or function to which you are applying the pragma as the first argument. In C++, the name is omitted; the pragma applies to the declaration of the object or function that follows it.
6.9.1 The CHECK_MISRAPragma

The CHECK_MISRA pragma enables/disables MISRA-C:2004 rules at the source level. This pragma is equivalent to using the --check_misra option.

The syntax of the pragma in C is:

```
#pragma CHECK_MISRA("{all|required|advisory|none|rulespec}");
```

The rulespec parameter is a comma-separated list of specifiers. See Section 6.3 for details.

The RESET_MISRA pragma can be used to reset any CHECK_MISRA pragmas; see Section 6.9.25.

6.9.2 The CLINKPragma

The CLINK pragma can be applied to a code or data symbol. It causes a .clink directive to be generated into the section that contains the definition of the symbol. The .clink directive indicates to the linker that the section is eligible for removal during conditional linking. Therefore, if the section is not referenced by any other section in the application that is being compiled and linked, it will not be included in the output file result of the link.

The syntax of the pragma in C/C++ is:

```
#pragma CLINK(symbol)
```

The RETAIN pragma has the opposite effect of the CLINK pragma. See Section 6.9.26 for more details.

6.9.3 The CODE_SECTIONPragma

The CODE_SECTION pragma allocates space for the symbol in C, or the next symbol declared in C++, in a section named section name.

The syntax of the pragma in C is:

```
#pragma CODE_SECTION(symbol,"section name")
```

The syntax of the pragma in C++ is:

```
#pragma CODE_SECTION("section name")
```

The CODE_SECTION pragma is useful if you have code objects that you want to link into an area separate from the .text section.

The following examples demonstrate the use of the CODE_SECTION pragma.

Example 6-5. Using the CODE_SECTIONPragma C Source File

```
#pragma CODE_SECTION(fn, "my_sect")

int fn(int x)
{
    return x;
}
```
Example 6-6. Generated Assembly Code From Example 6-5

```
.sect "my_sect"
.global _fn

;*****************************************************************************
;* FUNCTION NAME: _fn *
;* *
;* Regs Modified : SP *
;* *
;* Regs Used : A4,B3,SP *
;* *
;* Local Frame Size : 0 Args + 4 Auto + 0 Save = 4 byte *
;*****************************************************************************

_fn:
;** --------------------------------------------------------------------------*
    RET .S2 B3 ; |6|
    SUB .D2 SP,8,SP ; |4|
    STW .D2T1 A4,*+SP(4) ; |4|
    ADD .S2 8,SP,SP ; |6|
    NOP 2
    ; BRANCH OCCURS ; |6|
```

6.9.4 The DATA_ALIGN Pragma

The DATA_ALIGN pragma aligns the symbol in C, or the next symbol declared in C++, to an alignment boundary. The alignment boundary is the maximum of the symbol's default alignment value or the value of the constant in bytes. The constant must be a power of 2.

The syntax of the pragma in C is:

```
#pragma DATA_ALIGN ( symbol , constant );
```

The syntax of the pragma in C++ is:

```
#pragma DATA_ALIGN ( constant );
```
6.9.5 The DATA_MEM_BANK Pragma

The DATA_MEM_BANK pragma aligns a symbol or variable to a specified C6000 internal data memory bank boundary. The constant specifies a specific memory bank to start your variables on. (See Figure 4-1 for a graphic representation of memory banks.) The value of constant depends on the C6000 device:

- **C6200** The C6200 devices contain four memory banks (0, 1, 2, and 3); constant can be 0 or 2.
- **C6400** The C6400 devices contain 8 memory banks; constant can be 0, 2, 4, or 6.
- **C6400+** The C6400+ devices contain 8 memory banks; constant can be 0, 2, 4, or 6.
- **C6600** The C6600 devices contain 8 memory banks; constant can be 0, 2, 4, or 6.
- **C6700** The C6700 devices contain 8 memory banks; constant can be 0, 2, 4, or 6.
- **C6740** The C6740 devices contain 8 memory banks; constant can be 0, 2, 4, or 6.

The syntax of the pragma in C is:

```c
#pragma DATA_MEM_BANK (symbol, constant);
```

The syntax of the pragma in C++ is:

```c
#pragma DATA_MEM_BANK (constant);
```

Both global and local variables can be aligned with the DATA_MEM_BANK pragma. The DATA_MEM_BANK pragma must reside inside the function that contains the local variable being aligned. The symbol can also be used as a parameter in the DATA_SECTION pragma.

When optimization is enabled, the tools may or may not use the stack to store the values of local variables.

The DATA_MEM_BANK pragma allows you to align data on any data memory bank that can hold data of the type size of the symbol. This is useful if you need to align data in a particular way to avoid memory bank conflicts in your hand-coded assembly code versus padding with zeros and having to account for the padding in your code.

This pragma increases the amount of space used in data memory by a small amount as padding is used to align data onto the correct bank.

For C6200, the code in Example 6-7 guarantees that array x begins at an address ending in 4 or c (in hexadecimal), and that array y begins at an address ending in 4 or c. The alignment for array y affects its stack placement. Array z is placed in the .z_sect section, and begins at an address ending in 0 or 8.

**Example 6-7. Using the DATA_MEM_BANK Pragma**

```c
#pragma DATA_MEM_BANK (x, 2);
short x[100];

#pragma DATA_MEM_BANK (z, 0);
#pragma DATA_SECTION (z, ".z_sect");
short z[100];

void main()
{
    #pragma DATA_MEM_BANK (y, 2);
    short y[100];
    ...
}
```
6.9.6 The DATA_SECTION Pragma

The DATA_SECTION pragma allocates space for the symbol in C, or the next symbol declared in C++, in a section named section name.

The syntax of the pragma in C is:

```c
#pragma DATA_SECTION ( symbol, " section name ");
```

The syntax of the pragma in C++ is:

```c
#pragma DATA_SECTION (" section name ");
```

The DATA_SECTION pragma is useful if you have data objects that you want to link into an area separate from the .bss section. If you allocate a global variable using a DATA_SECTION pragma and you want to reference the variable in C code, you must declare the variable as extern far.

Example 6-8 through Example 6-10 demonstrate the use of the DATA_SECTION pragma.

**Example 6-8. Using the DATA_SECTION Pragma C Source File**

```c
#pragma DATA_SECTION(bufferB, "my_sect")
char bufferA[512];
char bufferB[512];
```

**Example 6-9. Using the DATA_SECTION Pragma C++ Source File**

```c
char bufferA[512];
#pragma DATA_SECTION("my_sect")
char bufferB[512];
```

**Example 6-10. Using the DATA_SECTION Pragma Assembly Source File**

```asm
.globl _bufferA
.bss   _bufferA,512,4
.globl _bufferB
```
### 6.9.7 The Diagnostic Message Pragmas

The following pragmas can be used to control diagnostic messages in the same ways as the corresponding command line options:

<table>
<thead>
<tr>
<th>Pragma</th>
<th>Option</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>DIAG_SUPPRESS num</td>
<td>-pds=num[, num2, num3...]</td>
<td>Suppress diagnostic num</td>
</tr>
<tr>
<td>DIAG_REMARK num</td>
<td>-pdrs=num[, num2, num3...]</td>
<td>Treat diagnostic num as a remark</td>
</tr>
<tr>
<td>DIAG_WARNING num</td>
<td>-pdsw=num[, num2, num3...]</td>
<td>Treat diagnostic num as a warning</td>
</tr>
<tr>
<td>DIAG_ERROR num</td>
<td>-pdse=num[, num2, num3...]</td>
<td>Treat diagnostic num as an error</td>
</tr>
<tr>
<td>DIAG_DEFAULT num</td>
<td>n/a</td>
<td>Use default severity of the diagnostic</td>
</tr>
</tbody>
</table>

The syntax of the pragmas in C is:

```c
#pragma DIAG_XXX [=]num[, num2, num3...]
```

The diagnostic affected (num) is specified using either an error number or an error tag name. The equal sign (=) is optional. Any diagnostic can be overridden to be an error, but only diagnostics with a severity of discretionary error or below can have their severity reduced to a warning or below, or be suppressed. The diag_default pragma is used to return the severity of a diagnostic to the one that was in effect before any pragmas were issued (i.e., the normal severity of the message as modified by any command-line options).

The diagnostic identifier number is output along with the message when the -pden command line option is specified.

### 6.9.8 The FUNC_ALWAYS_INLINE Pragma

The FUNC_ALWAYS_INLINE pragma instructs the compiler to always inline the named function. The compiler only inlines the function if it is legal to inline the function and the compiler is invoked with any level of optimization (--opt_level=0).

The pragma must appear before any declaration or reference to the function that you want to inline. In C, the argument `func` is the name of the function that will be inlined. In C++, the pragma applies to the next function declared.

The syntax of the pragma in C is:

```c
#pragma FUNC_ALWAYS_INLINE (func);
```

The syntax of the pragma in C++ is:

```c
#pragma FUNC_ALWAYS_INLINE;
```

---

**Use Caution with the FUNC_ALWAYS_INLINE Pragma**

**NOTE:** The FUNC_ALWAYS_INLINE pragma overrides the compiler's inlining decisions. Overuse of the pragma could result in increased compilation times or memory usage, potentially enough to consume all available memory and result in compilation tool failures.
6.9.9 The FUNC_CANNOT_INLINEPragma

The FUNC_CANNOT_INLINE pragma instructs the compiler that the named function cannot be expanded inline. Any function named with this pragma overrides any inlining you designate in any other way, such as using the inline keyword. Automatic inlining is also overridden with this pragma; see Section 2.11.

The pragma must appear before any declaration or reference to the function that you want to keep. In C, the argument func is the name of the function that cannot be inlined. In C++, the pragma applies to the next function declared.

The syntax of the pragma in C is:

```
#pragma FUNC_CANNOT_INLINE (func);
```

The syntax of the pragma in C++ is:

```
#pragma FUNC_CANNOT_INLINE;
```

6.9.10 The FUNC_EXT_CALLEDPragma

When you use the --program_level_compile option, the compiler uses program-level optimization. When you use this type of optimization, the compiler removes any function that is not called, directly or indirectly, by main. You might have C/C++ functions that are called by hand-coded assembly instead of main.

The FUNC_EXT_CALLED pragma specifies to the optimizer to keep these C functions or any other functions that these C/C++ functions call. These functions act as entry points into C/C++.

The pragma must appear before any declaration or reference to the function that you want to keep. In C, the argument func is the name of the function that you do not want removed. In C++, the pragma applies to the next function declared.

The syntax of the pragma in C is:

```
#pragma FUNC_EXT_CALLED (func);
```

The syntax of the pragma in C++ is:

```
#pragma FUNC_EXT_CALLED;
```

Except for _c_int00, which is the name reserved for the system reset interrupt for C/C++ programs, the name of the interrupt (the func argument) does not need to conform to a naming convention.

When you use program-level optimization, you may need to use the FUNC_EXT_CALLED pragma with certain options. See Section 3.7.2.
6.9.11 The `FUNC_INTERRUPT_THRESHOLD` Pragma

The compiler allows interrupts to be disabled around software pipelined loops for threshold cycles within
the function. This implements the `--interrupt_threshold` option for a single function (see Section 2.12). The
`FUNC_INTERRUPT_THRESHOLD` pragma always overrides the `--interrupt_threshold=n` command line
option. A threshold value less than 0 assumes that the function is never interrupted, which is equivalent to
an interrupt threshold of infinity.

The syntax of the pragma in C is:

```
#pragma FUNC_INTERRUPT_THRESHOLD ( func, threshold );
```

The syntax of the pragma in C++ is:

```
#pragma FUNC_INTERRUPT_THRESHOLD ( threshold );
```

The following examples demonstrate the use of different thresholds:

- The function `foo` must be interruptible at least every 2,000 cycles:
  ```
  #pragma FUNC_INTERRUPT_THRESHOLD ( foo, 2000 )
  ```
- The function `foo` must always be interruptible:
  ```
  #pragma FUNC_INTERRUPT_THRESHOLD ( foo, 1 )
  ```
- The function `foo` is never interrupted:
  ```
  #pragma FUNC_INTERRUPT_THRESHOLD ( foo, -1 )
  ```

6.9.12 The `FUNC_IS_PURE` Pragma

The `FUNC_IS_PURE` pragma specifies to the compiler that the named function has no side effects. This
allows the compiler to do the following:

- Delete the call to the function if the function's value is not needed
- Delete duplicate functions

The pragma must appear before any declaration or reference to the function. In C, the argument `func` is
the name of a function. In C++, the pragma applies to the next function declared.

The syntax of the pragma in C is:

```
#pragma FUNC_IS_PURE ( func );
```

The syntax of the pragma in C++ is:

```
#pragma FUNC_IS_PURE;
```
6.9.13 The FUNC_IS_SYSTEM Pragma

The FUNC_IS_SYSTEM pragma specifies to the compiler that the named function has the behavior defined by the ANSI/ISO standard for a function with that name.

The pragma must appear before any declaration or reference to the function that you want to keep. In C, the argument `func` is the name of the function to treat as an ANSI/ISO standard function. In C++, the pragma applies to the next function declared.

The syntax of the pragma in C is:

```c
#pragma FUNC_IS_SYSTEM ( func );
```

The syntax of the pragma in C++ is:

```cpp
#pragma FUNC_IS_SYSTEM;
```

6.9.14 The FUNC_NEVER_RETURNS Pragma

The FUNC_NEVER_RETURNS pragma specifies to the compiler that the function never returns to its caller.

The pragma must appear before any declaration or reference to the function that you want to keep. In C, the argument `func` is the name of the function that does not return. In C++, the pragma applies to the next function declared.

The syntax of the pragma in C is:

```c
#pragma FUNC_NEVER_RETURNS ( func );
```

The syntax of the pragma in C++ is:

```cpp
#pragma FUNC_NEVER_RETURNS;
```

6.9.15 The FUNC_NO_GLOBAL_ASG Pragma

The FUNC_NO_GLOBAL_ASG pragma specifies to the compiler that the function makes no assignments to named global variables and contains no asm statements.

The pragma must appear before any declaration or reference to the function that you want to keep. In C, the argument `func` is the name of the function that makes no assignments. In C++, the pragma applies to the next function declared.

The syntax of the pragma in C is:

```c
#pragma FUNC_NO_GLOBAL_ASG ( func );
```

The syntax of the pragma in C++ is:

```cpp
#pragma FUNC_NO_GLOBAL_ASG;
```
6.9.16 The FUNC_NO_IND_ASG Pragma

The FUNC_NO_IND_ASG pragma specifies to the compiler that the function makes no assignments through pointers and contains no asm statements.

The pragma must appear before any declaration or reference to the function that you want to keep. In C, the argument `func` is the name of the function that makes no assignments. In C++, the pragma applies to the next function declared.

The syntax of the pragma in C is:

```
#pragma FUNC_NO_IND_ASG ( func );
```

The syntax of the pragma in C++ is:

```
#pragma FUNC_NO_IND_ASG;
```

6.9.17 The FUNCTION_OPTIONS Pragma

The FUNCTION_OPTIONS pragma allows you to compile a specific function in a C or C++ file with additional command-line compiler options. The affected function will be compiled as if the specified list of options appeared on the command line after all other compiler options. In C, the pragma is applied to the function specified. In C++, the pragma is applied to the next function.

The syntax of the pragma in C is:

```
#pragma FUNCTION_OPTIONS ( func, "additional options" );
```

The syntax of the pragma in C++ is:

```
#pragma FUNCTION_OPTIONS( "additional options" );
```

6.9.18 The INTERRUPT Pragma

The INTERRUPT pragma enables you to handle interrupts directly with C code. In C, the argument `func` is the name of a function. In C++, the pragma applies to the next function declared.

The syntax of the pragma in C is:

```
#pragma INTERRUPT ( func );
```

The syntax of the pragma in C++ is:

```
#pragma INTERRUPT ;
```

The code for the function will return via the IRP (interrupt return pointer).

Except for `_c_int00`, which is the name reserved for the system reset interrupt for C programs, the name of the interrupt (the `func` argument) does not need to conform to a naming convention.

HWI Objects and the INTERRUPT Pragma

**NOTE:** The INTERRUPT pragma must not be used when BIOS HWI objects are used in conjunction with C functions. The HWI_enter/HWI_exit macros and the HWI dispatcher contain this functionality, and the use of the C modifier can cause negative results.
6.9.19 The LOCATION Pragma

The compiler supports the ability to specify the run-time address of a variable at the source level. This can be accomplished with the LOCATION pragma or attribute. Location support is only available in EABI.

The syntax of the pragma in C is:

```
#pragma LOCATION( x, address );
int x;
```

The syntax of the pragmas in C++ is:

```
#pragma LOCATION(address);
int x;
```

The syntax of the pragma for IAR is:

```
#pragma location=address
int x;
```

The syntax of the GCC attribute is:

```
int x __attribute__((location(address)));
```

The noinit pragma may be used in conjunction with the location pragma to map variables to special memory locations; see Section 6.9.22.

6.9.20 The MUST_ITERATE Pragma

The MUST_ITERATE pragma specifies to the compiler certain properties of a loop. You guarantee that these properties are always true. Through the use of the MUST_ITERATE pragma, you can guarantee that a loop executes a specific number of times. Anytime the UNROLL pragma is applied to a loop, MUST_ITERATE should be applied to the same loop. For loops the MUST_ITERATE pragma's third argument, multiple, is the most important and should always be specified.

Furthermore, the MUST_ITERATE pragma should be applied to any other loops as often as possible. This is because the information provided via the pragma (especially the minimum number of iterations) aids the compiler in choosing the best loops and loop transformations (that is, software pipelining and nested loop transformations). It also helps the compiler reduce code size.

No statements are allowed between the MUST_ITERATE pragma and the for, while, or do-while loop to which it applies. However, other pragmas, such as UNROLL and PROB_ITERATE, can appear between the MUST_ITERATE pragma and the loop.

6.9.20.1 The MUST_ITERATE Pragma Syntax

The syntax of the pragma for C and C++ is:

```
#pragma MUST_ITERATE ( min, max, multiple);
```

The arguments min and max are programmer-guaranteed minimum and maximum trip counts. The trip count is the number of times a loop iterates. The trip count of the loop must be evenly divisible by multiple. All arguments are optional. For example, if the trip count could be 5 or greater, you can specify the argument list as follows:

```
#pragma MUST_ITERATE(5);
```

However, if the trip count could be any nonzero multiple of 5, the pragma would look like this:

```
#pragma MUST_ITERATE(5, , 5); /* Note the blank field for max */
```
It is sometimes necessary for you to provide min and multiple in order for the compiler to perform unrolling. This is especially the case when the compiler cannot easily determine how many iterations the loop will perform (that is, the loop has a complex exit condition).

When specifying a multiple via the MUST_ITERATE pragma, results of the program are undefined if the trip count is not evenly divisible by multiple. Also, results of the program are undefined if the trip count is less than the minimum or greater than the maximum specified.

If no min is specified, zero is used. If no max is specified, the largest possible number is used. If multiple MUST_ITERATE pragmas are specified for the same loop, the smallest max and largest min are used.

### 6.9.20.2 Using MUST_ITERATE to Expand Compiler Knowledge of Loops

Through the use of the MUST_ITERATE pragma, you can guarantee that a loop executes a certain number of times. The example below tells the compiler that the loop is guaranteed to run exactly 10 times:

```c
#pragma MUST_ITERATE(10,10);
for(i = 0; i < trip_count; i++) { ... }
```

In this example, the compiler attempts to generate a software pipelined loop even without the pragma. However, if MUST_ITERATE is not specified for a loop such as this, the compiler generates code to bypass the loop, to account for the possibility of 0 iterations. With the pragma specification, the compiler knows that the loop iterates at least once and can eliminate the loop-bypassing code.

MUST_ITERATE can specify a range for the trip count as well as a factor of the trip count. For example:

```c
#pragma MUST_ITERATE(8, 48, 8);
for(i = 0; i < trip_count; i++) { ... }
```

This example tells the compiler that the loop executes between 8 and 48 times and that the trip_count variable is a multiple of 8 (8, 16, 24, 32, 40, 48). The multiple argument allows the compiler to unroll the loop.

You should also consider using MUST_ITERATE for loops with complicated bounds. In the following example:

```c
for(i2 = ipos[2]; i2 < 40; i2 += 5) { ... }
```

The compiler would have to generate a divide function call to determine, at run time, the exact number of iterations performed. The compiler will not do this. In this case, using MUST_ITERATE to specify that the loop always executes eight times allows the compiler to attempt to generate a software pipelined loop:

```c
#pragma MUST_ITERATE(8, 8);
for(i2 = ipos[2]; i2 < 40; i2 += 5) { ... }
```

### 6.9.21 The NMI_INTERRUPTPragma

The NMI_INTERRUPT pragma enables you to handle non-maskable interrupts directly with C code. In C, the argument `func` is the name of a function. In C++, the pragma applies to the next function declared.

The syntax of the pragma in C is:

```c
#pragma NMI_INTERRUPT( func );
```

The syntax of the pragma in C++ is:

```c
#pragma NMI_INTERRUPT;
```

The code generated for the function will return via the NRP versus the IRP as for a function declared with the interrupt keyword or INTERRUPT pragma.

Except for `_c_int00`, which is the name reserved for the system reset interrupt for C programs, the name of the interrupt (function) does not need to conform to a naming convention.
6.9.22 The NOINIT and PERSISTENT Pragmas

When using EABI, global and static variables will be zero-initialized. However, in applications using non-volatile memory, it may be desirable to have variables that are not initialized. Noinit variables are global or static variables that are not zero-initialized at startup or reset.

The NOINIT pragma may be used in conjunction with the location pragma to map variables to special memory locations, like memory-mapped registers, without generating unwanted writes.

Noinit variables cannot have an initializer. However, statically-initialized variables may be declared "persistent" to disable startup initialization. Persistent variables are given an initial value when the code is loaded, but are never again initialized. Persistent and noinit variables behave identically with the exception of whether or not they are initialized at load time.

The syntax of the pragmas in C is:

```c
#pragma NOINIT (x);
int x;

#pragma PERSISTENT (x);
int x=10;
```

The syntax of the pragmas in C++ is:

```c
#pragma NOINIT;
int x;

#pragma PERSISTENT;
int x=10;
```

The syntax of the GCC attributes is:

```c
int x __attribute__((noinit));

int x = 0 __attribute__((persistent));
```

6.9.23 The NO_HOOKSPragma

The NO_HOOKS pragma prevents entry and exit hook calls from being generated for a function.

The syntax of the pragma in C is:

```c
#pragma NO_HOOKS (func);
```

The syntax of the pragma in C++ is:

```c
#pragma NO_HOOKS;
```

See Section 2.17 for details on entry and exit hooks.
### 6.9.24 The PROB_ITERATE Pragma

The PROB_ITERATE pragma specifies to the compiler certain properties of a loop. You assert that these properties are true in the common case. The PROB_ITERATE pragma aids the compiler in choosing the best loops and loop transformations (that is, software pipelining and nested loop transformations). PROB_ITERATE is useful only when the MUST_ITERATE pragma is not used or the PROB_ITERATE parameters are more constraining than the MUST_ITERATE parameters.

No statements are allowed between the PROB_ITERATE pragma and the for, while, or do-while loop to which it applies. However, other pragmas, such as UNROLL and MUST_ITERATE, may appear between the PROB_ITERATE pragma and the loop.

The syntax of the pragma for C and C++ is:

```c
#pragma PROB_ITERATE( min, max )
```

Where min and max are the minimum and maximum trip counts of the loop in the common case. The trip count is the number of times a loop iterates. Both arguments are optional.

For example, PROB_ITERATE could be applied to a loop that executes for eight iterations in the majority of cases (but sometimes may execute more or less than eight iterations):

```c
#pragma PROB_ITERATE(8, 8);
```

If only the minimum expected trip count is known (say it is 5), the pragma would look like this:

```c
#pragma PROB_ITERATE(5);
```

If only the maximum expected trip count is known (say it is 10), the pragma would look like this:

```c
#pragma PROB_ITERATE(, 10); /* Note the blank field for min */
```

### 6.9.25 The RESET_MISRA Pragma

The RESET_MISRA pragma resets the specified MISRA-C:2004 rules to the state they were before any CHECK_MISRA pragmas (see Section 6.9.1) were processed. For instance, if a rule was enabled on the command line but disabled in the source, the RESET_MISRA pragma resets it to enabled. This pragma accepts the same format as the --check_misra option, except for the "none" keyword.

The syntax of the pragma in C is:

```c
#pragma RESET_MISRA ( "{all|required|advisory|rulespec} ")
```

The `rulespec` parameter is a comma-separated list of specifiers. See Section 6.3 for details.

### 6.9.26 The RETAIN Pragma

The RETAIN pragma can be applied to a code or data symbol. It causes a .retain directive to be generated into the section that contains the definition of the symbol. The .retain directive indicates to the linker that the section is ineligible for removal during conditional linking. Therefore, regardless whether or not the section is referenced by another section in the application that is being compiled and linked, it will be included in the output file result of the link.

The syntax of the pragma in C/C++ is:

```c
#pragma RETAIN ( symbol )
```

The CLINK pragma has the opposite effect of the RETAIN pragma. See Section 6.9.2 for more details.
6.9.27 The SET_CODE_SECTION and SET_DATA_SECTION Pragmas

These pragmas can be used to set the section for all declarations below the pragma.

The syntax of the pragmas in C/C++ is:

```c
#pragma SET_CODE_SECTION ("section name")
#pragma SET_DATA_SECTION ("section name")
```

In Example 6-11 x and y are put in the section mydata. To reset the current section to the default used by the compiler, a blank parameter should be passed to the pragma. An easy way to think of the pragma is that it is like applying the CODE_SECTION or DATA_SECTION pragma to all symbols below it.

**Example 6-11. Setting Section With SET_DATA_SECTION Pragma**

```c
#pragma SET_DATA_SECTION("mydata")
int x;
int y;
#pragma SET_DATA_SECTION()
```

The pragmas apply to both declarations and definitions. If applied to a declaration and not the definition, the pragma that is active at the declaration is used to set the section for that symbol. Here is an example:

**Example 6-12. Setting a Section With SET_CODE_SECTION Pragma**

```c
#pragma SET_CODE_SECTION("func1")
extern void func1();
#pragma SET_CODE_SECTION()
...
void func1() { ... }
```

In Example 6-12 func1 is placed in section func1. If conflicting sections are specified at the declaration and definition, a diagnostic is issued.

The current CODE_SECTION and DATA_SECTION pragmas and GCC attributes can be used to override the SET_CODE_SECTION and SET_DATA_SECTION pragmas. For example:

**Example 6-13. Overriding SET_DATA_SECTION Setting**

```c
#pragma DATA_SECTION(x, "x_data")
#pragma SET_DATA_SECTION("mydata")
int x;
int y;
#pragma SET_DATA_SECTION()
```

In Example 6-13 x is placed in x_data and y is placed in mydata. No diagnostic is issued for this case.

The pragmas work for both C and C++. In C++, the pragmas are ignored for templates and for implicitly created objects, such as implicit constructors and virtual function tables.
6.9.28 The STRUCT_ALIGN Pragma

The STRUCT_ALIGN pragma is similar to DATA_ALIGN, but it can be applied to a structure, union type, or typedef and is inherited by any symbol created from that type. The STRUCT_ALIGN pragma is supported only in C.

The syntax of the pragma is:

```c
#pragma STRUCT_ALIGN( type , constant expression )
```

This pragma guarantees that the alignment of the named type or the base type of the named typedef is at least equal to that of the expression. (The alignment may be greater as required by the compiler.) The alignment must be a power of 2. The `type` must be a type or a typedef name. If a type, it must be either a structure tag or a union tag. If a typedef, its base type must be either a structure tag or a union tag.

Since ANSI/ISO C declares that a typedef is simply an alias for a type (i.e. a struct) this pragma can be applied to the struct, the typedef of the struct, or any typedef derived from them, and affects all aliases of the base type.

This example aligns any st_tag structure variables on a page boundary:

```c
typedef struct st_tag
{
    int a;
    short b;
} st_typedef;

#pragma STRUCT_ALIGN ( st_tag, 128);
#pragma STRUCT_ALIGN ( st_typedef, 128);
```

Any use of STRUCT_ALIGN with a basic type (int, short, float) or a variable results in an error.

6.9.29 The UNROLL Pragma

The UNROLL pragma specifies to the compiler how many times a loop should be unrolled. The UNROLL pragma is useful for helping the compiler utilize SIMD instructions on the C6400 family. It is also useful in cases where better utilization of software pipeline resources are needed over a non-unrolled loop.

The optimizer must be invoked (use --opt_level=[1|2|3] or -O1, -O2, or -O3) in order for pragma-specified loop unrolling to take place. The compiler has the option of ignoring this pragma.

No statements are allowed between the UNROLL pragma and the for, while, or do-while loop to which it applies. However, other pragmas, such as MUST_ITERATE and PROB_ITERATE, can appear between the UNROLL pragma and the loop.

The syntax of the pragma for C and C++ is:

```c
#pragma UNROLL( n );
```

If possible, the compiler unrolls the loop so there are \( n \) copies of the original loop. The compiler only unrolls if it can determine that unrolling by a factor of \( n \) is safe. In order to increase the chances the loop is unrolled, the compiler needs to know certain properties:

- The loop iterates a multiple of \( n \) times. This information can be specified to the compiler via the multiple argument in the MUST_ITERATE pragma.
- The smallest possible number of iterations of the loop
- The largest possible number of iterations of the loop

The compiler can sometimes obtain this information itself by analyzing the code. However, sometimes the compiler can be overly conservative in its assumptions and therefore generates more code than is necessary when unrolling. This can also lead to not unrolling at all.

Furthermore, if the mechanism that determines when the loop should exit is complex, the compiler may not be able to determine these properties of the loop. In these cases, you must tell the compiler the properties of the loop by using the MUST_ITERATE pragma.
Specifying #pragma UNROLL(1); asks that the loop not be unrolled. Automatic loop unrolling also is not performed in this case.

If multiple UNROLL pragmas are specified for the same loop, it is undefined which pragma is used, if any.

6.10 The _Pragma Operator

The C6000 C/C++ compiler supports the C99 preprocessor _Pragma() operator. This preprocessor operator is similar to #pragma directives. However, _Pragma can be used in preprocessing macros (#defines).

The syntax of the operator is:

```
_Pragma (" string_literal ");
```

The argument string_literal is interpreted in the same way the tokens following a #pragma directive are processed. The string_literal must be enclosed in quotes. A quotation mark that is part of the string_literal must be preceded by a backward slash.

You can use the _Pragma operator to express #pragma directives in macros. For example, the DATA_SECTION syntax:

```
#pragma DATA_SECTION( func ," section ");
```

Is represented by the _Pragma() operator syntax:

```
_Pragma ("DATA_SECTION( func ," section ")")
```

The following code illustrates using _Pragma to specify the DATA_SECTION pragma in a macro:

```
...
#define EMIT_PRAGMA(x) _Pragma(#x)
#define COLLECT_DATA(var) EMIT_PRAGMA(DATA_SECTION(var,"mysection"))

COLLECT_DATA(x)
int x;
...
```

The EMIT_PRAGMA macro is needed to properly expand the quotes that are required to surround the section argument to the DATA_SECTION pragma.
6.11 Application Binary Interface

Selecting one of the two ABIs supported by the C6000 compiler is discussed in Section 2.16.

An ABI should define how functions that are written separately, and compiled or assembled separately can work together. This involves standardizing the data type representation, register conventions, and function structure and calling conventions. It should define linkname generation from C symbol names. It should define the object file format and the debug format. It should document how the system is initialized. In the case of C++ it defines C++ name mangling and exception handling support.

An application must be only one of COFF ABI and EABI; these ABIs are not compatible.

6.11.1 COFF ABI

COFF ABI is the only ABI supported by older compilers. To generate object files compatible with older COFF ABI object files, you must use COFF ABI (--abi=coffabi, the default). This option must also be used when assembly hand-coded assembly source files intended to be used in a COFF ABI application.

6.11.2 EABI

EABI requires the ELF object file format which enables supporting modern language features like early template instantiation and export inline functions support.

TI-specific information on EABI mode is described in Section 7.8.2.

To generate object files compatible with EABI, you must use C6000 compiler version 7.2 or greater; see Section 2.16. The __TI_EABI__ predefined symbol is defined and set to 1 if compiling for EABI and is not defined otherwise.

6.12 Object File Symbol Naming Conventions (Linknames)

Each externally visible identifier is assigned a unique symbol name to be used in the object file, a so-called linkname. This name is assigned by the compiler according to an algorithm which depends on the name, type, and source language of the symbol. This algorithm may add a prefix to the identifier (typically an underscore), and it may mangle the name. This algorithm may mangle the name.

In COFF ABI, the linkname for all objects and functions is the same as the name in the C source with an added underscore prefix. This prevents any C identifier from colliding with any identifier in the assembly code namespace, such as an assembler keyword.

In EABI, no prefix is used. If a C identifier would collide with an assembler keyword, the compiler will escape the identifier with double parallel bars, which instructs the assembler not to treat the identifier as a keyword. You are responsible for making sure that C identifiers do not collide with user-defined assembly code identifiers.

Name mangling encodes the types of the parameters of a function in the linkname for a function. Name mangling only occurs for C++ functions which are not declared 'extern "C"'. Mangling allows function overloading, operator overloading, and type-safe linking. Be aware that the return value of the function is not encoded in the mangled name, as C++ functions cannot be overloaded based on the return value.

For COFF ABI, the mangling algorithm used closely follows that described in The Annotated Reference Manual (ARM).

For example, the general form of a C++ linkname for a function named func is:

_func__F parmcodes

Where parmcodes is a sequence of letters that encodes the parameter types of func.

For this simple C++ source file:

```c
int foo(int i){ }  //global C++ function
```

This is the resulting assembly code:

_foo__Fi
The linkname of foo is _foo__Fi, indicating that foo is a function that takes a single argument of type int. To aid inspection and debugging, a name demangling utility is provided that demangles names into those found in the original C++ source. See Chapter 9 for more information.

For EABI, the mangling algorithm follows that described in the Itanium C++ ABI (http://www.codesourcery.com/cxx-abi/abi.html).

```c
int foo(int i) {} would be mangled "_Z3fooi"
```

6.13 Initializing Static and Global Variables in COFF ABI Mode

The ANSI/ISO C standard specifies that global (extern) and static variables without explicit initializations must be initialized to 0 before the program begins running. This task is typically done when the program is loaded. Because the loading process is heavily dependent on the specific environment of the target application system, in COFF ABI mode the compiler itself makes no provision for initializing to 0 otherwise uninitialized static storage class variables at run time. It is up to your application to fulfill this requirement.

**Initialize Global Objects**

**NOTE:** You should explicitly initialize all global objects which you expected the compiler would set to zero by default.

In C6000 EABI mode the uninitialized variables are zero initialized automatically.

**6.13.1 Initializing Static and Global Variables With the Linker**

If your loader does not preinitialize variables, you can use the linker to preinitialize the variables to 0 in the object file. For example, in the linker command file, use a fill value of 0 in the .bss section:

```c
SECTIONS
{
...
.bss: {} = 0x00;
...
}
```

Because the linker writes a complete load image of the zeroed .bss section into the output COFF file, this method can have the unwanted effect of significantly increasing the size of the output file (but not the program).

If you burn your application into ROM, you should explicitly initialize variables that require initialization. The preceding method initializes .bss to 0 only at load time, not at system reset or power up. To make these variables 0 at run time, explicitly define them in your code.

For more information about linker command files and the SECTIONS directive, see the linker description information in the TMS320C6000 Assembly Language Tools User’s Guide.

**6.13.2 Initializing Static and Global Variables With the const Type Qualifier**

Static and global variables of type `const` without explicit initializations are similar to other static and global variables because they might not be preinitialized to 0 (for the same reasons discussed in Section 6.13). For example:

```c
const int zero; /* may not be initialized to 0 */
```

However, the initialization of const global and static variables is different because these variables are declared and initialized in a section called `.const`. For example:

```c
const int zero = 0 /* guaranteed to be 0 */
```

This corresponds to an entry in the `.const` section:

```c
.sect .const
_zero
.word 0
```
This feature is particularly useful for declaring a large table of constants, because neither time nor space is wasted at system startup to initialize the table. Additionally, the linker can be used to place the .const section in ROM.

You can use the DATA_SECTION pragma to put the variable in a section other than .const. For example, the following C code:

```c
#pragma DATA_SECTION (var, ".mysect");
    const int zero=0;
```

is compiled into this assembly code:

```assembly
.sect .mysect
_zero
.word 0
```

6.14 Changing the ANSI/ISO C Language Mode

The --kr_compatible, --relaxed_ansi, and --strict_ansi options let you specify how the C/C++ compiler interprets your source code. You can compile your source code in the following modes:

- Normal ANSI/ISO mode
- K&R C mode
- Relaxed ANSI/ISO mode
- Strict ANSI/ISO mode

The default is normal ANSI/ISO mode. Under normal ANSI/ISO mode, most ANSI/ISO violations are emitted as errors. Strict ANSI/ISO violations (those idioms and allowances commonly accepted by C/C++ compilers, although violations with a strict interpretation of ANSI/ISO), however, are emitted as warnings. Language extensions, even those that conflict with ANSI/ISO C, are enabled.

K&R C mode does not apply to C++ code.

6.14.1 Compatibility With K&R C (--kr_compatible Option)

The ANSI/ISO C/C++ language is a superset of the de facto C standard defined in Kernighan and Ritchie's *The C Programming Language*. Most programs written for other non-ANSI/ISO compilers correctly compile and run without modification.

There are subtle changes, however, in the language that can affect existing code. Appendix C in *The C Programming Language* (second edition, referred to in this manual as K&R) summarizes the differences between ANSI/ISO C and the first edition's C standard (the first edition is referred to in this manual as K&R C).

To simplify the process of compiling existing C programs with the ANSI/ISO C/C++ compiler, the compiler has a K&R option (--kr_compatible) that modifies some semantic rules of the language for compatibility with older code. In general, the --kr_compatible option relaxes requirements that are stricter for ANSI/ISO C than for K&R C. The --kr_compatible option does not disable any new features of the language such as function prototypes, enumerations, initializations, or preprocessor constructs. Instead, --kr_compatible simply liberalizes the ANSI/ISO rules without revoking any of the features.

The specific differences between the ANSI/ISO version of C and the K&R version of C are as follows:

- The integral promotion rules have changed regarding promoting an unsigned type to a wider signed type. Under K&R C, the result type was an unsigned version of the wider type; under ANSI/ISO, the result type is a signed version of the wider type. This affects operations that perform differently when applied to signed or unsigned operands; namely, comparisons, division (and mod), and right shift:

  ```c
  unsigned short u;
  int i;
  if (u < i) /* SIGNED comparison, unless --kr_compatible used */
  ```

- ANSI/ISO prohibits combining two pointers to different types in an operation. In most K&R compilers, this situation produces only a warning. Such cases are still diagnosed when --kr_compatible is used, but with less severity:

  ```c
  int *p;
  char *q = p; /* error without --kr_compatible, warning with --kr_compatible */
  ```
• External declarations with no type or storage class (only an identifier) are illegal in ANSI/ISO but legal in K&R:
  a;  /* illegal unless --kr_compatible used */

• ANSI/ISO interprets file scope definitions that have no initializers as tentative definitions. In a single module, multiple definitions of this form are fused together into a single definition. Under K&R, each definition is treated as a separate definition, resulting in multiple definitions of the same object and usually an error. For example:

  int a;
  int a;  /* illegal if --kr_compatible used, OK if not */

Under ANSI/ISO, the result of these two definitions is a single definition for the object a. For most K&R compilers, this sequence is illegal, because int a is defined twice.

• ANSI/ISO prohibits, but K&R allows objects with external linkage to be redeclared as static:

  extern int a;
  static int a;  /* illegal unless --kr_compatible used */

• Unrecognized escape sequences in string and character constants are explicitly illegal under ANSI/ISO but ignored under K&R:

  char c = '\q';  /* same as 'q' if --kr_compatible used, error if not */

• ANSI/ISO specifies that bit fields must be of type int or unsigned. With --kr_compatible, bit fields can be legally defined with any integral type. For example:

  struct s
  {
    short f : 2;  /* illegal unless --kr_compatible used */
  };

• K&R syntax allows a trailing comma in enumerator lists:

  enum { a, b, c, };  /* illegal unless --kr_compatible used */

• K&R syntax allows trailing tokens on preprocessor directives:

  #endif NAME  /* illegal unless --kr_compatible used */


Use the --strict_ansi option when you want to compile under strict ANSI/ISO mode. In this mode, error messages are provided when non-ANSI/ISO features are used, and language extensions that could invalidate a strictly conforming program are disabled. Examples of such extensions are the inline and asm keywords.

Use the --relaxed_ansi option when you want the compiler to ignore strict ANSI/ISO violations rather than emit a warning (as occurs in normal ANSI/ISO mode) or an error message (as occurs in strict ANSI/ISO mode). In relaxed ANSI/ISO mode, the compiler accepts extensions to the ANSI/ISO C standard, even when they conflict with ANSI/ISO C. The GCC language extensions described in Section 6.15 are available in relaxed ANSI/ISO mode.
6.14.3 **Enabling Embedded C++ Mode (--embedded_cpp Option)**

The compiler supports the compilation of embedded C++. In this mode, some features of C++ are removed that are of less value or too expensive to support in an embedded system. When compiling for embedded C++, the compiler generates diagnostics for the use of omitted features.

Embedded C++ is enabled by compiling with the --embedded_cpp option.

Embedded C++ omits these C++ features:

- Templates
- Exception handling
- Run-time type information
- The new cast syntax
- The keyword mutable
- Multiple inheritance
- Virtual inheritance

Under the standard definition of embedded C++, namespaces and using-declarations are not supported. The C6000 compiler nevertheless allows these features under embedded C++ because the C++ run-time-support library makes use of them. Furthermore, these features impose no run-time penalty.

The compiler does not support embedded C++ run-time-support libraries.

6.15 **GNU Language Extensions**

The GNU compiler collection (GCC) defines a number of language features not found in the ANSI/ISO C and C++ standards. The definition and examples of these extensions (for GCC version 3.4) can be found at the GNU web site, [http://gcc.gnu.org/onlinedocs/gcc-3.4.6/gcc/C-Extensions.html](http://gcc.gnu.org/onlinedocs/gcc-3.4.6/gcc/C-Extensions.html).

Most of these extensions are also available for C++ source code.

6.15.1 **Extensions**

Most of the GCC language extensions are available in the TI compiler when compiling in relaxed ANSI mode (--relaxed_ansi) or if the --gcc option is used.

The extensions that the TI compiler supports are listed in Table 6-4, which is based on the list of extensions found at the GNU web site. The shaded rows describe extensions that are not supported.

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6.15.2 Function Attributes

The following GCC function attributes are supported: always_inline, const, constructor, deprecated, format, format_arg, malloc, noinline, noreturn, pure, section, unused, used and warn_unused_result.

In addition, the visibility function attribute is supported for EABI mode (--abi=eabi).

The format attribute is applied to the declarations of printf, fprintf, sprintf, vsprintf, vfprintf, vsnprintf, scanf, fscanf, vfscanf, vscanf, vsscanf, and sscanf in stdio.h. Thus when GCC extensions are enabled, the data arguments of these functions are type checked against the format specifiers in the format string argument and warnings are issued when there is a mismatch. These warnings can be suppressed in the usual ways if they are not desired.

The malloc attribute is applied to the declarations of malloc, calloc, realloc and memalign in stdlib.h.
6.15.3 Variable Attributes

The following variable attributes are supported: aligned, deprecated, mode, packed, section, transparent_union, unused, and used.

The used attribute is defined in GCC 4.2 (see http://gcc.gnu.org/onlinedocs/gcc-4.2.4/gcc/Variable-Attributes.html#Variable-Attributes).

The packed attribute for structure and union types is available only when there is hardware support for unaligned accesses. For C6000 this means C6400+, C6400, C6740, and C6600.

In addition, the weak variable attribute is supported for EABI mode (--abi=eabi).

6.15.4 Type Attributes

The following type attributes are supported: aligned, deprecated, packed, transparent_union, and unused.

In addition, the visibility type attribute is supported for EABI mode (--abi=eabi).

The packed attribute on struct and union types is available only for target architectures that have hardware support for unaligned access (such as C64x+, C64x).

Members of a packed structure are stored as closely to each other as possible, omitting additional bytes of padding usually added to preserve word-alignment. For example, assuming a word-size of 4 bytes ordinarily has 3 bytes of padding between members c1 and i, and another 3 bytes of trailing padding after member c2, leading to a total size of 12 bytes:

```
struct unpacked_struct { char c1; int i; char c2;};
```

However, the members of a packed struct are byte-aligned. Thus the following does not have any bytes of padding between or after members and totals 6 bytes:

```
struct __attribute__((__packed__)) packed_struct { char c1; int i; char c2; };  
```

Subsequently, packed structures in an array are packed together without trailing padding between array elements.

Bit fields of a packed structure are bit-aligned. The byte alignment of adjacent struct members that are not bit fields does not change. However, there are no bits of padding between adjacent bit fields.

The packed attribute can only be applied to the original definition of a structure or union type. It cannot be applied with a typedef to a non-packed structure that has already been defined, nor can it be applied to the declaration of a struct or union object. Therefore, any given structure or union type can only be packed or non-packed, and all objects of that type will inherit its packed or non-packed attribute.

The packed attribute is not applied recursively to structure types that are contained within a packed structure. Thus, in the following example the member s retains the same internal layout as in the first example above. There is no padding between c and s, so s falls on an unaligned boundary:

```
struct __attribute__((__packed__)) outer_packed_struct { char c; struct unpacked_struct s; };  
```

It is illegal to implicitly or explicitly cast the address of a packed struct member as a pointer to any non-packed type except an unsigned char. In the following example, p1, p2, and the call to foo are all illegal.

```
void foo(int *param);
struct packed_struct ps;

int *p1 = &ps.i;
int *p2 = (int *)&ps.i;
foo(&ps.i);
```

However, it is legal to explicitly cast the address of a packed struct member as a pointer to an unsigned char:

```
unsigned char *pc = (unsigned char *)&ps.i;
```

The TI compiler also supports an unpacked attribute for an enumeration type to allow you to indicate that the representation is to be an integer type that is no smaller than int; in other words, it is not packed.
6.15.5 Built-In Functions

The following builtin functions are supported: __builtin_abs, __builtin_classify_type, __builtin_constant_p,
__builtin_expect, __builtin_fabs, __builtin_fabsf, __builtin_frame_address, __builtin_labs,
__builtin_memcpy, and __builtin_return_address.

The __builtin_frame_address function returns zero unless the argument is a constant zero.

The __builtin_return_address function always returns zero.
This chapter describes the TMS320C6000 C/C++ run-time environment. To ensure successful execution of C/C++ programs, it is critical that all run-time code maintain this environment. It is also important to follow the guidelines in this chapter if you write assembly language functions that interface with C/C++ code.

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7.1 Memory Model

The C6000 compiler treats memory as a single linear block that is partitioned into subblocks of code and data. Each subblock of code or data generated by a C program is placed in its own continuous memory space. The compiler assumes that a full 32-bit address space is available in target memory.

The Linker Defines the Memory Map

NOTE: The linker, not the compiler, defines the memory map and allocates code and data into target memory. The compiler assumes nothing about the types of memory available, about any locations not available for code or data (holes), or about any locations reserved for I/O or control purposes. The compiler produces relocatable code that allows the linker to allocate code and data into the appropriate memory spaces.

For example, you can use the linker to allocate global variables into on-chip RAM or to allocate executable code into external ROM. You can allocate each block of code or data individually into memory, but this is not a general practice (an exception to this is memory-mapped I/O, although you can access physical memory locations with C/C++ pointer types).

7.1.1 Sections

The compiler produces relocatable blocks of code and data called sections. The sections are allocated into memory in a variety of ways to conform to a variety of system configurations. For more information about sections and allocating them, see the introductory object file information in the TMS320C6000 Assembly Language Tools User's Guide.

There are two basic types of sections:

- **Initialized sections** contain data or executable code. The C/C++ compiler creates the following initialized sections:
  - The `.args` section contains the command argument for a host-based loader. This section is read-only. See the --arg_size option for details.
  - For EABI only, the `.binit` section contains boot time copy tables. For details on BINIT, see the TMS320C6000 Assembly Language Tools User's Guide for linker command file information.
  - For COFF ABI only, the `.cinit` section contains tables for initializing variables and constants.
  - The `.pinit` section for COFF ABI, or the `.init_array` section for EABI, contains the table for calling global constructor tables.
  - For EABI only, the `.c6xabi.exidx` section contains the index table for exception handling. The `.c6xabi.extab` section contains un-winded instructions for exception handling. These sections are read-only. See the --exceptions option for details.
  - The `.name.load` section contains the compressed image of section name. This section is read-only. See the TMS320C6000 Assembly Language Tools User's Guide for information on copy tables.
  - The `.ppinfo` section contains correlation tables and the `.ppdata` section contains data tables for compiler-based profiling. See the --gen_profile_info option for details.
  - The `.const` section contains string literals, floating-point constants, and data defined with the C/C++ qualifiers `far` and `const` (provided the constant is not also defined as `volatile`).
  - For EABI only, the `.fardata` section reserves space for non-const, initialized far global and static variables.
  - For EABI only, the `.neardata` section reserves space for non-const, initialized near global and static variables.
  - For EABI only, the `.rodata` section reserves space for const near global and static variables.
  - The `.switch` section contains jump tables for large switch statements.
  - The `.text` section contains all the executable code.
• **Uninitialized sections** reserve space in memory (usually RAM). A program can use this space at run time to create and store variables. The compiler creates the following uninitialized sections:
  
  – For COFF ABI only, the `.bss section` reserves space for global and static variables. When you specify the --rom_model linker option, at program startup, the C boot routine copies data out of the .cinit section (which can be in ROM) and stores it in the .bss section. The compiler defines the global symbol $bss and assigns $bss the value of the starting address of the .bss section.
  – For EABI only, the `.bss section` reserves space for uninitialized global and static variables.
  – The `.far section` reserves space for global and static variables that are declared far.
  – The `.stack section` reserves memory for the system stack.
  – The `.sysmem section` reserves space for dynamic memory allocation. The reserved space is used by dynamic memory allocation routines, such as malloc, calloc, realloc, or new. If a C/C++ program does not use these functions, the compiler does not create the .sysmem section.

**Use Only Code in Program Memory**

**NOTE:** With the exception of code sections, the initialized and uninitialized sections cannot be allocated into internal program memory.

The assembler creates the default sections .text, .bss, and .data. The C/C++ compiler, however, does not use the .data section. You can instruct the compiler to create additional sections by using the CODE_SECTION and DATA_SECTION pragmas (see Section 6.9.3 and Section 6.9.6).

### 7.1.2 C/C++ System Stack

The C/C++ compiler uses a stack to:

- Save function return addresses
- Allocate local variables
- Pass arguments to functions
- Save temporary results

The run-time stack grows from the high addresses to the low addresses. The compiler uses the B15 register to manage this stack. B15 is the stack pointer (SP), which points to the next unused location on the stack.

The linker sets the stack size, creates a global symbol, __TI_STACK_SIZE, and assigns it a value equal to the stack size in bytes. The default stack size is 1K bytes. You can change the stack size at link time by using the --stack_size option with the linker command. For more information on the --stack_size option, see the linker description chapter in the TMS320C6000 Assembly Language Tools User's Guide.

At system initialization, SP is set to the first 8-byte aligned address before the end (highest numerical address) of the .stack section. For C6600, SP is set to the first 16-byte aligned address. Since the position of the stack depends on where the .stack section is allocated, the actual address of the stack is determined at link time.

The C/C++ environment automatically decrements SP at the entry to a function to reserve all the space necessary for the execution of that function. The stack pointer is incremented at the exit of the function to restore the stack to the state before the function was entered. If you interface assembly language routines to C/C++ programs, be sure to restore the stack pointer to the same state it was in before the function was entered.

For more information about the stack and stack pointer, see Section 7.4.

**Unaligned SP Can Cause Application Crash**

**NOTE:** The HWI dispatcher uses SP during an interrupt call regardless of SP alignment. Therefore, SP must never be misaligned, even for 1 cycle.
NOTE: The compiler provides no means to check for stack overflow during compilation or at run time. A stack overflow disrupts the run-time environment, causing your program to fail. Be sure to allow enough space for the stack to grow. You can use the --entry_hook option to add code to the beginning of each function to check for stack overflow; see Section 2.17.

7.1.3 Dynamic Memory Allocation

The run-time-support library supplied with the C6000 compiler contains several functions (such as malloc, calloc, and realloc) that allow you to allocate memory dynamically for variables at run time.

Memory is allocated from a global pool, or heap, that is defined in the .sysmem section. You can set the size of the .sysmem section by using the --heap_size=size option with the linker command. The linker also creates a global symbol, __TI_SYSMEM_SIZE, and assigns it a value equal to the size of the heap in bytes. The default size is 1K bytes. For more information on the --heap_size option, see the linker description chapter in the TMS320C6000 Assembly Language Tools User's Guide.

Dynamically allocated objects are not addressed directly (they are always accessed with pointers) and the memory pool is in a separate section (.sysmem); therefore, the dynamic memory pool can have a size limited only by the amount of available memory in your system. To conserve space in the .bss section, you can allocate large arrays from the heap instead of defining them as global or static. For example, instead of a definition such as:

```c
struct big table[100];
```

Use a pointer and call the malloc function:

```c
struct big *table
    table = (struct big *)malloc(100*sizeof(struct big));
```

7.1.4 Initialization of Variables in COFF ABI

The C/C++ compiler produces code that is suitable for use as firmware in a ROM-based system. In such a system, the initialization tables in the .cinit section are stored in ROM. At system initialization time, the C/C++ boot routine copies data from these tables (in ROM) to the initialized variables in .bss (RAM).

In situations where a program is loaded directly from an object file into memory and run, you can avoid having the .cinit section occupy space in memory. A loader can read the initialization tables directly from the object file (instead of from ROM) and perform the initialization directly at load time instead of at run time. You can specify this to the linker by using the --ram_model link option. For more information, see Section 7.8.

7.1.5 Data Memory Models

Several options extend the C6000 data addressing model.

7.1.5.1 Determining the Data Address Model

As of the 5.1.0 version of the compiler tools, if a near or far keyword is not specified for an object, the compiler generates far accesses to aggregate data and near accesses to all other data. This means that structures, unions, C++ classes, and arrays are not accessed through the data-page (DP) pointer.

Non-aggregate data, by default, is placed in the .bss section and is accessed using relative-offset addressing from the data page pointer (DP, which is B14). DP points to the beginning of the .bss section. Accessing data via the data page pointer is generally faster and uses fewer instructions than the mechanism used for far data accesses.

If you want to use near accesses to aggregate data, you must specify the --mem_model:data=near option, or declare your data with the near keyword.

If you have too much static and extern data to fit within a 15-bit scaled offset from the beginning of the .bss section, you cannot use --mem_model:data=near. The linker will issue an error message if there is a DP-relative data access that will not reach.
The `--mem_model:data=type` option controls how data is accessed:

- `--mem_model:data=near`  
  Data accesses default to near

- `--mem_model:data=far`  
  Data accesses default to far

- `--mem_model:data=far_aggregates`  
  Data accesses to aggregate data default to far, data accesses to non-aggregate data default to near. This is the default behavior.

The `--mem_model:data` options do not affect the access to objects explicitly declared with the near or far keyword.

By default, all run-time-support data is defined as far.

For more information on near and far accesses to data, see Section 6.5.4.

### 7.1.5.2 Using DP-Relative Addressing

The default behavior of the compiler is to use DP-relative addressing for near (.bss) data, and absolute addressing for all other (far) data. The `--dprel` option specifies that all data, including const data and far data, is addressed using DP-relative addressing.

The purpose of the `--dprel` option is to support a shared object model so multiple applications running simultaneously can share code, but each have their own copy of the data.

The `--dprel` option is supported for ELF only.

### 7.1.5.3 Const Objects as Far

The `--mem_model:const` option allows const objects to be made far independently of the `--mem_model:data` option. This enables an application with a small amount of non-const data but a large amount of const data to move the const data out of .bss. Also, since consts can be shared, but .bss cannot, it saves memory by moving the const data into .const.

The `--mem_model:const=type` option has the following values:

- `--mem_model:const=data`  
  Const objects are placed according to the `--mem_model:data` option. This is the default behavior.

- `--mem_model:const=far`  
  Const objects default to far independent of the `--mem_model:data` option.

- `--mem_model:const=far_aggregates`  
  Const aggregate objects default to far, scalar consts default to near.

Consts that are declared far, either explicitly through the far keyword or implicitly using `--mem_model:const` are always placed in the .const section.

### 7.1.6 Trampoline Generation for Function Calls

The C6000 compiler generates trampolines by default. Trampolines are a method for modifying function calls at link time to reach destinations that would normally be too far away. When a function call is more than +/- 1M instructions away from its destination, the linker will generate an indirect branch (or trampoline) to that destination, and will redirect the function call to point to the trampoline. The end result is that these function calls branch to the trampoline, and then the trampoline branches to the final destination. With trampolines, you no longer need to specify memory model options to generate far calls.
7.1.7 Position Independent Data

Near global and static data are stored in the .bss section. All near data for a program must fit within 32K bytes of memory. This limit comes from the addressing mode used to access near data, which is limited to a 15-bit unsigned offset from DP (B14), which is the data page pointer.

For some applications, it may be desirable to have multiple data pages with separate instances of near data. For example, a multi-channel application may have multiple copies of the same program running with different data pages. The functionality is supported by the C6000 compiler’s memory model, and is referred to as position independent data.

Position independent data means that all near data accesses are relative to the data page (DP) pointer, allowing for the DP to be changed at run time. There are three areas where position independent data is implemented by the compiler:

- Near direct memory access
  
  ```
  STW B4,*DP(._a)
  .global _a
  .bss _a,4,4
  ```

  All near direct accesses are relative to the DP.

- Near indirect memory access
  
  ```
  MVK (_a - $bss),A0
  ADD DP,A0,A0
  ```

  The expression (_a - $bss) calculates the offset of the symbol _a from the start of the .bss section. The compiler defines the global $bss in generated assembly code. The value of $bss is the starting address of the .bss section.

- Initialized near pointers
  
  The .cinit record for an initialized near pointer value is stored as an offset from the beginning of the .bss section. During the autoinitialization of global variables, the data page pointer is added to these offsets. (See Section 7.8.3.)
# 7.2 Object Representation

This section explains how various data objects are sized, aligned, and accessed.

## 7.2.1 Data Type Storage

Table 7-1 lists register and memory storage for various data types:

<table>
<thead>
<tr>
<th>Data Type</th>
<th>Register Storage</th>
<th>Memory Storage</th>
</tr>
</thead>
<tbody>
<tr>
<td>char</td>
<td>Bits 0-7 of register</td>
<td>8 bits aligned to 8-bit boundary</td>
</tr>
<tr>
<td>unsigned char</td>
<td>Bits 0-7 of register</td>
<td>8 bits aligned to 8-bit boundary</td>
</tr>
<tr>
<td>short</td>
<td>Bits 0-15 of register</td>
<td>16 bits aligned to 16-bit boundary</td>
</tr>
<tr>
<td>unsigned short</td>
<td>Bits 0-15 of register</td>
<td>16 bits aligned to 16-bit boundary</td>
</tr>
<tr>
<td>int</td>
<td>Entire register</td>
<td>32 bits aligned to 32-bit boundary</td>
</tr>
<tr>
<td>unsigned int</td>
<td>Entire register</td>
<td>32 bits aligned to 32-bit boundary</td>
</tr>
<tr>
<td>enum</td>
<td>Entire register</td>
<td>32 bits aligned to 32-bit boundary</td>
</tr>
<tr>
<td>float</td>
<td>Entire register</td>
<td>32 bits aligned to 32-bit boundary</td>
</tr>
<tr>
<td>long (EABI)</td>
<td>Entire register</td>
<td>32 bits aligned to 32-bit boundary</td>
</tr>
<tr>
<td>unsigned long (EABI)</td>
<td>Entire register</td>
<td>32 bits aligned to 32-bit boundary</td>
</tr>
<tr>
<td>long (COFF ABI)</td>
<td>Bits 0-39 of even/odd register pair</td>
<td>64 bits aligned to 64-bit boundary</td>
</tr>
<tr>
<td>unsigned long (COFF ABI)</td>
<td>Bits 0-39 of even/odd regis</td>
<td>64 bits aligned to 64-bit boundary</td>
</tr>
<tr>
<td>__int40_t</td>
<td>Even/odd register pair</td>
<td>64 bits aligned to 64-bit boundary</td>
</tr>
<tr>
<td>unsigned __int40_t</td>
<td>Even/odd register pair</td>
<td>64 bits aligned to 64-bit boundary</td>
</tr>
<tr>
<td>long</td>
<td>Even/odd register pair</td>
<td>64 bits aligned to 64-bit boundary</td>
</tr>
<tr>
<td>unsigned long long</td>
<td>Even/odd register pair</td>
<td>64 bits aligned to 64-bit boundary</td>
</tr>
<tr>
<td>double</td>
<td>Even/odd register pair</td>
<td>64 bits aligned to 64-bit boundary</td>
</tr>
<tr>
<td>long double</td>
<td>Even/odd register pair</td>
<td>64 bits aligned to 64-bit boundary</td>
</tr>
<tr>
<td>__x128_t (C6600 only)</td>
<td>Register quad</td>
<td>128-bits aligned to 128-bit boundary</td>
</tr>
<tr>
<td>struct</td>
<td>Members are stored as their individual types require.</td>
<td>Multiple of 8 bits aligned to boundary of largest member type; members are stored and aligned as their individual types require.</td>
</tr>
<tr>
<td>array</td>
<td>Members are stored as their individual types require.</td>
<td>Members are stored as their individual types require. All arrays inside a structure are aligned according to the type of each element in the array.</td>
</tr>
<tr>
<td>pointer to data member</td>
<td>Bits 0-31 of register</td>
<td>32 bits aligned to 32-bit boundary</td>
</tr>
<tr>
<td>pointer to member function</td>
<td>Components stored as their individual types require.</td>
<td>64 bits aligned to 32-bit boundary</td>
</tr>
</tbody>
</table>

(1) For details on the __x128_t container type see Section 7.5.6.

(2) For C6400, C6400+, C6740, and C6600, aligned to a 64-bit boundary. For C6200, C6700, and C6700+, aligned to a 32-bit boundary for all types 32 bits and smaller, and to a 64-bit boundary for all types larger than 32 bits. For C6600, aligned to a 128-bit boundary.
7.2.1.1 char and short Data Types (signed and unsigned)

The char and unsigned char data types are stored in memory as a single byte and are loaded to and stored from bits 0-7 of a register (see Figure 7-1). Objects defined as short or unsigned short are stored in memory as two bytes at a halfword (2 byte) aligned address and they are loaded to and stored from bits 0-15 of a register (see Figure 7-1).

In big-endian mode, 2-byte objects are loaded to registers by moving the first byte (that is, the lower address) of memory to bits 8-15 of the register and moving the second byte of memory to bits 0-7. In little-endian mode, 2-byte objects are loaded to registers by moving the first byte (that is, the lower address) of memory to bits 0-7 of the register and moving the second byte of memory to bits 8-15.

Figure 7-1. Char and Short Data Storage Format

<table>
<thead>
<tr>
<th>Signed 8-bit char</th>
<th>MS</th>
<th>LS</th>
</tr>
</thead>
<tbody>
<tr>
<td>S S S S S S S S S S</td>
<td>31</td>
<td>7</td>
</tr>
<tr>
<td>Unsigned 8-bit char</td>
<td>MS</td>
<td>LS</td>
</tr>
<tr>
<td>0 0 0 0 0 0 0 0</td>
<td>31</td>
<td>7</td>
</tr>
<tr>
<td>Signed 16-bit short</td>
<td>MS</td>
<td>LS</td>
</tr>
<tr>
<td>S S S S S S S S S S S S S S S</td>
<td>31</td>
<td>15</td>
</tr>
<tr>
<td>Unsigned 16-bit short</td>
<td>MS</td>
<td>LS</td>
</tr>
<tr>
<td>0 0 0 0 0 0 0 0</td>
<td>31</td>
<td>15</td>
</tr>
</tbody>
</table>

LEGEND: S = sign, I = signed integer, U = unsigned integer, MS = most significant, LS = least significant
7.2.1.2 enum, int, and long (EABI) Data Types (signed and unsigned)

The int, unsigned int, and enum data types are stored in memory as 32-bit objects (see Figure 7-2). Objects of these types are loaded to and stored from bits 0-31 of a register. In big-endian mode, 4-byte objects are loaded to registers by moving the first byte (that is, the lower address) of memory to bits 24-31 of the register, moving the second byte of memory to bits 16-23, moving the third byte to bits 8-15, and moving the fourth byte to bits 0-7. In little-endian mode, 4-byte objects are loaded to registers by moving the first byte (that is, the lower address) of memory to bits 0-7 of the register, moving the second byte to bits 8-15, moving the third byte to bits 16-23, and moving the fourth byte to bits 24-31.

Figure 7-2. 32-Bit Data Storage Format

Signed 32-bit integer, or enum char

<table>
<thead>
<tr>
<th>MS</th>
<th>LS</th>
</tr>
</thead>
<tbody>
<tr>
<td>S</td>
<td></td>
</tr>
<tr>
<td>31</td>
<td></td>
</tr>
</tbody>
</table>

Unsigned 32-bit integer

<table>
<thead>
<tr>
<th>MS</th>
<th>LS</th>
</tr>
</thead>
<tbody>
<tr>
<td>U</td>
<td></td>
</tr>
<tr>
<td>31</td>
<td>0</td>
</tr>
</tbody>
</table>

LEGEND: S = sign, U = unsigned integer, I = signed integer, MS = most significant, LS = least significant

7.2.1.3 float Data Type

The float data type is stored in memory as 32-bit objects (see Figure 7-3). Objects defined as float are loaded to and stored from bits 0-31 of a register. In big-endian mode, 4-byte objects are loaded to registers by moving the first byte (that is, the lower address) of memory to bits 24-31 of the register, moving the second byte of memory to bits 16-23, moving the third byte to bits 8-15, and moving the fourth byte to bits 0-7. In little-endian mode, 4-byte objects are loaded to registers by moving the first byte (that is, the lower address) of memory to bits 0-7 of the register, moving the second byte to bits 8-15, moving the third byte to bits 16-23, and moving the fourth byte to bits 24-31.

Figure 7-3. Single-Precision Floating-Point Char Data Storage Format

<table>
<thead>
<tr>
<th>MS</th>
<th>LS</th>
</tr>
</thead>
<tbody>
<tr>
<td>S</td>
<td></td>
</tr>
<tr>
<td>31</td>
<td>23</td>
</tr>
</tbody>
</table>

LEGEND: S = sign, M = mantissa, E = exponent, MS = most significant, LS = least significant
7.2.1.4 \texttt{__int40_t} and COFF ABI long Data Types (signed and unsigned)

Long and unsigned long data types are stored in an odd/even pair of registers (see Figure 7-4) and are always referenced as a pair in the format of odd register:even register (for example, A1:A0). In little-endian mode, the lower address is loaded into the even register and the higher address is loaded into the odd register; if data is loaded from location 0, then the byte at 0 is the lowest byte of the even register. In big-endian mode, the higher address is loaded into the even register and the lower address is loaded into the odd register; if data is loaded from location 0, then the byte at 0 is the highest byte of the odd register but is ignored.

![Figure 7-4. 40-Bit Data Storage Format Signed \texttt{__int40_t} or 40-bit long](image)

Odd register

<table>
<thead>
<tr>
<th>31</th>
<th>8</th>
<th>7</th>
<th>6</th>
<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>S</td>
<td>I</td>
<td>I</td>
<td>I</td>
<td>I</td>
<td>I</td>
<td>I</td>
<td>I</td>
<td>I</td>
<td>I</td>
</tr>
</tbody>
</table>

Even register

<table>
<thead>
<tr>
<th>31</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>I</td>
</tr>
</tbody>
</table>

LEGEND: S = sign, U = unsigned integer, I = signed integer, X = unused, MS = most significant, LS = least significant

![Figure 7-5. Unsigned 40-bit \texttt{__int40_t} or long](image)

Odd register

<table>
<thead>
<tr>
<th>31</th>
<th>8</th>
<th>7</th>
<th>6</th>
<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>U</td>
<td>U</td>
<td>U</td>
<td>U</td>
<td>U</td>
<td>U</td>
<td>U</td>
<td>U</td>
<td>U</td>
<td>U</td>
</tr>
</tbody>
</table>

Even register

<table>
<thead>
<tr>
<th>31</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td>U</td>
<td>U</td>
</tr>
</tbody>
</table>

LEGEND: S = sign, U = unsigned integer, I = signed integer, X = unused, MS = most significant, LS = least significant
7.2.1.5 long long Data Types (signed and unsigned)

Long long and unsigned long long data types are stored in an odd/even pair of registers (see Figure 7-6) and are always referenced as a pair in the format of odd register:even register (for example, A1:A0). In little-endian mode, the lower address is loaded into the even register and the higher address is loaded into the odd register; if data is loaded from location 0, then the byte at 0 is the lowest byte of the even register. In big-endian mode, the higher address is loaded into the even register and the lower address is loaded into the odd register; if data is loaded from location 0, then the byte at 0 is the highest byte of the odd register.

**Figure 7-6. 64-Bit Data Storage Format Signed 64-bit long**

Odd register

|          | S | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | I | |
7.2.1.6 double and long double Data Types

Double and long double data types are stored in an odd/even pair of registers (see Figure 7-8) and can only exist in a register in one format: as a pair in the format of odd register:even register (for example, A1:A0). The odd memory word contains the sign bit, exponent, and the most significant part of the mantissa. The even memory word contains the least significant part of the mantissa. In little-endian mode, the lower address is loaded into the even register and the higher address is loaded into the odd register. In big-endian mode, the higher address is loaded into the even register and the lower address is loaded into the odd register. In little-endian mode, if code is loaded from location 0, then the byte at 0 is the lowest byte of the even register. In big-endian mode, if code is loaded from location 0, then the byte at 0 is the highest byte of the odd register.

Figure 7-8. Double-Precision Floating-Point Data Storage Format

<table>
<thead>
<tr>
<th>Odd register</th>
<th>MS</th>
</tr>
</thead>
<tbody>
<tr>
<td>S E E E E E E E E E E M M M M M M M M M M M M M</td>
<td>31 20 0</td>
</tr>
<tr>
<td>Even register</td>
<td>LS</td>
</tr>
<tr>
<td>M M M M M M M M M M M M M M M M M M M M</td>
<td>31 0</td>
</tr>
</tbody>
</table>

LEGEND: S = sign, M = mantissa, E = exponent, MS = most significant, LS = least significant

7.2.1.7 Pointer to Data Member Types

Pointer to data member objects are stored in memory like an unsigned int (32 bit) integral type. Its value is the byte offset to the data member in the class, plus 1. The zero value is reserved to represent the NULL pointer.

7.2.1.8 Pointer to Member Function Types

Pointer to member function objects are stored as a structure with three members, and the layout is equivalent to:

```c
struct {
    short int d;
    short int i;
    union {
        void (*f) ();
        int 0;  }
};
```

The parameter d is the offset to be added to the beginning of the class object for this pointer. The parameter i is the index into the virtual function table, offset by 1. The index enables the NULL pointer to be represented. Its value is -1 if the function is nonvirtual. The parameter f is the pointer to the member function if it is nonvirtual, when i is 0. The 0 is the offset to the virtual function pointer within the class object.

7.2.1.9 Structures and Arrays

A nested structure is aligned to a boundary required by the largest type it contains. For example, if the largest type in a nested structure is of type short, then the nested structure is aligned to a 2-byte boundary. If the largest type in a nested structure is of type long, unsigned long, double, or long double, then the nested structure is aligned to an 8-byte boundary.

Structures always reserve memory in multiples of the size of the largest element type. For example, if a structure contains an int, unsigned int, or float, a multiple of 4 bytes of storage is reserved in memory. Members of structures are stored in the same manner as if they were individual objects. An array member in a struct is aligned to the natural boundary of its elements.
Top-level arrays are aligned on an 8-byte boundary for C6400, C6400+, C6740, and C6600, and either a 4-byte (for all element types of 32 bits or smaller) or an 8-byte boundary for C6200, C6700, or C6700+.
Top-level arrays are aligned on a 16-byte boundary for C6600. Elements of arrays are stored in the same manner as if they were individual objects.

7.2.2 Bit Fields

Bit fields are handled differently in COFF ABI and EABI modes. Section 7.2.2.1 details how bit fields are handled in all modes. Section 7.2.2.2 details how bit fields differ in EABI mode.

7.2.2.1 Generic Bit Fields

Bit fields are the only objects that are packed within a byte. That is, two bit fields can be stored in the same byte. Bit fields can range in size from 1 to 32 bits for COFF ABI, and 1 to 64 bits in C or larger in C++ for EABI.

For big-endian mode, bit fields are packed into registers from most significant bit (MSB) to least significant bit (LSB) in the order in which they are defined. Bit fields are packed in memory from most significant byte (MSbyte) to least significant byte (LSbyte). For little-endian mode, bit fields are packed into registers from the LSB to the MSB in the order in which they are defined, and packed in memory from LSbyte to MSbyte.

Figure 7-9 illustrates bit-field packing, using the following bit field definitions:

```
struct{
    int A:7
    int B:10
    int C:3
    int D:2
    int E:9
} x;
```

A0 represents the least significant bit of the field A; A1 represents the next least significant bit, etc. Again, storage of bit fields in memory is done with a byte-by-byte, rather than bit-by-bit, transfer.

Figure 7-9. Bit-Field Packing in Big-Endian and Little-Endian Formats

---

**Legend:** X = not used, MS = most significant, LS = least significant
7.2.2.2 EABI Bit Field Differences

Bit fields are handled differently in TIABI mode versus EABI mode in these ways:

- In COFF ABI, bit fields of type long long are not allowed. In EABI, long long bit fields are supported.
- In COFF ABI, all bit fields are treated as signed or unsigned int type. In EABI, bit fields are treated as the declared type.
- In COFF ABI, the size and alignment a bit field contributes to the struct containing it depends on the number of bits in the bit field. In EABI, the size and alignment of the struct containing the bit field depends on the declared type of the bit field. For example, consider the struct:

```c
struct st
{
  int a:4;
};
```

In COFF ABI, this struct takes up 1 byte and is aligned at 1 byte. In EABI, this struct uses up 4 bytes and is aligned at 4 bytes.

- In COFF ABI, unnamed bit fields are zero-sized bit fields do not affect the struct or union alignment. In EABI, such fields affect the alignment of the struct or union. For example, consider the struct:

```c
struct st
{
  char a:4;
  int :22;
};
```

In COFF ABI, this struct uses 4 bytes and is aligned at a 1-byte boundary. In EABI, this struct uses 4 bytes and is aligned at a 4-byte boundary.

- With EABI, bit fields declared volatile are accessed according to the bit field's declared type. A volatile bit field reference generates exactly one reference to its storage; multiple volatile bit field accesses are not merged.

7.2.3 Character String Constants

In C, a character string constant is used in one of the following ways:

- To initialize an array of characters. For example:

```c
char s[] = "abc";
```

When a string is used as an initializer, it is simply treated as an initialized array; each character is a separate initializer. For more information about initialization, see Section 7.8.

- In an expression. For example:

```c
strcpy (s, "abc");
```

When a string is used in an expression, the string itself is defined in the .const:string section with the .string assembler directive, along with a unique label that points to the string; the terminating 0 byte is explicitly added by the compiler. For example, the following lines define the string abc, and the terminating 0 byte (the label SL5 points to the string):

```c
.sect ".const:string"
$C$SL5: .string "abc",0
```

String labels have the form $C$SSLn, where $C$ is the compiler-generated symbol prefix and $n$ is a number assigned by the compiler to make the label unique. The number begins at 0 and is increased by 1 for each string defined. All strings used in a source module are defined at the end of the compiled assembly language module.

The label $C$SSLn represents the address of the string constant. The compiler uses this label to reference the string expression.

Because strings are stored in the .const section (possibly in ROM) and shared, it is bad practice for a program to modify a string constant. The following code is an example of incorrect string use:

```c
const char *a = "abc"
a[1] = 'x'; /* Incorrect! */
```
7.3 Register Conventions

Strict conventions associate specific registers with specific operations in the C/C++ environment. If you plan to interface an assembly language routine to a C/C++ program, you must understand and follow these register conventions.

The register conventions dictate how the compiler uses registers and how values are preserved across function calls. Table 7-2 summarizes how the compiler uses the TMS320C6000 registers.

The registers in Table 7-2 are available to the compiler for allocation to register variables and temporary expression results. If the compiler cannot allocate a register of a required type, spilling occurs. Spilling is the process of moving a register's contents to memory to free the register for another purpose.

Objects of type double, long, long long, or long double are allocated into an odd/even register pair and are always referenced as a register pair (for example, A1:A0). The odd register contains the sign bit, the exponent, and the most significant part of the mantissa. The even register contains the least significant part of the mantissa. The A4 register is used with A5 for passing the first argument if the first argument is a double, long, long long, or long double. The same is true for B4 and B5 for the second parameter, and so on. For more information about argument-passing registers and return registers, see Section 7.4.

<table>
<thead>
<tr>
<th>Register</th>
<th>Function Preserved By</th>
<th>Special Uses</th>
<th>Register</th>
<th>Function Preserved By</th>
<th>Special Uses</th>
</tr>
</thead>
<tbody>
<tr>
<td>A0</td>
<td>Parent</td>
<td>–</td>
<td>B0</td>
<td>Parent</td>
<td>–</td>
</tr>
<tr>
<td>A1</td>
<td>Parent</td>
<td>–</td>
<td>B1</td>
<td>Parent</td>
<td>–</td>
</tr>
<tr>
<td>A2</td>
<td>Parent</td>
<td>–</td>
<td>B2</td>
<td>Parent</td>
<td>–</td>
</tr>
<tr>
<td>A3</td>
<td>Parent</td>
<td>Structure register (pointer to a returned structure)¹</td>
<td>B3</td>
<td>Parent</td>
<td>Return register (address to return to)</td>
</tr>
<tr>
<td>A4</td>
<td>Parent</td>
<td>Argument 1 or return value</td>
<td>B4</td>
<td>Parent</td>
<td>Argument 2</td>
</tr>
<tr>
<td>A5</td>
<td>Parent</td>
<td>Argument 1 or return value with A4 for doubles, longs and long longs</td>
<td>B5</td>
<td>Parent</td>
<td>Argument 2 with B4 for doubles, longs and long longs</td>
</tr>
<tr>
<td>A6</td>
<td>Parent</td>
<td>Argument 3</td>
<td>B6</td>
<td>Parent</td>
<td>Argument 4</td>
</tr>
<tr>
<td>A7</td>
<td>Parent</td>
<td>Argument 3 with A6 for doubles, longs, and long longs</td>
<td>B7</td>
<td>Parent</td>
<td>Argument 4 with B6 for doubles, longs, and long longs</td>
</tr>
<tr>
<td>A8</td>
<td>Parent</td>
<td>Argument 5</td>
<td>B8</td>
<td>Parent</td>
<td>Argument 6</td>
</tr>
<tr>
<td>A9</td>
<td>Parent</td>
<td>Argument 5 with A8 for doubles, longs, and long longs</td>
<td>B9</td>
<td>Parent</td>
<td>Argument 6 with B8 for doubles, longs, and long longs</td>
</tr>
<tr>
<td>A10</td>
<td>Child</td>
<td>Argument 7</td>
<td>B10</td>
<td>Child</td>
<td>Argument 8</td>
</tr>
<tr>
<td>A11</td>
<td>Child</td>
<td>Argument 7 with A10 for doubles, longs, and long longs</td>
<td>B11</td>
<td>Child</td>
<td>Argument 8 with B10 for doubles, longs, and long longs</td>
</tr>
<tr>
<td>A12</td>
<td>Child</td>
<td>Argument 9</td>
<td>B12</td>
<td>Child</td>
<td>Argument 10</td>
</tr>
<tr>
<td>A13</td>
<td>Child</td>
<td>Argument 9 with A12 for doubles, longs, and long longs</td>
<td>B13</td>
<td>Child</td>
<td>Argument 10 with B12 for doubles, longs, and long longs</td>
</tr>
<tr>
<td>A14</td>
<td>Child</td>
<td>–</td>
<td>B14</td>
<td>Child</td>
<td>Data page pointer (DP)</td>
</tr>
<tr>
<td>A15</td>
<td>Child</td>
<td>Frame pointer (FP)</td>
<td>B15</td>
<td>Child</td>
<td>Stack pointer (SP)</td>
</tr>
<tr>
<td>A16-A31</td>
<td>Parent</td>
<td>C6400, C6400+, C6700+, C6740, and C6600 only</td>
<td>B16-B31</td>
<td>Parent</td>
<td>C6400, C6400+, C6700+, C6740, and C6600 only</td>
</tr>
<tr>
<td>ILC</td>
<td>Child</td>
<td>C6400+, C6740, and C6600 only, loop buffer counter</td>
<td>NRP</td>
<td>Parent</td>
<td>–</td>
</tr>
<tr>
<td>IRP</td>
<td>Parent</td>
<td>–</td>
<td>RILC</td>
<td>Child</td>
<td>C6400+, C6740, and C6600 only, loop buffer counter</td>
</tr>
</tbody>
</table>

¹ For EABI, structs of size 64 or less are passed by value in registers instead of by reference using a pointer in A3.
All other control registers are not saved or restored by the compiler.

The compiler assumes that control registers not listed in Table 7-2 that can have an effect on compiled code have default values. For example, the compiler assumes all circular addressing-enabled registers are set for linear addressing (the AMR is used to enable circular addressing). Enabling circular addressing and then calling a C/C++ function without restoring the AMR to a default setting violates the calling convention. You must be certain that control registers which affect compiler-generated code have a default value when calling a C/C++ function from assembly.

Assembly language programmers must be aware that the linker assumes B15 contains the stack pointer. The linker needs to save and restore values on the stack in trampoline code that it generates. If you do not use B15 as the stack pointer in assembly code, you should use the linker option that disables trampolines, --trampolines=off. Otherwise, trampolines could corrupt memory and overwrite register values.

7.4 Function Structure and Calling Conventions

The C/C++ compiler imposes a strict set of rules on function calls. Except for special run-time support functions, any function that calls or is called by a C/C++ function must follow these rules. Failure to adhere to these rules can disrupt the C/C++ environment and cause a program to fail.

For details on the calling conventions in EABI mode, refer to The C6000 Embedded Application Binary Interface Application Report (SPRAB89).

7.4.1 How a Function Makes a Call

A function (parent function) performs the following tasks when it calls another function (child function).

1. Arguments passed to a function are placed in registers or on the stack.
   A function (parent function) performs the following tasks when it calls another function (child function):
   If arguments are passed to a function, up to the first ten arguments are placed in registers A4, B4, A6, B6, A8, B8, A10, B10, A12, and B12. If longs, long longs, doubles, or long doubles are passed, they are placed in register pairs A5:A4, B5:B4, A7:A6, and so on.
   However, for C6600, if one or more __x128_t arguments are passed, the next __x128_t argument is passed in the first available quad, where the list of available quads has the ordering: A7:A6:A5:A4, B7:B6:B5:B4, A11:A10:A9:A8, B11:B10:B9:B8. If there are no more available quads, the __x128_t goes onto the stack. A subsequent 32-bit, 40-bit, or 64-bit argument can take the first available register or register pair even if an earlier __x128_t argument has been put on the stack.
   Any remaining arguments are placed on the stack (that is, the stack pointer points to the next free location; SP + offset points to the eleventh argument, and so on, assuming for C6600 an __x128_t is not passed.) Arguments placed on the stack must be aligned to a value appropriate for their size. An argument that is not declared in a prototype and whose size is less than the size of int is passed as an int. An argument that is a float is passed as double if it has no prototype declared.
   A structure argument is passed as the address of the structure. It is up to the called function to make a local copy.
   For a function declared with an ellipsis indicating that it is called with varying numbers of arguments, the convention is slightly modified. The last explicitly declared argument is passed on the stack, so that its stack address can act as a reference for accessing the undeclared arguments.
   Figure 7-10 shows the register argument conventions.
   2. The calling function must save registers A0 to A9 and B0 to B9 (and A16 to A31 and B16 to B31 for C6400, C6400+, and C6700+), if their values are needed after the call, by pushing the values onto the stack.
   3. The caller (parent) calls the function (child).
   4. Upon returning, the caller reclaims any stack space needed for arguments by adding to the stack pointer. This step is needed only in assembly programs that were not compiled from C/C++ code. This is because the C/C++ compiler allocates the stack space needed for all calls at the beginning of the function and deallocates the space at the end of the function.
### 7.4.2 How a Called Function Responds

A called function (child function) must perform the following tasks:

1. The called function (child) allocates enough space on the stack for any local variables, temporary storage areas, and arguments to functions that this function might call. This allocation occurs once at the beginning of the function and may include the allocation of the frame pointer (FP).

   The frame pointer is used to read arguments from the stack and to handle register spilling instructions. If any arguments are placed on the stack or if the frame size exceeds 128K bytes, the frame pointer (A15) is allocated in the following manner:
   (a) The old A15 is saved on the stack.
   (b) The new frame pointer is set to the current SP (B15).
   (c) The frame is allocated by decrementing SP by a constant.
   (d) Neither A15 (FP) nor B15 (SP) is decremented anywhere else within this function.

   If the above conditions are not met, the frame pointer (A15) is not allocated. In this situation, the frame is allocated by subtracting a constant from register B15 (SP). Register B15 (SP) is not decremented anywhere else within this function.

2. If the called function calls any other functions, the return address must be saved on the stack. Otherwise, it is left in the return register (B3) and is overwritten by the next function call.
3. If the called function modifies any registers numbered A10 to A15 or B10 to B15, it must save them, either in other registers or on the stack. The called function can modify any other registers without saving them.
4. If the called function expects a structure argument, it receives a pointer to the structure instead. If writes are made to the structure from within the called function, space for a local copy of the structure must be allocated on the stack and the local structure must be copied from the passed pointer to the structure. If no writes are made to the structure, it can be referenced in the called function indirectly through the pointer argument.
You must be careful to declare functions properly that accept structure arguments, both at the point
where they are called (so that the structure argument is passed as an address) and at the point where
they are declared (so the function knows to copy the structure to a local copy).

5. The called function executes the code for the function.

6. If the called function returns any integer, pointer, or float type, the return value is placed in the A4
register. If the function returns a double, long double, long, or long long type, the value is placed in the
A5:A4 register pair. For C6600 if the function returns a __x128_t, the value is placed in A7:A6:A5:A4.

If the function returns a structure, the caller allocates space for the structure and passes the address of
the return space to the called function in A3. To return a structure, the called function copies the
structure to the memory block pointed to by the extra argument.

In this way, the caller can be smart about telling the called function where to return the structure. For
example, in the statement s = f(x), where s is a structure and f is a function that returns a structure, the
caller can actually make the call as f(&s, x). The function f then copies the return structure directly into
s, performing the assignment automatically.

If the caller does not use the return structure value, an address value of 0 can be passed as the first
argument. This directs the called function not to copy the return structure.

You must be careful to declare functions properly that return structures, both at the point where they
are called (so that the extra argument is passed) and at the point where they are declared (so the
function knows to copy the result).

7. Any register numbered A10 to A15 or B10 to B15 that was saved in is restored.

8. If A15 was used as a frame pointer (FP), the old value of A15 is restored from the stack. The space
allocated for the function in is reclaimed at the end of the function by adding a constant to register B15
(SP).

9. The function returns by jumping to the value of the return register (B3) or the saved value of the return
register.

### 7.4.3 Accessing Arguments and Local Variables

A function accesses its stack arguments and local nonregister variables indirectly through register A15
(FP) or through register B15 (SP), one of which points to the top of the stack. Since the stack grows
toward smaller addresses, the local and argument data for a function are accessed with a positive offset
from FP or SP. Local variables, temporary storage, and the area reserved for stack arguments to functions
called by this function are accessed with offsets smaller than the constant subtracted from FP or SP at the
beginning of the function.

Stack arguments passed to this function are accessed with offsets greater than or equal to the constant
subtracted from register FP or SP at the beginning of the function. The compiler attempts to keep register
arguments in their original registers if optimization is used or if they are defined with the register keyword.
Otherwise, the arguments are copied to the stack to free those registers for further allocation.

For information on whether FP or SP is used to access local variables, temporary storage, and stack
arguments, see Section 7.4.2. For more information on the C/C++ System stack, see Section 7.1.2.
7.5 Interfacing C and C++ With Assembly Language

The following are ways to use assembly language with C/C++ code:

- Use separate modules of assembled code and link them with compiled C/C++ modules (see Section 7.5.1).
- Use assembly language variables and constants in C/C++ source (see Section 7.5.2).
- Use inline assembly language embedded directly in the C/C++ source (see Section 7.5.4).
- Use intrinsics in C/C++ source to directly call an assembly language statement (see Section 7.5.5).

7.5.1 Using Assembly Language Modules With C/C++ Code

Interfacing C/C++ with assembly language functions is straightforward if you follow the calling conventions defined in Section 7.4, and the register conventions defined in Section 7.3. C/C++ code can access variables and call functions defined in assembly language, and assembly code can access C/C++ variables and call C/C++ functions.

Follow these guidelines to interface assembly language and C:

- All functions, whether they are written in C/C++ or assembly language, must follow the register conventions outlined in Section 7.3.
- You must preserve registers A10 to A15, B3, and B10 to B15, and you may need to preserve A3. If you use the stack normally, you do not need to explicitly preserve the stack. In other words, you are free to use the stack inside a function as long as you pop everything you pushed before your function exits. You can use all other registers freely without preserving their contents.
- A10 to A15 and B10 to B15 need to be restored before a function returns, even if any of A10 to A13 and B10 to B13 are being used for passing arguments.
- Interrupt routines must save all the registers they use. For more information, see Section 7.6.
- When you call a C/C++ function from assembly language, load the designated registers with arguments and push the remaining arguments onto the stack as described in Section 7.4.1.
- Remember that only A10 to A15 and B10 to B15 are preserved by the C/C++ compiler. C/C++ functions can alter any other registers, save any other registers whose contents need to be preserved by pushing them onto the stack before the function is called, and restore them after the function returns.
- Functions must return values correctly according to their C/C++ declarations. Integers and 32-bit floating-point (float) values are returned in A4. Doubles, long doubles, longs, and long longs are returned in A5:A4. For C6600 __x128_t values are returned in A7:A6:A5:A4. Structures are returned by copying them to the address in A3.
- No assembly module should use the .cinit section for any purpose other than autoinitialization of global variables. The C/C++ startup routine assumes that the .cinit section consists entirely of initialization tables. Disrupting the tables by putting other information in .cinit can cause unpredictable results.
- The compiler assigns linknames to all external objects. Thus, when you are writing assembly language code, you must use the same linknames as those assigned by the compiler. See Section 6.12 for more information.
- Any object or function declared in assembly language that is accessed or called from C/C++ must be declared with the .def or .global directive in the assembly language modifier. This declares the symbol as external and allows the linker to resolve references to it.
- Likewise, to access a C/C++ function or object from assembly language, declare the C/C++ object with the .ref or .global directive in the assembly language module. This creates an undeclared external reference that the linker resolves.
- The SGIE bit of the TSR control register may need to be saved. Please see Section 7.6.1 for more information.
- The compiler assumes that control registers not listed in Table 7-2 that can have an effect on compiled code have default values. For example, the compiler assumes all circular-addressing-enabled registers are set for linear addressing (the AMR is used to enable circular addressing). Enabling circular addressing and then calling a C/C++ function without restoring the AMR to a default setting violates the calling convention. Also, enabling circular addressing and having interrupts enabled violates the calling
convention. You must be certain that control registers that affect compiler-generated code have a
default value when calling a C/C++ function from assembly.

- Assembly language programmers must be aware that the linker assumes B15 contains the stack
  pointer. The linker needs to save and restore values on the stack in trampoline code that it generates.
  If you do not use B15 as the stack pointer in your assembly code, you should use the linker option that
disables trampolines, --trampolines=off. Otherwise, trampolines could corrupt memory and overwrite
register values.

- Assembly code that utilizes B14 and/or B15 for localized purposes other than the data-page pointer
  and stack pointer may violate the calling convention. The assembly programmer needs to protect these
areas of non-standard use of B14 and B15 by turning off interrupts around this code. Because interrupt
handling routines need the stack (and thus assume the stack pointer is in B15) interrupts need to be
turned off around this code. Furthermore, because interrupt service routines may access global data
and may call other functions which access global data, this special treatment also applies to B14. After
the data-page pointer and stack pointer have been restored, interrupts may be turned back on.

Example 7-1 illustrates a C++ function called main, which calls an assembly language function called
asmfunc, Example 7-2. The asmfunc function takes its single argument, adds it to the C++ global variable
called gvar, and returns the result.

Example 7-1. Calling an Assembly Language Function From a C/C++ Program

```c
extern "C" {
extern int asmfunc(int a); /* declare external asm function */
int gvar = 0; /* define global variable */
}

go

void main()
{
  int I = 5;

  I = asmfunc(I); /* call function normally */
```

Example 7-2. Assembly Language Program Called by Example 7-1

```assembly
.global _asmfunc
.global _gvar
_asmfunc:
  LDF  *+b14(_gvar),A3
  NOP 4
  ADD  a3,a4,a3
  STB  *+b14(_gvar)
  MVP  a3,a4
  B   b3
  NOP 5
```

In the C++ program in Example 7-1, the extern declaration of asmfunc is optional because the return type
is int. Like C/C++ functions, you need to declare assembly functions only if they return noninteger values
or pass noninteger parameters.

NOTE: SP Semantics

The stack pointer must always be 8-byte aligned. For C6600 the stack pointer must always
be 16-byte aligned. This is automatically performed by the C compiler and system
initialization code in the run-time-support libraries. Any hand assembly code that has
interrupts enabled or calls a function defined in C or linear assembly source should also
reserve a multiple of 8 bytes (multiple of 16 bytes for C6600) on the stack.
NOTE: Stack Allocation

Even though the compiler guarantees a doubleword alignment of the stack and the stack pointer (SP) points to the next free location in the stack space, there is only enough guaranteed room to store one 32-bit word at that location. The called function must allocate space to store the doubleword.

NOTE: Alignment of __x128_t Data Objects (C6600 Only)

The C6600 introduces the 128-bit container type __x128_t. Global data objects of this type are aligned to a 16-byte boundary (128 bits). Local __x128_t variables are allocated on the stack, but are not necessarily aligned on a 16-byte boundary since its actual alignment will depend on the alignment of the stack and the SP-relative offset of the local __x128_t type object. For the C6400/C6400+/C6740/C6600 ISAs, the compiler will always align the stack to an 8-byte boundary.

7.5.2 Accessing Assembly Language Variables From C/C++

It is sometimes useful for a C/C++ program to access variables or constants defined in assembly language. There are several methods that you can use to accomplish this, depending on where and how the item is defined: a variable defined in the .bss section, a variable not defined in the .bss section, or a constant.

7.5.2.1 Accessing Assembly Language Global Variables

Accessing uninitialized variables from the .bss section or a section named with .usect is straightforward:
1. Use the .bss or .usect directive to define the variable.
2. When you use .usect, the variable is defined in a section other than .bss and therefore must be declared far in C.
3. Use the .def or .global directive to make the definition external.
4. Use the appropriate linkname in assembly language.
5. In C/C++, declare the variable as extern and access it normally.

Example 7-4 and Example 7-3 show how you can access a variable defined in .bss.

**Example 7-3. Assembly Language Variable Program**

```assembly
.bss _var1,4,4 ; Define the variable
.global var1 ; Declare it as external
_var2 .usect "mysect",4,4 ; Define the variable
.global _var2 ; Declare it as external
```

**Example 7-4. C Program to Access Assembly Language From Example 7-3**

```c
extern int var1; /* External variable */
extern far int var2; /* External variable */
var1 = 1; /* Use the variable */
var2 = 1; /* Use the variable */
```
7.5.2.2 Accessing Assembly Language Constants

You can define global constants in assembly language by using the .set, .def, and .global directives, or you can define them in a linker command file using a linker assignment statement. These constants are accessible from C/C++ only with the use of special operators.

For normal variables defined in C/C++ or assembly language, the symbol table contains the address of the value of the variable. For assembler constants, however, the symbol table contains the value of the constant. The compiler cannot tell which items in the symbol table are values and which are addresses.

If you try to access an assembler (or linker) constant by name, the compiler attempts to fetch a value from the address represented in the symbol table. To prevent this unwanted fetch, you must use the & (address of) operator to get the value. In other words, if x is an assembly language constant, its value in C/C++ is &x.

You can use casts and #defines to ease the use of these symbols in your program, as in Example 7-5 and Example 7-6.

Example 7-5. Accessing an Assembly Language Constant From C

```c
extern int table_size; /*external ref */
#define TABLE_SIZE ((int) ( & table_size))
    /* use cast to hide address-of */
    .
    .
    for (I=0; i<TABLE_SIZE; ++I) /* use like normal symbol */
```

Example 7-6. Assembly Language Program for Example 7-5

```assembly
_table_size .set 10000 ; define the constant
    .global _table_size ; make it global
```

Because you are referencing only the symbol's value as stored in the symbol table, the symbol's declared type is unimportant. In Example 7-5, int is used. You can reference linker-defined symbols in a similar manner.

7.5.3 Sharing C/C++ Header Files With Assembly Source

You can use the .cdecls assembler directive to share C headers containing declarations and prototypes between C and assembly code. Any legal C/C++ can be used in a .cdecls block and the C/C++ declarations will cause suitable assembly to be generated automatically, allowing you to reference the C/C++ constructs in assembly code. For more information, see the C/C++ header files chapter in the TMS320C6000 Assembly Language Tools User's Guide.
### 7.5.4 Using Inline Assembly Language

Within a C/C++ program, you can use the `asm` statement to insert a single line of assembly language into the assembly language file created by the compiler. A series of `asm` statements places sequential lines of assembly language into the compiler output with no intervening code. For more information, see Section 6.8.

The `asm` statement is useful for inserting comments in the compiler output. Simply start the assembly code string with a semicolon (`;`) as shown below:

```c
asm(";*** this is an assembly language comment");
```

---

**NOTE:** Using the `asm` Statement

Keep the following in mind when using the `asm` statement:

- Be extremely careful not to disrupt the C/C++ environment. The compiler does not check or analyze the inserted instructions.
- Avoid inserting jumps or labels into C/C++ code because they can produce unpredictable results by confusing the register-tracking algorithms that the code generator uses.
- Do not change the value of a C/C++ variable when using an `asm` statement. This is because the compiler does not verify such statements. They are inserted as is into the assembly code, and potentially can cause problems if you are not sure of their effect.
- Do not use the `asm` statement to insert assembler directives that change the assembly environment.
- Avoid creating assembly macros in C code and compiling with the `--symdebug:dwarf` (or `-g`) option. The C environment’s debug information and the assembly macro expansion are not compatible.

---

### 7.5.5 Using Intrinsics to Access Assembly Language Statements

The C6000 compiler recognizes a number of intrinsic operators. Intrinsics allow you to express the meaning of certain assembly statements that would otherwise be cumbersome or inexpressible in C/C++. Intrinsics are used like functions; you can use C/C++ variables with these intrinsics, just as you would with any normal function.

The intrinsics are specified with a leading underscore, and are accessed by calling them as you do a function. For example:

```c
int x1, x2, y;
y = _sadd(x1, x2);
```

---

**Intrinsic Instructions in C Versus Assembly Language**

**NOTE:** In some instances, an intrinsic’s exact corresponding assembly language instruction may not be used by the compiler. When this is the case, the meaning of the program does not change.

---

**Table 7-4** provides a summary of the C6000 intrinsics clarifying which devices support which intrinsics.
Table 7-3. C6000 C/C++ Intrinsics Support by Device

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<th>C6400+</th>
<th>C6600</th>
<th>C6700/C6700+</th>
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Table 7-3. C6000 C/C++ Intrinsics Support by Device (continued)

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### Table 7-3. C6000 C/C++ Intrinsics Support by Device (continued)

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<th>Intrinsic</th>
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<th>C6400</th>
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<th>C6600</th>
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</table>
The intrinsics listed in Table 7-4 can be used on all C6000 devices. They correspond to the indicated C6000 assembly language instruction(s). See the *TMS320C6000 CPU and Instruction Set Reference Guide* for more information.

See Table 7-5 for the listing of C6400-specific intrinsics, which are also compatible with C6400+, C6740, and C6600. See Table 7-6 for the listing of C6400+-specific intrinsics, which are also compatible with C6740 and C6600 devices. See Table 7-7 for the listing of C6700-specific intrinsics. See Table 7-8 for a listing of C6600-specific intrinsics.
Table 7-4. TMS320C6000 C/C++ Compiler Intrinsics

<table>
<thead>
<tr>
<th>C/C++ Compiler Intrinsic</th>
<th>Assembly Instruction</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>int _abs (int src); int _labs (_int40_t src);</td>
<td>ABS</td>
<td>Returns the saturated absolute value of src</td>
</tr>
<tr>
<td>int _add2 (int src1, int src2);</td>
<td>ADD2</td>
<td>Adds the upper and lower halves of src1 to the upper and lower halves of src2 and returns the result. Any overflow from the lower half add does not affect the upper half add.</td>
</tr>
<tr>
<td>ushort &amp; _amem2 (void *ptr);</td>
<td>LDHU STHU</td>
<td>Allows aligned loads and stores of 2 bytes to memory. The pointer must be aligned to a two-byte boundary. (1)</td>
</tr>
<tr>
<td>const ushort &amp; _amem2_const (const void *ptr);</td>
<td>LDHU</td>
<td>Allows aligned loads of 2 bytes from memory. The pointer must be aligned to a two-byte boundary. (1)</td>
</tr>
<tr>
<td>unsigned &amp; _amem4 (void *ptr);</td>
<td>LDW STW</td>
<td>Allows aligned loads and stores of 4 bytes to memory. The pointer must be aligned to a four-byte boundary. (1)</td>
</tr>
<tr>
<td>const unsigned &amp; _amem4_const (const void *ptr);</td>
<td>LDW</td>
<td>Allows aligned loads of 4 bytes from memory. The pointer must be aligned to a four-byte boundary. (1)</td>
</tr>
<tr>
<td>double &amp; _amemd8 (void *ptr);</td>
<td>LDW/LDW STW/STW</td>
<td>Allows aligned loads and stores of 8 bytes to memory. The pointer must be aligned to an eight-byte boundary. (1)(2) For C6400 _amemd8 corresponds to different assembly instructions than when used with other C6000 devices; see Table 7-5 for specifics.</td>
</tr>
<tr>
<td>const double &amp; _amemd8_const (const void *ptr);</td>
<td>LDDW</td>
<td>Allows aligned loads of 8 bytes from memory. The pointer must be aligned to an eight-byte boundary. (1)(2)</td>
</tr>
<tr>
<td>unsigned _clr (unsigned src2, unsigned csta, unsigned cstb);</td>
<td>CLR</td>
<td>Clears the specified field in src2. The beginning and ending bits of the field to be cleared are specified by csta and cstb, respectively.</td>
</tr>
<tr>
<td>unsigned _clrr (unsigned src2, int src1);</td>
<td>CLR</td>
<td>Clears the specified field in src2. The beginning and ending bits of the field to be cleared are specified by the lower 10 bits of src1.</td>
</tr>
<tr>
<td>__int40_t _dtol (double src);</td>
<td>Reinterprets double register pair src as an __int40_t (stored as a register pair).</td>
<td></td>
</tr>
<tr>
<td>long long _dtoll (double src);</td>
<td>Reinterprets double register pair src as a long long register pair.</td>
<td></td>
</tr>
<tr>
<td>int _ext (int src2, unsigned csta, unsigned cstb);</td>
<td>EXT</td>
<td>Extracts the specified field in src2, sign-extended to 32 bits. The extract is performed by a shift left followed by a signed shift right; csta and cstb are the shift left and shift right amounts, respectively.</td>
</tr>
<tr>
<td>int _extr (int src2, int src1);</td>
<td>EXT</td>
<td>Extracts the specified field in src2, sign-extended to 32 bits. The extract is performed by a shift left followed by a signed shift right; the shift left and shift right amounts are specified by the lower 10 bits of src1.</td>
</tr>
<tr>
<td>unsigned _extu (unsigned src2, unsigned csta, unsigned cstb);</td>
<td>EXTU</td>
<td>Extracts the specified field in src2, zero-extended to 32 bits. The extract is performed by a shift left followed by an unsigned shift right; csta and cstb are the shift left and shift right amounts, respectively.</td>
</tr>
<tr>
<td>unsigned _extur (unsigned src2, int src1);</td>
<td>EXTU</td>
<td>Extracts the specified field in src2, zero-extended to 32 bits. The extract is performed by a shift left followed by an unsigned shift right; the shift left and shift right amounts are specified by the lower 10 bits of src1.</td>
</tr>
<tr>
<td>unsigned _ftoi (float src);</td>
<td>Reinterprets the bits in the float as an unsigned. For example: _ftoi(1.0) == 1065353216U</td>
<td></td>
</tr>
<tr>
<td>unsigned _hi (double src);</td>
<td>Returns the high (odd) register of a double register pair</td>
<td></td>
</tr>
<tr>
<td>unsigned _hill (long long src);</td>
<td>Returns the high (odd) register of a long long register pair</td>
<td></td>
</tr>
<tr>
<td>double _ltdod (unsigned src2, unsigned src1);</td>
<td>Builds a new double register pair by reinterpreting two unsigned values, where src2 is the high (odd) register and src1 is the low (even) register</td>
<td></td>
</tr>
<tr>
<td>float _ltof (unsigned src);</td>
<td>Reinterprets the bits in the unsigned as a float. For example: _ltof(0x3F800000) = 1.0</td>
<td></td>
</tr>
<tr>
<td>long long _ltoll (unsigned src2, unsigned src1);</td>
<td>Builds a new long long register pair by reinterpreting two unsigned values, where src2 is the high (odd) register and src1 is the low (even) register</td>
<td></td>
</tr>
<tr>
<td>unsigned _lmbd (unsigned src1, unsigned src2);</td>
<td>LMBD</td>
<td>Searches for a leftmost 1 or 0 of src2 determined by the LSB of src1. Returns the number of bits up to the bit change.</td>
</tr>
<tr>
<td>unsigned _lo (double src);</td>
<td>Returns the low (even) register of a double register pair</td>
<td></td>
</tr>
</tbody>
</table>

(1) See the TMS320C6000 Programmer's Guide for more information.
(2) See Section 7.5.9 for details on manipulating 8-byte data quantities.
### Table 7-4. TMS320C6000 C/C++ Compiler Intrinsics (continued)

<table>
<thead>
<tr>
<th>C/C++ Compiler Intrinsic</th>
<th>Assembly Instruction</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>unsigned _loll (long long src);</td>
<td></td>
<td>Returns the low (even) register of a long long register pair.</td>
</tr>
<tr>
<td>double _lload (___int40_t src);</td>
<td></td>
<td>Reinterprets an ___int40_t register pair src as a double register pair.</td>
</tr>
<tr>
<td>double _lload (long src);</td>
<td></td>
<td>Reinterprets long register pair src as a double register pair.</td>
</tr>
<tr>
<td>int _mpy (int src1, int src2);</td>
<td>MPY</td>
<td>Multiplies the 16 LSBs of src1 by the 16 LSBs of src2 and returns the result. Values can be signed or unsigned.</td>
</tr>
<tr>
<td>int _mpyus (unsigned src1, int src2);</td>
<td>MPYUS</td>
<td>Multiplies the 16 MSBs of src1 by the 16 MSBs of src2 and returns the result. Values can be signed or unsigned.</td>
</tr>
<tr>
<td>int _mpyu (unsigned src1, unsigned src2);</td>
<td>MPYU</td>
<td>Multiplies the 16 MSBs of src1 by the 16 MSBs of src2 and returns the result. Values can be signed or unsigned.</td>
</tr>
<tr>
<td>int _mpyh (int src1, int src2);</td>
<td>MPYH</td>
<td>Multiplies the 16 MSBs of src1 by the 16 MSBs of src2 and returns the result. Values can be signed or unsigned.</td>
</tr>
<tr>
<td>int _mpyhls (unsigned src1, int src2);</td>
<td>MPYHLS</td>
<td>Multiplies the 16 MSBs of src1 by the 16 MSBs of src2 and returns the result. Values can be signed or unsigned.</td>
</tr>
<tr>
<td>int _mpyhu (unsigned src1, unsigned src2);</td>
<td>MPYHU</td>
<td>Multiplies the 16 MSBs of src1 by the 16 MSBs of src2 and returns the result. Values can be signed or unsigned.</td>
</tr>
<tr>
<td>int _mpylhu (int src1, int src2);</td>
<td>MPYLUHS</td>
<td>Generates no code. Tells the optimizer that the expression declared with the assert function is true; this gives a hint to the optimizer as to what optimizations might be valid.</td>
</tr>
<tr>
<td>int _sadd (int src1, int src2);</td>
<td>SADD</td>
<td>Adds src1 to src2 and saturates the result. Returns the result.</td>
</tr>
<tr>
<td>long _lsadd (int src1, __int40_t src2);</td>
<td>SAT</td>
<td>Converts a 40-bit long to a 32-bit signed int and saturates if necessary.</td>
</tr>
<tr>
<td>int _sat (__int40_t src2);</td>
<td>SET</td>
<td>Sets the specified field in src2 to all 1s and returns the src2 value. The beginning and ending bits of the field to be set are specified by csta and cstb, respectively.</td>
</tr>
<tr>
<td>unsigned _set (unsigned src2, unsigned csta , unsigned cstb);</td>
<td>SET</td>
<td>Sets the specified field in src2 to all 1s and returns the src2 value. The beginning and ending bits of the field to be set are specified by the lower ten bits of src1.</td>
</tr>
<tr>
<td>int _smpy (int src1, int src2);</td>
<td>SMPY</td>
<td>Multiplies src1 by src2, left shifts the result by 1, and returns the result. If the result is 0x80000000, saturates the result to 0xFFFFFFF.</td>
</tr>
<tr>
<td>int _smpyh (int src1, int src2);</td>
<td>SMPYH</td>
<td>Multiplies src1 by src2, left shifts the result by 1, and returns the result. If the result is 0x80000000, saturates the result to 0xFFFFFFF.</td>
</tr>
<tr>
<td>int _smpyhl (int src1, int src2);</td>
<td>SMPYHL</td>
<td>Multiplies src1 by src2, left shifts the result by 1, and returns the result. If the result is 0x80000000, saturates the result to 0xFFFFFFF.</td>
</tr>
<tr>
<td>int _sshl (int src2, unsigned src1);</td>
<td>SHL</td>
<td>Shifts src2 left by the contents of src1, saturates the result to 32 bits, and returns the result.</td>
</tr>
<tr>
<td>int _ssub (int src1, int src2);</td>
<td>SSUB</td>
<td>Subtracts src2 from src1, saturates the result, and returns the result.</td>
</tr>
<tr>
<td>__int40_t _issub (int src1, __int40_t src2);</td>
<td>SUBC</td>
<td>Conditional subtract divide step</td>
</tr>
<tr>
<td>unsigned _subc (unsigned src1, unsigned src2);</td>
<td>SUB2</td>
<td>Subtracts the upper and lower halves of src2 from the upper and lower halves of src1, and returns the result. Borrowing in the lower half subtract does not affect the upper half subtract.</td>
</tr>
</tbody>
</table>

The intrinsics listed in Table 7-5 can be used for C6400, C6400+, C6740, and C6600 devices. The intrinsics shown correspond to the indicated C6000 assembly language instruction(s). See the TMS320C6000 CPU and Instruction Set Reference Guide for more information.

See Table 7-4 for the listing of generic C6000 intrinsics. See Table 7-6 for the listing of C6400+, C6740-, and C6600-specific intrinsics. See Table 7-7 for the listing of C6700-specific intrinsics. See Table 7-8 for the listing of C6600-specific intrinsics.
Table 7-5. TMS320C6400, C6400+, C6740, and C6600 C/C++ Compiler Intrinsics

<table>
<thead>
<tr>
<th>C/C++ Compiler Intrinsic</th>
<th>Assembly Instruction</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>int _abs2 (int src);</td>
<td>ABS2</td>
<td>Calculates the absolute value for each 16-bit value</td>
</tr>
<tr>
<td>int _add4 (int src1, int src2);</td>
<td>ADD4</td>
<td>Performs 2s-complement addition to pairs of packed 8-bit numbers</td>
</tr>
<tr>
<td>long long &amp; _amem8 (void *ptr);</td>
<td>LDDW STDW</td>
<td>Allows aligned loads and stores of 8 bytes to memory. The pointer must be aligned to an eight-byte boundary.</td>
</tr>
<tr>
<td>const long &amp; _amem8_const (const void *ptr);</td>
<td>LDDW</td>
<td>Allows aligned loads of 8 bytes from memory. The pointer must be aligned to an eight-byte boundary.</td>
</tr>
<tr>
<td>__float2_t &amp; _amem8_f2(void *ptr);</td>
<td>LDDW STDW</td>
<td>Allows aligned loads of 8 bytes from memory. The pointer must be aligned to an eight-byte boundary. You must include c6x.h.(1)(2)</td>
</tr>
<tr>
<td>double &amp; _amemd8 (void *ptr);</td>
<td>LDDW STDW</td>
<td>Allows aligned loads and stores of 8 bytes to memory. The pointer must be aligned to an eight-byte boundary. For C6400 _amemd8 corresponds to different assembly instructions than when used with other C6000 devices; see Table 7-4.</td>
</tr>
<tr>
<td>const double &amp; _amemd8_const (const void *ptr);</td>
<td>LDDW</td>
<td>Allows aligned loads of 8 bytes from memory. The pointer must be aligned to an eight-byte boundary.</td>
</tr>
<tr>
<td>int _avg2 (int src1, int src2);</td>
<td>AVG2</td>
<td>Calculates the average for each pair of signed 16-bit values</td>
</tr>
<tr>
<td>unsigned _avgu4 (unsigned, unsigned);</td>
<td>AVGU4</td>
<td>Calculates the average for each pair of signed 8-bit values</td>
</tr>
<tr>
<td>unsigned _bitc4 (unsigned src);</td>
<td>BITC4</td>
<td>For each of the 8-bit quantities in src, the number of 1 bits is written to the corresponding position in the return value</td>
</tr>
<tr>
<td>unsigned _bitr (unsigned src);</td>
<td>BITR</td>
<td>Reverses the order of the bits</td>
</tr>
<tr>
<td>int _cmpeq2 (int src1, int src2);</td>
<td>CMPEQ2</td>
<td>Performs equality comparisons on each pair of 16-bit values. Equality results are packed into the two least-significant bits of the return value.</td>
</tr>
<tr>
<td>int _cmpeq4 (int src1, int src2);</td>
<td>CMPEQ4</td>
<td>Performs equality comparisons on each pair of 8-bit values. Equality results are packed into the four least-significant bits of the return value.</td>
</tr>
<tr>
<td>int _cmpgt2 (int src1, int src2);</td>
<td>CMPGT2</td>
<td>Compares each pair of signed 16-bit values. Results are packed into the two least-significant bits of the return value.</td>
</tr>
<tr>
<td>unsigned _cmpgtu4 (unsigned src1, unsigned src2);</td>
<td>CMPGTU4</td>
<td>Compares each pair of 8-bit values. Results are packed into the four least-significant bits of the return value.</td>
</tr>
<tr>
<td>int _cmplt2 (int src1, int src2);</td>
<td>CMPLT2</td>
<td>Swaps operands and calls _cmpgt2.</td>
</tr>
<tr>
<td>unsigned _cmpltu4 (unsigned src1, unsigned src2);</td>
<td>CMPLTU4</td>
<td>Swaps operands and calls _cmpgtu4.</td>
</tr>
<tr>
<td>unsigned _deal (unsigned src);</td>
<td>DEAL</td>
<td>The odd and even bits of src are extracted into two separate 16-bit values.</td>
</tr>
<tr>
<td>int _dotp2 (int src1, int src2);</td>
<td>DOTP2</td>
<td>The product of the signed lower 16-bit values of src1 and src2 is added to the product of the signed upper 16-bit values of src1 and src2. The _lo and _hi intrinsics are needed to access each half of the 64-bit integer result.</td>
</tr>
<tr>
<td>__int40_t _ldotp2 (int src1, int src2);</td>
<td>DOTP2</td>
<td>The product of the signed lower 16-bit values of src1 and src2 is subtracted from the product of the signed upper 16-bit values of src1 and src2.</td>
</tr>
<tr>
<td>int _dotpnrsu2 (int src1, unsigned src2);</td>
<td>DOTPNRSU2</td>
<td>The product of the lower 16-bit values of src1 and src2 is subtracted from the product of the upper 16-bit values of src1 and src2. The values in src1 are treated as signed packed quantities; the values in src2 are treated as unsigned packed quantities. 2^15 is added and the result is sign shifted right by 16.</td>
</tr>
<tr>
<td>int _dotpnrus2 (unsigned src1, int src2);</td>
<td>DOTPNRUS2</td>
<td>Swaps the operands and calls _dotpnrsu2.</td>
</tr>
<tr>
<td>int _doprsu2 (int src1, unsigned src2);</td>
<td>DOTPRS U2</td>
<td>The product of the lower 16-bit values of src1 and src2 is added to the product of the upper 16-bit values of src1 and src2. The values in src1 are treated as signed packed quantities; the values in src2 are treated as unsigned packed quantities. 2^15 is added and the result is sign shifted by 16.</td>
</tr>
</tbody>
</table>

(1) See Section 7.5.9 for details on manipulating 8-byte data quantities.
(2) See the TMS320C6000 Programmer’s Guide for more information.
Table 7-5. TMS320C6400, C6400+, C6740, and C66000 C/C++ Compiler Intrinsics (continued)

<table>
<thead>
<tr>
<th>C++ Compiler Intrinsic</th>
<th>Assembly Instruction</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>int _dotpus4</code> (int src1, unsigned src2);</td>
<td>DOTPUS4</td>
<td>For each pair of 8-bit values in src1 and src2, the 8-bit value from src1 is multiplied with the 8-bit value from src2. The four products are summed together.</td>
</tr>
<tr>
<td><code>int _gmpy4</code> (int src1, int src2);</td>
<td>GMPY4</td>
<td>Performs the Galois Field multiply on four values in src1 with four parallel values in src2. The four products are packed into the return value.</td>
</tr>
<tr>
<td><code>unsigned _dotpu4</code> (unsigned src1, int src2);</td>
<td>DOTPU4</td>
<td></td>
</tr>
<tr>
<td><code>int _max2</code> (int src1, int src2);</td>
<td>MAX2</td>
<td>Places the larger/smaller of each pair of values in the corresponding position in the return value. Values can be 16-bit signed or 8-bit unsigned.</td>
</tr>
<tr>
<td><code>int _min2</code> (int src1, int src2);</td>
<td>MIN2</td>
<td></td>
</tr>
<tr>
<td><code>unsigned _maxu4</code> (unsigned src1, unsigned src2);</td>
<td>MAX4</td>
<td></td>
</tr>
<tr>
<td><code>unsigned _minu4</code> (unsigned src1, unsigned src2);</td>
<td>MINU4</td>
<td></td>
</tr>
<tr>
<td><code>ushort &amp; _mem2</code> (void * ptr);</td>
<td>LDB/LDB</td>
<td>Allows unaligned loads and stores of 2 bytes to memory(2)</td>
</tr>
<tr>
<td><code>const ushort &amp; _mem2_const</code> (const void * ptr);</td>
<td>LDB/LDB</td>
<td>Allows unaligned loads of 2 bytes to memory(2)</td>
</tr>
<tr>
<td><code>unsigned &amp; _mem4</code> (void * ptr);</td>
<td>LDNW STNW</td>
<td>Allows unaligned loads and stores of 4 bytes to memory(2)</td>
</tr>
<tr>
<td><code>const unsigned &amp; _mem4_const</code> (const void * ptr);</td>
<td>LDNW</td>
<td>Allows unaligned loads of 4 bytes from memory(2)</td>
</tr>
<tr>
<td><code>long long &amp; _mem8</code> (void * ptr);</td>
<td>LDNDW STNDW</td>
<td>Allows unaligned loads and stores of 8 bytes to memory(2)</td>
</tr>
<tr>
<td><code>const long long &amp; _mem8_const</code> (const void * ptr);</td>
<td>LDNDW</td>
<td>Allows unaligned loads of 8 bytes from memory(3)</td>
</tr>
<tr>
<td><code>double &amp; _memd8</code> (void * ptr);</td>
<td>LDNDW STNDW</td>
<td>Allows unaligned loads and stores of 8 bytes from memory(8)(3)</td>
</tr>
<tr>
<td><code>const double &amp; _memd8_const</code> (const void * ptr);</td>
<td>LDNDW</td>
<td>Allows unaligned loads of 8 bytes from memory(4)(3)</td>
</tr>
<tr>
<td><code>long long _mpy2ll</code> (int src1, int src2);</td>
<td>MPY2</td>
<td>Returns the products of the lower and higher 16-bit values in src1 and src2</td>
</tr>
<tr>
<td><code>long long _mpyhill</code> (int src1, int src2);</td>
<td>MPYH</td>
<td>Produces a 16 by 32 multiply. The result is placed into the lower 48 bits of the return type. Can use the upper or lower 16 bits of src1.</td>
</tr>
<tr>
<td><code>long long _mpyillll</code> (int src1, int src2);</td>
<td>MPYILL</td>
<td></td>
</tr>
<tr>
<td><code>int _mpyhir</code> (int src1, int src2);</td>
<td>MPPYHIR</td>
<td></td>
</tr>
<tr>
<td><code>int _mpyilr</code> (int src1, int src2);</td>
<td>MPYILR</td>
<td></td>
</tr>
<tr>
<td><code>long long _mpyus4ll</code> (int src1, unsigned src2);</td>
<td>MPYUS4</td>
<td>For each 8-bit quantity in src1 and src2, performs an 8-bit by 8-bit multiply. The four 16-bit results are packed into a 64-bit result. The results can be signed or unsigned.</td>
</tr>
<tr>
<td><code>long long _mpyu4ll</code> (unsigned src1, int src2);</td>
<td>MPPYUS4</td>
<td></td>
</tr>
<tr>
<td><code>long long _mpyu4lil</code> (unsigned src1, unsigned src2);</td>
<td>MPPYU4</td>
<td></td>
</tr>
<tr>
<td><code>int _mvd</code> (int src2);</td>
<td>MVD</td>
<td>Moves the data from src2 to the return value over four cycles using the multiplier pipeline</td>
</tr>
<tr>
<td><code>unsigned _pack2</code> (unsigned src1, unsigned src2);</td>
<td>PACK2</td>
<td></td>
</tr>
<tr>
<td><code>unsigned _packh2</code> (unsigned src1, unsigned src2);</td>
<td>PACKH2</td>
<td>The lower/upper halfwords of src1 and src2 are placed in the return value.</td>
</tr>
<tr>
<td><code>unsigned _packh4</code> (unsigned src1, unsigned src2);</td>
<td>PACKH4</td>
<td>Packs alternate bytes into return value. Can pack high or low bytes.</td>
</tr>
<tr>
<td><code>unsigned _packkl4</code> (unsigned src1, unsigned src2);</td>
<td>PACKKL4</td>
<td></td>
</tr>
<tr>
<td><code>unsigned _rotl</code> (unsigned src1, unsigned src2);</td>
<td>ROTL</td>
<td>Rotates src2 to the left by the amount in src1</td>
</tr>
<tr>
<td><code>int _sadd2</code> (int src1, int src2);</td>
<td>SADD2</td>
<td>Performs saturated addition between pairs of 16-bit values in src1 and src2. Values for src1 can be signed or unsigned.</td>
</tr>
<tr>
<td><code>int _saddus2</code> (unsigned src1, int src2);</td>
<td>SADDS2</td>
<td></td>
</tr>
<tr>
<td><code>int _saddus2</code> (unsigned src1, unsigned src2);</td>
<td>SADDSU2</td>
<td></td>
</tr>
<tr>
<td><code>unsigned _saddu4</code> (unsigned src1, unsigned src2);</td>
<td>SADDU4</td>
<td>Performs saturated addition between pairs of 8-bit unsigned values in src1 and src2.</td>
</tr>
<tr>
<td><code>unsigned _shfl</code> (unsigned src2);</td>
<td>SHFL</td>
<td>The lower 16 bits of src2 are placed in the even bit positions, and the upper 16 bits of src are placed in the odd bit positions.</td>
</tr>
<tr>
<td><code>unsigned _shlb</code> (unsigned src1, unsigned src2);</td>
<td>SHLMB</td>
<td>Shifts src2 left/right by one byte, and the most/least significant byte of src1 is merged into the least/most significant byte position.</td>
</tr>
<tr>
<td><code>unsigned _shrb</code> (unsigned src1, unsigned src2);</td>
<td>SHRMB</td>
<td></td>
</tr>
</tbody>
</table>

(2) See the TMS320C6000 Programmer’s Guide for more information.
(3) See Section 7.5.9 for details on manipulating 8-byte data quantities.
Table 7-5. TMS320C6400+, C6740, and C6600 C/C++ Compiler Intrinsics (continued)

<table>
<thead>
<tr>
<th>C/C++ Compiler Intrinsic</th>
<th>Assembly Instruction</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>int _shr2 (int src1, unsigned src2); unsigned shru2 (unsigned src1, unsigned src2);</td>
<td>SHR2 SHRU2</td>
<td>For each 16-bit quantity in src2, the quantity is arithmetically or logically shifted right by src1 number of bits. src2 can contain signed or unsigned values</td>
</tr>
<tr>
<td>long long _smpy2ll (int src1, int src2);</td>
<td>SMPY2</td>
<td>Performs 16-bit multiplication between pairs of signed packed 16-bit values, with an additional 1 bit left-shift and saturate into a 64-bit result.</td>
</tr>
<tr>
<td>int _spack2 (int src1, int src2);</td>
<td>SPACK2</td>
<td>Two signed 32-bit values are saturated to 16-bit values and packed into the return value</td>
</tr>
<tr>
<td>unsigned _spacku4 (int src1, int src2);</td>
<td>SPACKU4</td>
<td>Four signed 16-bit values are saturated to 8-bit values and packed into the return value</td>
</tr>
<tr>
<td>int _sshvl (int src2, int src1); int _sshvr (int src2, int src1);</td>
<td>SSHVL SHVR</td>
<td>Shifts src2 to the left/right src1 bits. Saturates the result if the shifted value is greater than MAX_INT or less than MIN_INT.</td>
</tr>
<tr>
<td>int _sub4 (int src1, int src2);</td>
<td>SUB4</td>
<td>Performs 2’s-complement subtraction between pairs of packed 8-bit values</td>
</tr>
<tr>
<td>int _subabs4 (int src1, int src2);</td>
<td>SUBABS4</td>
<td>Calculates the absolute value of the differences for each pair of packed 8-bit values</td>
</tr>
<tr>
<td>unsigned _swap4 (unsigned src);</td>
<td>SWAP4</td>
<td>Exchanges pairs of bytes (an endian swap) within each 16-bit value</td>
</tr>
<tr>
<td>unsigned _swap2 (unsigned src);</td>
<td>SWAP2</td>
<td>Calls _packh2.</td>
</tr>
<tr>
<td>unsigned _unpkhu4 (unsigned src);</td>
<td>UNPKHU4</td>
<td>Unpacks the two high unsigned 8-bit values into unsigned packed 16-bit values</td>
</tr>
<tr>
<td>unsigned _unpklu4 (unsigned src);</td>
<td>UNPKLU4</td>
<td>Unpacks the two low unsigned 8-bit values into unsigned packed 16-bit values</td>
</tr>
<tr>
<td>unsigned _xpnd2 (unsigned src);</td>
<td>XPND2</td>
<td>Bits 1 and 0 of src are replicated to the upper and lower halfwords of the result, respectively.</td>
</tr>
<tr>
<td>unsigned _xpnd4 (unsigned src);</td>
<td>XPND4</td>
<td>Bits 3 and 0 of src are replicated to bytes 3 through 0 of the result.</td>
</tr>
</tbody>
</table>

The intrinsics listed in Table 7-6 are included only for C6400+, C6740, and C6600 devices. The intrinsics shown correspond to the indicated C6000 assembly language instruction(s). See the TMS320C6000 CPU and Instruction Set Reference Guide for more information.

See Table 7-4 for the listing of generic C6000 intrinsics. See Table 7-5 for the general listing of intrinsics for C6400 devices, which includes C6400, C6400+, C6740 and C6600. See Table 7-7 for the listing of C6700-specific intrinsics. See Table 7-8 for a listing of additional intrinsics only for C6600.

Table 7-6. TMS320C6400+, C6740, and C6600 C/C++ Compiler Intrinsics

<table>
<thead>
<tr>
<th>C/C++ Compiler Intrinsic</th>
<th>Assembly Instruction</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>long long _addsdb (int src1, int src2);</td>
<td>ADDSDB</td>
<td>Performs an addition and subtraction in parallel.</td>
</tr>
<tr>
<td>long long _addsdb2 (int src1, int src2);</td>
<td>ADDSDB2</td>
<td>Performs an ADD2 and SUB2 in parallel.</td>
</tr>
<tr>
<td>long long _cmpy (unsigned src1, unsigned src2); unsigned _cmpyr (unsigned src1, unsigned src2); unsigned _cmpyr1 (unsigned src1, unsigned src2);</td>
<td>CMPY CMPYR CMPYR1</td>
<td>Performs various complex multiply operations.</td>
</tr>
<tr>
<td>long long _ddotp4 (unsigned src1, unsigned src2);</td>
<td>DDOTP4</td>
<td>Performs two DOTP2 operations simultaneously.</td>
</tr>
<tr>
<td>long long _ddotph2 (long long src1, unsigned src2); long long _ddotpl2 (long long src1, unsigned src2); unsigned _ddotph2r (long long src1, unsigned src2); unsigned _ddotpl2r (long long src1, unsigned src2);</td>
<td>DDOTPH2 DDOTPL2 DDOTPH2R DDOTPL2</td>
<td>Performs various dual dot-product operations between two pairs of signed, packed 16-bit values.</td>
</tr>
<tr>
<td>long long _dmv (int src1, int src2);</td>
<td>DMV</td>
<td>Places src1 in the 32 LSBs of the long and src2 in the 32 MSBs of the long long. See also __iitol().</td>
</tr>
<tr>
<td>long long _dpack2 (unsigned src1, unsigned src2);</td>
<td>DPACK2</td>
<td>PACK2 and PACKH2 operations performed in parallel.</td>
</tr>
<tr>
<td>long long _dpackx2 (unsigned src1, unsigned src2);</td>
<td>DPACKX2</td>
<td>PACKLH2 and PACKX2 operations performed in parallel.</td>
</tr>
<tr>
<td>__float2_t _fmdv_f2 (float src1, float src2)</td>
<td>DMV</td>
<td>Places src1 in the 32 LSBs of the __float2_t and src2 in the 32 MSBs of the __float2_t. See also __iitol().</td>
</tr>
<tr>
<td>C++ Compiler Intrinsic</td>
<td>Assembly Instruction</td>
<td>Description</td>
</tr>
<tr>
<td>------------------------</td>
<td>----------------------</td>
<td>-------------</td>
</tr>
<tr>
<td>unsigned _gmpy (unsigned src1, unsigned src2);</td>
<td>GMPY</td>
<td>Performs the Galois Field multiply.</td>
</tr>
<tr>
<td>long long _mpy2ir (int src1, int src2);</td>
<td>MPY2IR</td>
<td>Performs two 16 by 32 multiplies. Both results are shifted right by 15 bits to produce a rounded result.</td>
</tr>
<tr>
<td>int _mpy32 (int src1, int src2);</td>
<td>MPY32</td>
<td>Returns the 32 LSBs of a 32 by 32 multiply.</td>
</tr>
<tr>
<td>long long _mpy32ll (int src1, int src2);</td>
<td>MPY32SU</td>
<td>Returns all 64 bits of a 32 by 32 multiply. Values can be signed or unsigned.</td>
</tr>
<tr>
<td>int _mpy32 (int src1, int src2);</td>
<td>MPY32US</td>
<td>Returns the 32 LSBs of a 32 by 32 multiply.</td>
</tr>
<tr>
<td>long long _mpy32u (unsigned src1, unsigned src2);</td>
<td>MPY32US</td>
<td>Returns the 32 LSBs of a 32 by 32 multiply.</td>
</tr>
<tr>
<td>long long _mpy32us (int src1, int src2);</td>
<td>MPY32U</td>
<td>Returns the 32 LSBs of a 32 by 32 multiply.</td>
</tr>
<tr>
<td>long long _mpy32su (int src1, int src2);</td>
<td>MPY32U</td>
<td>Returns the 32 LSBs of a 32 by 32 multiply.</td>
</tr>
<tr>
<td>int _rpack2 (int src1, int src2);</td>
<td>RPACK2</td>
<td>Shifts src1 and src2 left by 1 with saturation. The 16 MSBs of the shifted src1 is placed in the 16 MSBs of the long long. The 16 MSBs of the shifted src2 is placed in the 16 LSBs of the long long.</td>
</tr>
<tr>
<td>long long _saddsub (unsigned src1, unsigned src2);</td>
<td>SADDSUB</td>
<td>Performs a saturated addition and a saturated subtraction in parallel.</td>
</tr>
<tr>
<td>long long _saddsub2 (unsigned src1, unsigned src2);</td>
<td>SADDSUB2</td>
<td>Performs a SADD2 and a SSUB2 in parallel.</td>
</tr>
<tr>
<td>long long _shfl3 (unsigned src1, unsigned src2);</td>
<td>SHFL3</td>
<td>Takes two 16-bit values from src1 and 16 LSBs from src2 to perform a 3-way interleave, creating a 48-bit result.</td>
</tr>
<tr>
<td>int _smpy32 (int src1, int src2);</td>
<td>SMPY32</td>
<td>Returns the 32 MSBs of a 32 by 32 multiply shifted left by 1.</td>
</tr>
<tr>
<td>int _ssub2 (unsigned src1, unsigned src2);</td>
<td>SSUB2</td>
<td>Subtracts the upper and lower halves of src2 from the upper and lower halves of src1 and saturates each result.</td>
</tr>
<tr>
<td>unsigned _xormpy (unsigned src1, unsigned src2);</td>
<td>XORMPY</td>
<td>Performs a Galois Field multiply</td>
</tr>
</tbody>
</table>

The intrinsics listed in Table 7-7 can be used for C6700, C6700+, C6740, and C6600 devices. The intrinsics shown correspond to the indicated C6000 assembly language instruction(s). See the TMS320C6000 CPU and Instruction Set Reference Guide for more information.

See Table 7-4 for the listing of generic C6000 intrinsics. See Table 7-5 for the listing of C6400-specific intrinsics, which are also compatible with C6400+, C6740 and C6600. See Table 7-6 for the listing of C6400+-specific intrinsics, which are also compatible with C6740 and C6600 devices. See Table 7-8 for the listing of C6600-specific intrinsics.

### Table 7-7. TMS320C6700, C6700+, C6740, and C6600 C/C++ Compiler Intrinsics

<table>
<thead>
<tr>
<th>C++ Compiler Intrinsic</th>
<th>Assembly Instruction</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>int _dpint (double src);</td>
<td>DPINT</td>
<td>Converts 64-bit double to 32-bit signed integer, using the rounding mode set by the CSR register.</td>
</tr>
<tr>
<td>__int40_t _f2tol(__float2_t src);</td>
<td>Reinterprets a __float2_t register pair src as an __int40_t (stored as a register pair). You must include c6x.h.</td>
<td></td>
</tr>
<tr>
<td>__float2_t _f2toll(__int40_t src);</td>
<td>Reinterprets an __int40_t register pair as a __float2_t register pair. You must include c6x.h.</td>
<td></td>
</tr>
<tr>
<td>double __fabs (double src); float __fabsf (float src);</td>
<td>ABSDP ABSSP</td>
<td>Returns absolute value of src.</td>
</tr>
<tr>
<td>__float2_t _lltof2(long long src);</td>
<td>Reinterprets a long long register pair as a __float2_t register pair. You must include c6x.h.</td>
<td></td>
</tr>
<tr>
<td>__float2_t _ltol2(__int40_t src);</td>
<td>Reinterprets an __int40_t register pair as a __float2_t register pair. You must include c6x.h.</td>
<td></td>
</tr>
<tr>
<td>__float2_t &amp; _mem8_f2(void * ptf);</td>
<td>LDNDW STNDW</td>
<td>Allows unaligned loads and stores of 8 bytes to memory.</td>
</tr>
<tr>
<td>const __float2_t &amp; _mem8_f2 const(void * ptf);</td>
<td>LDNDW STNDW</td>
<td>Allows unaligned loads of 8 bytes from memory.</td>
</tr>
<tr>
<td>long long _mpyidll (int src1, int src2);</td>
<td>MPYID</td>
<td>Produces a signed integer multiply. The result is placed in a register pair.</td>
</tr>
</tbody>
</table>

(1) See the TMS320C6000 Programmer's Guide for more information.
### Table 7-7. TMS320C6700, C6700+, C6740, and C6600 C/C++ Compiler Intrinsics (continued)

<table>
<thead>
<tr>
<th>C++/Compiler Intrinsic</th>
<th>Assembly Instruction</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>double_mpysp2dp(float src1, float src2);</td>
<td>MPYSP2DP</td>
<td>(C6700+, C6740, and C6600 only) Produces a double-precision floating-point multiply. The result is placed in a register pair.</td>
</tr>
<tr>
<td>double_mpyspdp(float src1, double src2);</td>
<td>MPYSPDP</td>
<td>(C6700+, C6740, and C6600 only) Produces a double-precision floating-point multiply. The result is placed in a register pair.</td>
</tr>
<tr>
<td>double_rcpdp(double src);</td>
<td>RCPDP</td>
<td>Computes the approximate 64-bit double reciprocal</td>
</tr>
<tr>
<td>float_rcpsp(float src);</td>
<td>RCPSP</td>
<td>Computes the approximate 32-bit float reciprocal</td>
</tr>
<tr>
<td>double_rsqrdp(double src);</td>
<td>RSQRDP</td>
<td>Computes the approximate 64-bit double square root reciprocal</td>
</tr>
<tr>
<td>float_rsqrsp(float src);</td>
<td>RSQRSP</td>
<td>Computes the approximate 32-bit float square root reciprocal</td>
</tr>
<tr>
<td>int_spint(float);</td>
<td>SPIINT</td>
<td>Converts 32-bit float to 32-bit signed integer, using the rounding mode set by the CSR register</td>
</tr>
</tbody>
</table>

The intrinsics listed in Table 7-8 are included only for C6600 devices. These intrinsics are in addition to those listed in Table 7-5 and Table 7-6. The intrinsics shown correspond to the indicated C6000 assembly language instruction(s). See the TMS320C6000 CPU and Instruction Set Reference Guide for more information.

See Table 7-4 for the listing of generic C6000 intrinsics. See Table 7-5 for the listing of C6400-specific intrinsics, which are also compatible with C6400+, C6740 and C6600. See Table 7-6 for the listing of C6400+-specific intrinsics, which are also compatible with C6740 and C6600 devices. See Table 7-7 for the listing of C6700-specific intrinsics.

### Table 7-8. TMS320C6600 C/C++ Compiler Intrinsics

<table>
<thead>
<tr>
<th>C++/Compiler Intrinsic</th>
<th>Assembly Instruction</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ADDDP</td>
<td>No intrinsic. Use native C: ( a + b ) where ( a ) and ( b ) are doubles</td>
<td></td>
</tr>
<tr>
<td>ADDSP</td>
<td>No intrinsic. Use native C: ( a + b ) where ( a ) and ( b ) are floats.</td>
<td></td>
</tr>
<tr>
<td>AND</td>
<td>No intrinsic: Use native C: ( \text{&quot;}a \text{&amp; } b\text{&quot;} ) where ( a ) and ( b ) are long longs</td>
<td></td>
</tr>
<tr>
<td>ANDN</td>
<td>No intrinsic: Use native C: ( \text{&quot;}a \text{&amp; } \sim{b}\text{&quot;} ) where ( a ) and ( b ) are long longs</td>
<td></td>
</tr>
<tr>
<td>MPYSP</td>
<td>No intrinsic. Use native C: ( \text{&quot;}a \text{&amp; } b\text{&quot;} ) where ( a ) and ( b ) are doubles</td>
<td></td>
</tr>
<tr>
<td>OR</td>
<td>No intrinsic: Use native C: ( \text{&quot;}a \text{&amp; } b\text{&quot;} ) where ( a ) and ( b ) are long longs</td>
<td></td>
</tr>
<tr>
<td>SUBDP</td>
<td>No intrinsic. Use native C: ( a \text{ - } b ) where ( a ) and ( b ) are doubles</td>
<td></td>
</tr>
<tr>
<td>SUBSP</td>
<td>No intrinsic. Use native C: ( a \text{ - } b ) where ( a ) and ( b ) are floats</td>
<td></td>
</tr>
<tr>
<td>XOR</td>
<td>No intrinsic: Use native C: ( \text{&quot;}a \text{&amp; } b\text{&quot;} ) where ( a ) and ( b ) are long longs. See also _xor_ll_c().</td>
<td></td>
</tr>
<tr>
<td>__x128_t_ccmatmpy(long long src1, __x128_t src2);</td>
<td>CMATMPY</td>
<td>Multiply the conjugate of 1x2 complex vector by a 2x2 complex matrix, producing two 64-bit results.</td>
</tr>
<tr>
<td>long long_ccmatmpy_r1(long long src1, __x128_t src2);</td>
<td>CCMATMPYR1</td>
<td>Multiply the complex conjugate of a 1x2 complex vector by a 2x2 complex matrix, producing two 32-bit complex results.</td>
</tr>
<tr>
<td>long long_ccmpe_r1(long long src1, long long src2);</td>
<td>CCPYE_R1</td>
<td>32-bit complex conjugate multiply of Q31 numbers with rounding</td>
</tr>
<tr>
<td>__x128_t_cmatmpy(long long src1, __x128_t src2);</td>
<td>CMATMPY</td>
<td>Multiply a 1x2 vector by a 2x2 complex matrix, producing two 64-bit complex results.</td>
</tr>
<tr>
<td>long long_cmatmpy_r1(long long src1, __x128_t src2);</td>
<td>CMATMPYR1</td>
<td>Multiply a 1x2 complex vector by a 2x2 complex matrix, producing two 32-bit complex results.</td>
</tr>
<tr>
<td>long long_cmy32_r1(long long src1, long long src2);</td>
<td>CMPYE_R1</td>
<td>32-bit complex multiply of Q31 numbers with rounding</td>
</tr>
<tr>
<td>__x128_t_cmypsp(__float2_t src1, __float2_t src2);</td>
<td>CMPYPSP</td>
<td>Perform the multiply operations for a complex multiply of two complex numbers (See also _complex_mpysp and _complex_conjugate_mpysp.)</td>
</tr>
</tbody>
</table>
Table 7-8. TMS320C6600 C/C++ Compiler Intrinsics (continued)

<table>
<thead>
<tr>
<th>C/C++ Compiler Intrinsic</th>
<th>Assembly Instruction</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>double _complex_conjugate_mpsyp (double src1, double src2);</td>
<td>CMPYSP DSUBSP</td>
<td>Performs a complex conjugate multiply by performing a CMPYSP and DSUBSP</td>
</tr>
<tr>
<td>double _complex_mpsyp (double src1, double src2);</td>
<td>CMPYSP DADDSP</td>
<td>Performs a complex multiply by performing a CMPYSP and DADDSP</td>
</tr>
<tr>
<td>int _crotr90 (int src);</td>
<td>CROT90</td>
<td>Rotate complex number by 90 degrees</td>
</tr>
<tr>
<td>int _crotr270 (int src);</td>
<td>CROT270</td>
<td>Rotate complex number by 270 degrees</td>
</tr>
<tr>
<td>long long _dadd (long long src1, long long src2);</td>
<td>DADD</td>
<td>Two-way SIMD addition of signed 32-bit values producing two signed 32-bit results.</td>
</tr>
<tr>
<td>long long _dadd2 (long long src1, long long src2);</td>
<td>DADD2</td>
<td>Four-way SIMD addition of signed 16-bit values producing four signed 32-bit results. (Two-way _add2)</td>
</tr>
<tr>
<td>__float2_t _daddsp (__float2_t src1, __float2_t src2);</td>
<td>DADDSP</td>
<td>Two-way SIMD addition of 32-bit single precision numbers</td>
</tr>
<tr>
<td>long long _dadd_c (scst5 immediate src1, long long src2);</td>
<td>DADD</td>
<td>Use the sign bit of src1 to determine whether to multiply the four 16-bit values in src2 by 1 or -1. Yields four signed 16-bit results. (If src1 and src2 are the same register pair, it is equivalent to a two-way _abs2).</td>
</tr>
<tr>
<td>long long _dappys2 (long long src1, long long src2);</td>
<td>DAPYS2</td>
<td>Conversion of two packed signed 16-bit values into two single-precision floating point values</td>
</tr>
<tr>
<td>long long _davgu4 (long long src1, long long src2);</td>
<td>DAVGU4</td>
<td>Two-way SIMD addition of 32-bit single precision numbers</td>
</tr>
<tr>
<td>long long _davgnr2 (long long src1, long long src2);</td>
<td>DAVGNR2</td>
<td>Four-way SIMD average of signed 16-bit values, with rounding. (Two-way _avg2)</td>
</tr>
<tr>
<td>long long _davgnru4 (long long src1, long long src2);</td>
<td>DAVGNRU4</td>
<td>Eight-way SIMD average of signed 16-bit values, without rounding</td>
</tr>
<tr>
<td>long long _davgu4 (long long src1, long long src2);</td>
<td>DAVGU4</td>
<td>Eight-way SIMD average of unsigned 8-bit values, without rounding</td>
</tr>
<tr>
<td>long long _dccmpyr1 (long long src1, long long src2);</td>
<td>DCCMPYR1</td>
<td>Two-way SIMD complex multiply with rounding (_ccmpyr1) with complex conjugate of src2</td>
</tr>
<tr>
<td>unsigned _dcmpeq2 (long long src1, long long src2);</td>
<td>DCMPEQ2</td>
<td>Eight-way SIMD comparison of signed 16-bit values. Results are packed into the four least-significant bits of the return value. (Two-way _cmpeq2)</td>
</tr>
<tr>
<td>unsigned _dcmpeq4 (long long src1, long long src2);</td>
<td>DCMPEQ4</td>
<td>Eight-way SIMD comparison of signed 16-bit values. Results are packed into the four least-significant bits of the return value. (Two-way _cmpeq4)</td>
</tr>
<tr>
<td>unsigned _dcmpgt2 (long long src1, long long src2);</td>
<td>DCMPT2</td>
<td>Four-way SIMD comparison of signed 16-bit values. Results are packed into the four least-significant bits of the return value. (Two-way _cmpgt2)</td>
</tr>
<tr>
<td>unsigned _dcmpgtu4 (long long src1, long long src2);</td>
<td>DCMPTU4</td>
<td>Eight-way SIMD comparison of unsigned 8-bit values. Results are packed into the four least-significant bits of the return value. (Two-way _cmpgtu4)</td>
</tr>
<tr>
<td>__x128_t _dccmpy (long long src1, long long src2);</td>
<td>DCCMPY</td>
<td>Two complex multiply operations on two sets of packed complex numbers, with complex conjugate of src2</td>
</tr>
<tr>
<td>__x128_t _dcmpy (long long src1, long long src2);</td>
<td>DCMPT</td>
<td>Performs two complex multiply operations on two sets of packed complex numbers. (Two-way SIMD _cmpy)</td>
</tr>
<tr>
<td>long long _dcmpyr1 (long long src1, long long src2);</td>
<td>DCMPT1</td>
<td>Two-way SIMD complex multiply with rounding (_ccmpyr1)</td>
</tr>
<tr>
<td>long long _dcrotr90 (long long src);</td>
<td>DCROT90</td>
<td>Two-way SIMD version of _crotr90</td>
</tr>
<tr>
<td>long long _dcrot270 (long long src);</td>
<td>DCROT270</td>
<td>Two-way SIMD version of _crotr270</td>
</tr>
<tr>
<td>long long _ddot4h (__x128_t src1, __x128_t src2);</td>
<td>DDOTP4H</td>
<td>Performs two dot-products between four sets of packed 16-bit values. (Two-way _dotp4h)</td>
</tr>
<tr>
<td>long long _ddotp4u (__x128_t src1, __x128_t src2);</td>
<td>DDOTU4H</td>
<td>Performs two dot-products between four sets of packed 16-bit values. (Two-way _dotp4u)</td>
</tr>
<tr>
<td>__float2_t _dinthsp (int src);</td>
<td>DINTHSP</td>
<td>Converts two packed signed 16-bit values into two single-precision floating point values</td>
</tr>
<tr>
<td>__float2_t _dinthspu (unsigned src);</td>
<td>DINTHSPU</td>
<td>Converts two packed unsigned 16-bit values into two single-precision float point values</td>
</tr>
</tbody>
</table>
### Table 7-8. TMS320C6600 C/C++ Compiler Intrinsics (continued)

<table>
<thead>
<tr>
<th>C/C++ Compiler Intrinsic</th>
<th>Assembly Instruction</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>__float2_t _dintsp(long src);</td>
<td>DINTSP</td>
<td>Converts two 32-bit signed integers to two single-precision float point values.</td>
</tr>
<tr>
<td>__float2_t _dintspu(long src);</td>
<td>DINTSPU</td>
<td>Converts two 32-bit unsigned integers to two single-precision float point values.</td>
</tr>
<tr>
<td>long _dmax2 (long src1, long src2);</td>
<td>DMAX2</td>
<td>Four-way SIMD maximum of 16-bit signed values producing four signed 16-bit results. (Two-way _max2)</td>
</tr>
<tr>
<td>long _dmaxu4 (long src1, long src2);</td>
<td>DMAXU4</td>
<td>8-way SIMD maximum of unsigned 8-bit values producing eight unsigned 8-bit results. (Two-way _maxu4)</td>
</tr>
<tr>
<td>long _dmin2 (long src1, long src2);</td>
<td>DMIN2</td>
<td>Four-way SIMD minimum of 16-bit values producing four signed 16-bit results. (Two-way _min2)</td>
</tr>
<tr>
<td>long _dminu4 (long src1, long src2);</td>
<td>DMINU4</td>
<td>8-way SIMD minimum of unsigned 8-bit values producing eight unsigned 8-bit results. (Two-way _minu4)</td>
</tr>
<tr>
<td>__x128_t _dmpy2 (long src1, long src2);</td>
<td>DMPY2</td>
<td>Four-way SIMD multiply of signed 16-bit values producing four signed 32-bit results. (Two-way _mpy2)</td>
</tr>
<tr>
<td>__float2_t _dmpysp (__float2_t src1, __float2_t src2);</td>
<td>DMPYSP</td>
<td>Two-way single precision floating point multiply producing two single-precision results</td>
</tr>
<tr>
<td>__x128_t _dmpysu4 (long src1, long src2);</td>
<td>DMPYSU4</td>
<td>Eight-way SIMD multiply of signed 8-bit values by unsigned 8-bit producing eight signed 16-bit results. (Two-way _mpysu4)</td>
</tr>
<tr>
<td>__x128_t _dmpyu2 (long src1, long src2);</td>
<td>DMPYU2</td>
<td>Four-way SIMD multiply of unsigned 16-bit values producing four unsigned 32-bit results. (Two-way _mpyu2)</td>
</tr>
<tr>
<td>__x128_t _dmpyu4 (long src1, long src2);</td>
<td>DMPYU4</td>
<td>Eight-way SIMD multiply of signed 8-bit values producing eight signed 16-bit results. (Two-way _mpyu4)</td>
</tr>
<tr>
<td>long _dmvd (long src1, unsigned src2);</td>
<td>DMVD</td>
<td>Places src1 in the low register of the long long src2 in the high register of the long long. Takes four cycles. See also _dmv(), _dmv_f12, and _itoll().</td>
</tr>
<tr>
<td>int _dotp4h (long src1, long src2);</td>
<td>DDOTP4H</td>
<td>Multiply two sets of four signed 16-bit values and return the 32-bit sum.</td>
</tr>
<tr>
<td>long _dotp4hl (long src1, long src2);</td>
<td>DOTP4H</td>
<td>Multiply two sets of four signed 16-bit values and return the 64-bit sum.</td>
</tr>
<tr>
<td>int _dopsh4h (long src1, long src2);</td>
<td>DOTPSU4H</td>
<td>Multiply four signed 16-bit values by four unsigned 16-bit values and return the 32-bit sum.</td>
</tr>
<tr>
<td>long _dpsu4hl (long src1, long src2);</td>
<td>DOTPSU4H</td>
<td>Multiply four signed 16-bit values by four unsigned 16-bit values and return the 64-bit sum.</td>
</tr>
<tr>
<td>long _dpackh2 (long src1, long src2);</td>
<td>DPACKH2</td>
<td>Two-way _packh2</td>
</tr>
<tr>
<td>long _dpackh4 (long src1, long src2);</td>
<td>DPACKH4</td>
<td>Two-way _packh4</td>
</tr>
<tr>
<td>long _dpacklh2 (long src1, long src2);</td>
<td>DPACKLH2</td>
<td>Two-way _packlh2</td>
</tr>
<tr>
<td>long _dpacklh4 (unsigned src1, unsigned src2);</td>
<td>DPACKLH4</td>
<td>Performs a _pack4 and a _packh4. The output of the _packlh4 is in the low register of the result and the output of the _packh4 is in the high register of the result.</td>
</tr>
<tr>
<td>long _dpackl2 (long src1, long src2);</td>
<td>DPACKL2</td>
<td>Two-way _packl2</td>
</tr>
<tr>
<td>long _dpackl4 (long src1, long src2);</td>
<td>DPACKL4</td>
<td>Two-way _packl4</td>
</tr>
<tr>
<td>long _dsadd (long src1, long src2);</td>
<td>DSADD</td>
<td>Two-way SIMD saturated addition of signed 32-bit values producing two signed 32-bit results. (Two-way _sadd)</td>
</tr>
<tr>
<td>long _dsadd2 (long src1, long src2);</td>
<td>DSADD2</td>
<td>Four-way SIMD saturated addition of signed 16-bit values producing four signed 16-bit results. (Two-way _sadd2)</td>
</tr>
<tr>
<td>long _dshl (long src1, unsigned src2);</td>
<td>DSHL</td>
<td>Shift-left of two signed 32-bit values by a single value in the src2 argument.</td>
</tr>
<tr>
<td>long _dshl2 (long src1, unsigned src2);</td>
<td>DSHL2</td>
<td>Shift-left of four signed 16-bit values by a single value in the src2 argument. (Two-way _shl2)</td>
</tr>
<tr>
<td>long _dshr (long src1, unsigned src2);</td>
<td>DSHR</td>
<td>Shift-right of two signed 32-bit values by a single value in the src2 argument.</td>
</tr>
<tr>
<td>long _dshr2 (long src1, unsigned src2);</td>
<td>DSHR2</td>
<td>Shift-right of four signed 16-bit values by a single value in the src2 argument. (Two-way _shr2)</td>
</tr>
<tr>
<td>C/C++ Compiler Intrinsic</td>
<td>Assembly Instruction</td>
<td>Description</td>
</tr>
<tr>
<td>-------------------------</td>
<td>----------------------</td>
<td>-------------</td>
</tr>
<tr>
<td>long long _dshr(u) (long long src1, unsigned src2);</td>
<td>DSHRU</td>
<td>Shift-right of two unsigned 32-bit values by a single value in the src2 argument.</td>
</tr>
<tr>
<td>long long _dshr2(u) (long long src1, unsigned src2);</td>
<td>DSHRU2</td>
<td>Shift-right of four unsigned 16-bit values by a single value in the src2 argument. (Two-way _shru2)</td>
</tr>
<tr>
<td>__x128_t dsmpy2 (long long src1, long long src2);</td>
<td>DSMPY2</td>
<td>Four-way SIMD multiply of signed 16-bit values with 1-bit left-shift and saturate producing four signed 32-bit results. (Two-way _smpy2)</td>
</tr>
<tr>
<td>long long _dspacku4 (long long src1, long long src2);</td>
<td>DSPACKU4</td>
<td>Two-way _spacku4</td>
</tr>
<tr>
<td>long long _dspint (__float2_t src);</td>
<td>DSPINT</td>
<td>Converts two packed single-precision floating point values to two signed 32-bit values</td>
</tr>
<tr>
<td>unsigned _dspinth (__float2_t src);</td>
<td>DSPINTH</td>
<td>Converts two packed single-precision floating point values to two packed signed 16-bit values</td>
</tr>
<tr>
<td>long long _dssub (long long src1, long long src2);</td>
<td>DSSUB</td>
<td>Two-way SIMD saturated subtraction of 32-bit signed values producing two signed 32-bit results.</td>
</tr>
<tr>
<td>long long _dssub2 (long long src1, long long src2);</td>
<td>DSSUB2</td>
<td>Four-way SIMD saturated subtraction of signed 16-bit values producing four signed 16-bit results. (Two-way _ssub2)</td>
</tr>
<tr>
<td>long long _dsu(b) (long long src1, long long src2);</td>
<td>DSUB</td>
<td>Two-way SIMD subtraction of 32-bit signed values producing two signed 32-bit results.</td>
</tr>
<tr>
<td>long long _dsu(b)2 (long long src1, long long src2);</td>
<td>DSUB2</td>
<td>Four-way SIMD subtraction of signed 16-bit values producing four signed 16-bit results. (Two-way _sub2)</td>
</tr>
<tr>
<td>__float2_t _dsu(b)sp (__float2_t src1, __float2_t src2);</td>
<td>DSUBSP</td>
<td>Two-way SIMD subtraction of 32-bit single precision numbers</td>
</tr>
<tr>
<td>long long _dxpnd2 (unsigned src);</td>
<td>DXPND2</td>
<td>Expand four lower bits to four 16-bit fields.</td>
</tr>
<tr>
<td>long long _dxpnd4 (unsigned src);</td>
<td>DXPND4</td>
<td>Expand eight lower bits to eight 8-bit fields.</td>
</tr>
<tr>
<td>__float2_t _dxmvd_f2(float src1, float src2);</td>
<td>DMVD</td>
<td>Places src1 in the low register of the __float2_t and src2 in the high register of the __float2_t. Takes four cycles. See also _dvm(), _dmvd(), and _itoll(). You must include c6x.h.</td>
</tr>
<tr>
<td>int _land (int src1, int src2);</td>
<td>LAND</td>
<td>Logical AND of src1 and src2</td>
</tr>
<tr>
<td>int _landn (int src1, int src2);</td>
<td>LANDN</td>
<td>Logical AND of src1 and NOT of src2; i.e. src1 AND ~src2</td>
</tr>
<tr>
<td>int _lor (int src1, int src2);</td>
<td>LOR</td>
<td>Logical OR of src1 and src2</td>
</tr>
<tr>
<td>void _mfence();</td>
<td>MFENCE</td>
<td>Stall CPU while memory system is busy</td>
</tr>
<tr>
<td>double mpysp2dp (float src1, float src2);</td>
<td>MPYSP2DP</td>
<td>(C6600 and C6700+ only) Produces a double-precision floating-point multiply. The result is placed in a register pair.</td>
</tr>
<tr>
<td>double mpyspdp (float src1, double src2);</td>
<td>MPYSPDP</td>
<td>(C6600 and C6700+ only) Produces a double-precision floating-point multiply. The result is placed in a register pair.</td>
</tr>
<tr>
<td>long long _mpyu2 (unsigned src1, unsigned src2);</td>
<td>MPYU2</td>
<td>Two-way SIMD multiply of unsigned 16-bit values producing two signed 32-bit results.</td>
</tr>
<tr>
<td>__x128_t qmpy32 (__x128_t src1, __x128_t src2);</td>
<td>QMPY32</td>
<td>Four-way SIMD multiply of signed 32-bit values producing four 32-bit results. (Four-way _mpy32)</td>
</tr>
<tr>
<td>__x128_t qmpysp (__x128_t src1, __x128_t src2);</td>
<td>QMPYSP</td>
<td>Four-way SIMD 32-bit single precision multiply producing four 32-bit single precision results</td>
</tr>
<tr>
<td>__x128_t qspmpy32r1 (__x128_t src1, __x128_t src2);</td>
<td>QSPMPY32R1</td>
<td>4-way SIMD fractional 32-bit by 32-bit multiply where each result value is shifted right by 31 bits and rounded. This normalizes the result to lie within -1 and 1 in a Q31 fractional number system.</td>
</tr>
<tr>
<td>unsigned _shl2 (unsigned src1, unsigned src2);</td>
<td>SHL2</td>
<td>Shift-left of two signed 16-bit values by a single value in the src2 argument.</td>
</tr>
<tr>
<td>long long unpkbu4 (unsigned src);</td>
<td>UNPKBU4</td>
<td>Unpack four signed 8-bit values into four signed 16-bit values. (See also _unpklu4 and _unpkhu4)</td>
</tr>
<tr>
<td>long long unpkhu2 (unsigned src);</td>
<td>UNPKH2</td>
<td>Unpack two signed 16-bit values to two signed 32-bit values</td>
</tr>
</tbody>
</table>
Table 7-8. TMS320C6600 C/C++ Compiler Intrinsic (continued)

<table>
<thead>
<tr>
<th>C/C++ Compiler Intrinsic</th>
<th>Assembly Instruction</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>long long _unpkhu2 (unsigned src);</td>
<td>UNPKHU2</td>
<td>Unpack two unsigned 16-bit values to two unsigned 32-bit values</td>
</tr>
<tr>
<td>long long _xorll_c (scst5 immediate src1, long long src2);</td>
<td>XOR</td>
<td>XOR src1 with the upper and lower 32-bit portions of src2 (SIMD XOR by constant)</td>
</tr>
</tbody>
</table>

For details on the __x128_t container type see Section 7.5.6.
7.5.6 The __x128_t Container Type

The __x128_t container type is for storing 128-bits of data and its use is necessary when performing certain SIMD operations on C6600. This type can only be used when compiling for C6600. Also, note the leading double underscore. When using the __x128_t container type, you must include c6x.h.

This type can be used to define objects that can be used with certain C6600 intrinsics. (See Table 7-8.) The object can be filled and manipulated using various intrinsics. The type is not a full-fledged built-in type (like long long), and so various native C operations are not allowed. Think of this type as a struct with private members and special manipulation functions.

When the compiler puts a __x128_t object in the register file, the __x128_t object takes four registers (a register quad).

Objects of type __x128_t are aligned to a 128-bit boundary in memory.

The following operations are supported:

- Declare a __x128_t global object (for example: __x128_t a;). By default, it will be put in the .far section.
- Declare a __x128_t local object (for example: __x128_t a). It will be put on the stack.
- Declare a __x128_t global/local pointer (for example: __x128_t *a;).
- Declare an array of __x128_t objects (for example: __x128_t a[10]).
- Declare a __x128_t type as a member of a struct, class, or union.
- Assign a __x128_t object to another __x128_t object.
- Pass a __x128_t object to a function (including variadic argument functions). (Pass by value.)
- Return a __x128_t object from a function.
- Use 128-bit manipulation intrinsics to set and extract contents (see Table 7-9).

The following operations are not supported:

- Native-type operations on __x128_t objects, such as +, -, *, etc.
- Cast an object to a __x128_t type.
- Access the elements of a __x128_t using array or struct notation.
- Pass a __x128_t object to I/O functions like printf. Instead, extract the values from the __x128_t object by using appropriate intrinsics.

Example 7-7. The __x128_t Container Type

```c
#include <c6x.h>
#include <stdio.h>
__x128_t mpy_four_way_example(__x128_t s, int a, int b, int c, int d)
{
    __x128_t t = _ito128(a, b, c, d);       // Pack values into a __x128_t
    __x128_t results = _qmpy32(s, t);      // Perform a four-way SIMD multiply
    int lowest32 = _get32_128(results, 0);  // Extract lowest reg of __x128_t
    int highest32 = _get32_128(results, 3); // Extract highest reg of __x128_t
    printf("lowest = %d\n", lowest32);
    printf("highest = %d\n", highest32);
    return results;
}
```

Include c6x.h With Type __x128_t or __float2_t

NOTE: When using the __x128_t container type, or __float2_t typedef, or any intrinsics involving __float2_t, you must include c6x.h.
### Table 7-9. Vector-in-Scalar Support C/C++ Compiler v7.2 Intrinsics

<table>
<thead>
<tr>
<th>C/C++ Compiler Intrinsic</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>_x128_t_ifto128 (unsigned src1, unsigned src2, unsigned src3, unsigned src4);</td>
<td>Creates __x128_t from (u)int (reg+3, reg+2, reg+1, reg+0)</td>
</tr>
<tr>
<td>__x128_t_flo128 (float src1, float src2, float src3, float src4);</td>
<td>Creates __x128_t from float (reg+3, reg+2, reg+1, reg+0)</td>
</tr>
<tr>
<td>__x128_t_llo128 (long long src1, long long src2);</td>
<td>Creates __x128_t from two longs</td>
</tr>
<tr>
<td>__x128_t_dto128 (double src1, double src2);</td>
<td>Creates __x128_t from two doubles</td>
</tr>
<tr>
<td>__x128_t_fto128 (__float2_t src1, __float2_t src2);</td>
<td>Creates __x128_t from two __float2_t objects</td>
</tr>
<tr>
<td>__x128_t_dup32_128 (int src);</td>
<td>Creates __x128_t from duplicating src1</td>
</tr>
<tr>
<td>__float2_t_ftof2 (float src1, float src2);</td>
<td>Creates __float2_t from two floats</td>
</tr>
</tbody>
</table>

### Extraction

| float_hif (double src); | Extracts upper float from double |
| float_lof (double src); | Extracts lower float from double |
| float_hif2 (__float2_t src); | Extracts upper float from __float2_t |
| float_lof2 (__float2_t src); | Extracts lower float from __float2_t |
| long _hi128 (__x128_t src); | Extracts upper two registers of register quad |
| double _hid128 (__x128_t src); | Extracts upper two registers of register quad |
| __float2_t_hif2_128 (__x128_t src); | Extracts upper two registers of register quad |
| __float2_t_lof2_128 (__x128_t src); | Extracts lower two registers of register quad |
| long _lo128 (__x128_t src); | Extracts lower two registers of register quad |
| double _lod128 (__x128_t src); | Extracts lower two registers of register quad |
| unsigned_get32_128 (__x128_t src, 0); | Extracts first register of register quad (base reg + 0) |
| unsigned_get32_128 (__x128_t src, 1); | Extracts second register of register quad (base reg + 1) |
| unsigned_get32_128 (__x128_t src, 2); | Extracts third register of register quad (base reg + 2) |
| unsigned_get32_128 (__x128_t src, 3); | Extracts fourth register of register quad (base reg + 3) |
| float_get32f_128 (__x128_t src, 0); | Extracts first register of register quad (base reg + 0) |
| float_get32f_128 (__x128_t src, 1); | Extracts second register of register quad (base reg + 1) |
| float_get32f_128 (__x128_t src, 2); | Extracts third register of register quad (base reg + 2) |
| float_get32f_128 (__x128_t src, 3); | Extracts fourth register of register quad (base reg + 3) |

### 7.5.7 The __float2_t Container Type

The __float2_t container type should be used (instead of double) to store two floats. There are manipulation intrinsics to create and manipulate objects with the __float2_t type (see Table 7-9). The runtime-support file, c6x.h, must be included when using __float2_t or when using any of the __float2_t manipulation intrinsics.

Recommendations for using the __float2_t type:
- Use __float2_t to store two floats. Do not use double.
- Use long long to store 64-bit packed integer data. Do not use double or __float2_t for packed integer data.
7.5.8 Using Intrinsics for Interrupt Control and Atomic Sections

The C/C++ compiler supports three intrinsics for enabling, disabling, and restoring interrupts. The syntaxes are:

```c
unsigned int _disable_interrupts ( );
unsigned int _enable_interrupts ( );
void _restore_interrupts (unsigned int);
```

The _disable_interrupts() and _enable_interrupts( ) intrinsics both return an unsigned int that can be subsequently passed to _restore_interrupts( ) to restore the previous interrupt state. These intrinsics provide a barrier to optimization and are therefore appropriate for implementing a critical (or atomic) section. For example,

```c
unsigned int restore_value;
restore_value = _disable_interrupts();
if (sem) sem--;
_restore_interrupts(restore_value);
```

The example code disables interrupts so that the value of sem read for the conditional clause does not change before the modification of sem in the then clause. The intrinsics are barriers to optimization, so the memory reads and writes of sem do not cross the _disable_interrupts or _restore_interrupts locations.

**NOTE:** The _restore_interrupts( ) intrinsic overwrites the CSR control register with the value in the argument. Any CSR bits changed since the _disable_interrupts( ) intrinsic or _enable_interrupts( ) intrinsic will be lost.

On C6400+, C6740, and C6600, the _restore_interrupts( ) intrinsic does not use the RINT instruction.

7.5.9 Using Unaligned Data and 64-Bit Values

The C6400, C6400+, C6740, and C6600 families have support for unaligned loads and stores of 64-bit and 32-bit values via the use of the _mem8, _memd8, and _mem4 intrinsics. The _lo and _hi intrinsics are useful for extracting the two 32-bit portions from a 64-bit double. The _loll and _hill intrinsics are useful for extracting the two 32-bit portions from a 64-bit long long.

For the C6400+, C6740, and C6600 intrinsics that use 64-bit types, the equivalent C type is long long. Do not use the C type double or the compiler performs a call to a run-time-support math function to do the floating-point conversion. Here are ways to access 64-bit and 32-bit values:

- To get the upper 32 bits of a long long in C code, use >> 32 or the _hill( ) intrinsic.
- To get the lower 32 bits of a long long in C code, use a cast to int or unsigned, or use the _loll intrinsic.
- To get the upper 32 bits of a double (interpreted as an int), use _hi( ).
- To get the lower 32 bits of a double (interpreted as an int), use _lo( ).
- To get the upper 32 bits of a __float2_t, use _hif2().
- To get the lower 32 bits of a __float2_t, use _lof2().
- To create a long long value, use the _itoll(int high32bits, int low32bits) intrinsic.
- To create a __float2_t value, use the _ftof2(float high32bits, float low32bits) intrinsic.

Example 7-8 shows the usage of the _mem8 intrinsic.
Example 7-8. Using the _mem8 Intrinsic

```c
void alt_load_longlong_unaligned(void *a, int *high, int *low)
{
    long long p = _mem8(a);
    *high = p >> 32;
    *low = (unsigned int) p;
}
```

7.5.10 Using MUST_ITERATE and _nassert to Enable SIMD and Expand Compiler Knowledge of Loops

Through the use of MUST_ITERATE and _nassert, you can guarantee that a loop executes a certain number of times.

This example tells the compiler that the loop is guaranteed to run exactly 10 times:

```c
#pragma MUST_ITERATE(10,10);
for (I = 0; I < trip_count; I++) { ...
```

MUST_ITERATE can also be used to specify a range for the trip count as well as a factor of the trip count. For example:

```c
#pragma MUST_ITERATE(8,48,8);
for (I = 0; I < trip; I++) { ...
```

This example tells the compiler that the loop executes between 8 and 48 times and that the trip variable is a multiple of 8 (8, 16, 24, 32, 40, 48). The compiler can now use all this information to generate the best loop possible by unrolling better even when the --interrupt_threshold option is used to specify that interrupts do occur every n cycles.

The TMS320C6000 Programmer's Guide states that one of the ways to refine C/C++ code is to use word accesses to operate on 16-bit data stored in the high and low parts of a 32-bit register. Examples using casts to int pointers are shown with the use of intrinsics to use certain instructions like _mpyh. This can be automated by using the _nassert(); intrinsic to specify that 16-bit short arrays are aligned on a 32-bit (word) boundary.

The following examples generate the same assembly code:

- **Example 1**

```c
int dot_product(short *x, short *y, short z)
{
    int *w_x = (int *)x;
    int *w_y = (int *)y;
    int sum1 = 0, sum2 = 0, I;
    for (I = 0; I < z/2; I++)
    {
        sum1 += _mpy(w_x[I], w_y[I]);
        sum2 += _mpyh(w_x[I], w_y[I]);
    }
    return (sum1 + sum2);
}
```

- **Example 2**

```c
int dot_product(short *x, short *y, short z)
{
    int sum = 0, I;

    _nassert (((int)(x) & 0x3) == 0);
    _nassert (((int)(y) & 0x3) == 0);
    #pragma MUST_ITERATE(20, , 4);
    for (I = 0; I < z; I++) sum += x[I] * y[I];
    return sum;
}
```
C++ Syntax for _nassert

NOTE: In C++ code, _nassert is part of the standard namespace. Thus, the correct syntax is
std::_nassert().

7.5.11 Methods to Align Data

In the following code, the _nassert tells the compiler, for every invocation of f(), that ptr is aligned to an 8-byte boundary. Such an assertion often leads to the compiler producing code which operates on multiple data values with a single instruction, also known as SIMD (single instruction multiple data) optimization.

```c
void f(short *ptr)
{
    _nassert((int) ptr % 8 == 0);
    // a loop operating on data accessed by ptr
}
```

The following subsections describe methods you can use to ensure the data referenced by ptr is aligned. You have to employ one of these methods at every place in your code where f() is called.

7.5.11.1 Base Address of an Array

An argument such as ptr is most commonly passed the base address of an array, for example:

```c
short buffer[100];
...
f(buffer);
```

When compiling for C6600 devices, such an array is automatically aligned to a 16-byte boundary. When compiling for C6400, C6400+, C6740, and C6600 devices, such an array is automatically aligned to an 8-byte boundary. When compiling for C6200 or C6700, such an array is automatically aligned to 4-byte boundary, or, if the base type requires it, an 8-byte boundary. This is true whether the array is global, static, or local. This automatic alignment is all that is required to achieve SIMD optimization on those respective devices. You still need to include the _nassert because, in the general case, the compiler cannot guarantee that ptr holds the address of a properly aligned array.

If you always pass the base address of an array to pointers like ptr, then you can use the following macro to reflect that fact.

```c
#if defined(_TMS320C6600)
#define ALIGNED_ARRAY(ptr) _nassert((int) ptr % 16 == 0)
#elif defined(_TMS320C6400)
#define ALIGNED_ARRAY(ptr) _nassert((int) ptr % 8 == 0)
#elif defined(_TMS320C6200) || defined(_TMS320C6700)
#define ALIGNED_ARRAY(ptr) _nassert((int) ptr % 4 == 0)
#else
#define ALIGNED_ARRAY(ptr) /* empty */
#endif
```

```c
void f(short *ptr)
{
    ALIGNED_ARRAY(ptr);
    // a loop operating on data accessed by ptr
}
```

The macro works regardless of which C6000 device you build for, or if you port the code to another target.

7.5.11.2 Offset from the Base of an Array

A more rare case is to pass the address of an offset from an array, for example:

```c
f(&buffer[3]);
```

This code passes an unaligned address to ptr, thus violating the presumption coded in the _nassert(). There is no direct remedy for this case. Avoid this practice whenever possible.
7.5.11.3 Dynamic Memory Allocation

Ordinary dynamic memory allocation guarantees that the allocated memory is properly aligned for any scalar object of a native type (for instance, it is correctly aligned for a long double or long long int), but does not guarantee any larger alignment. For example:
```
buffer = calloc(100, sizeof(short))
```

To get a stricter alignment, use the function memalign with the desired alignment. To get an alignment of 256 bytes for example:
```
buffer = memalign(256, 100 * sizeof(short));
```

If you are using BIOS memory allocation routines, be sure to pass the alignment factor as the last argument using the syntax that follows:
```
buffer = MEM_alloc( segid , 100 * sizeof(short), 256);
```

See the TMS320C6000 DSP/BIOS Help for more information about BIOS memory allocation routines and the segid parameter in particular.

7.5.11.4 Member of a Structure or Class

Arrays which are members of a structure or a class are aligned only as the base type of the array requires. The automatic alignment described in Section 7.5.11.1 does not occur.

**Example 7-9. An Array in a Structure**
```
struct s {
    ...
    short buf1[50];
    ...
} g;
...
f(g.buf1);
```

**Example 7-10. An Array in a Class**
```
class c {
    public:
        short buf1[50];
        void mfunc(void);
    ...
};
void c::mfunc()
{
    f(buf1);
    ...
}
```
To align an array in a structure, place it inside a union with a dummy object that has the desired alignment. If you want 8 byte alignment, use a "long long" dummy field. For example:

```c
struct s {
    union u {
        long long dummy; /* 8-byte alignment */
        short buffer[50]; /* also 8-byte alignment */
    } u;
    ...
};
```

If you want to declare several arrays contiguously, and maintain a given alignment, you can do so by keeping the array size, measured in bytes, an even multiple of the desired alignment. For example:

```c
struct s {
    long long dummy; /* 8-byte alignment */
    short buffer[50]; /* also 8-byte alignment */
    short buf2[50]; /* 4-byte alignment */
    ...
};
```

Because the size of buf1 is 50 * 2-bytes per short = 100 bytes, and 100 is an even multiple of 4, not 8, buf2 is only aligned on a 4-byte boundary. Padding buf1 out to 52 elements makes buf2 8-byte aligned.

Within a structure or class, there is no way to enforce an array alignment greater than 8. For the purposes of SIMD optimization, this is not necessary.

### Alignment With Program-Level Optimization

**NOTE:** In most cases program-level optimization (see Section 3.7) entails compiling all of your source files with a single invocation of the compiler, while using the -pm -o3 options. This allows the compiler to see all of your source code at once, thus enabling optimizations that are rarely applied otherwise. Among these optimizations is seeing that, for instance, all of the calls to the function f() are passing the base address of an array to ptr, and thus ptr is always correctly aligned for SIMD optimization. In such a case, the _nassert() is not required. The compiler automatically determines that ptr must be aligned, and produces the optimized SIMD instructions.

### 7.5.12 SAT Bit Side Effects

The saturated intrinsic operations define the SAT bit if saturation occurs. The SAT bit can be set and cleared from C/C++ code by accessing the control status register (CSR). The compiler uses the following steps for generating code that accesses the SAT bit:

1. The SAT bit becomes undefined by a function call or a function return. This means that the SAT bit in the CSR is valid and can be read in C/C++ code until a function call or until a function returns.

2. If the code in a function accesses the CSR, then the compiler assumes that the SAT bit is live across the function, which means:
   - The SAT bit is maintained by the code that disables interrupts around software pipelined loops.
   - Saturated instructions cannot be speculatively executed.

3. If an interrupt service routine modifies the SAT bit, then the routine should be written to save and restore the CSR.
7.5.13 IRP and AMR Conventions

There are certain assumptions that the compiler makes about the IRP and AMR control registers. The assumptions should be enforced in all programs and are as follows:

1. The AMR must be set to 0 upon calling or returning from a function. A function does not have to save and restore the AMR, but must ensure that the AMR is 0 before returning.
2. The AMR must be set to 0 when interrupts are enabled, or the SAVE_AMR and STORE_AMR macros should be used in all interrupts (see Section 7.6.3).
3. The IRP can be safely modified only when interrupts are disabled.
4. The IRP's value must be saved and restored if you use the IRP as a temporary register.

7.5.14 Floating Point Control Register Side Effects

When performing floating point operations on a floating-point architecture, status bits in certain control registers may be set. In particular, status bits may be set in the FADCR, FAUCR, and FMCR registers, hereafter referred to as the "floating point control registers". These bits can be set and cleared from C/C++ code by writing to or reading from these registers, as shown in example 6-1.

In compiler versions released after July of 2009, the compiler uses the following steps for generating code that accesses any of the floating point control registers.

1. The floating point control registers become undefined by a function call or a function return. The means the data in the floating point control registers is valid and can be read in C/C++ code until a function call or a function returns.
2. If the code in a function accesses any of the floating point control registers, the compiler assumes that those registers are live across the function, which means that floating point instructions that may set bits in those floating point control registers cannot be speculatively executed.
3. If an interrupt service routine modifies any of the bits in a floating point control register, the interrupt service routine should be written to save and restore that floating point control register.

7.6 Interrupt Handling

As long as you follow the guidelines in this section, you can interrupt and return to C/C++ code without disrupting the C/C++ environment. When the C/C++ environment is initialized, the startup routine does not enable or disable interrupts. If the system is initialized by way of a hardware reset, interrupts are disabled. If your system uses interrupts, you must handle any required enabling or masking of interrupts. Such operations have no effect on the C/C++ environment and are easily incorporated with asm statements or calling an assembly language function.

7.6.1 Saving the SGIE Bit

When compiling for C6400+, C6740, and C6600, the compiler may use the C6400+-, C6740-, and C6600- specific instructions DINT and RINT to disable and restore interrupts around software-pipelined loops. These instructions utilize the CSR control register as well as the SGIE bit in the TSR control register. Therefore, the SGIE bit is considered to be save-on-call. If you have assembly code that calls compiler-generated code, the SGIE bit should be saved (e.g. to the stack) if it is needed later. The SGIE bit should then be restored upon return from compiler generated code.

7.6.2 Saving Registers During Interrupts

When C/C++ code is interrupted, the interrupt routine must preserve the contents of all machine registers that are used by the routine or by any functions called by the routine. The compiler handles register preservation if the interrupt service routine is written in C/C++ and declared with the interrupt keyword. For C6400+, C6740, and C6600, the compiler will save and restore the ILC and RILC control registers if needed.
7.6.3 Using C/C++ Interrupt Routines

A C/C++ interrupt routine is like any other C/C++ function in that it can have local variables and register variables; however, it should be declared with no arguments and should return void. C/C++ interrupt routines can allocate up to 32K on the stack for local variables. For example:

```c
interrupt void example (void)
{
  ...
}
```

If a C/C++ interrupt routine does not call any other functions, only those registers that the interrupt handler attempts to define are saved and restored. However, if a C/C++ interrupt routine does call other functions, these functions can modify unknown registers that the interrupt handler does not use. For this reason, the routine saves all usable registers if any other functions are called. Interrupts branch to the interrupt return pointer (IRP). Do not call interrupt handling functions directly.

Interrupts can be handled directly with C/C++ functions by using the interrupt pragma or the interrupt keyword. For more information, see Section 6.9.18 and Section 6.5.3, respectively.

You are responsible for handling the AMR control register and the SAT bit in the CSR correctly inside an interrupt. By default, the compiler does not do anything extra to save/restore the AMR and the SAT bit. Macros for handling the SAT bit and the AMR register are included in the c6x.h header file.

For example, you are using circular addressing in some hand assembly code (that is, the AMR does not equal 0). This hand assembly code can be interrupted into a C code interrupt service routine. The C code interrupt service routine assumes that the AMR is set to 0. You need to define a local unsigned int temporary variable and call the SAVE_AMR and RESTORE_AMR macros at the beginning and end of your C interrupt service routine to correctly save/restore the AMR inside the C interrupt service routine.

Example 7-11. AMR and SAT Handling

```c
#include <c6x.h>

interrupt void interrupt_func()
{
  unsigned int temp_amr;
  /* define other local variables used inside interrupt */

  /* save the AMR to a temp location and set it to 0 */
  SAVE_AMR(temp_amr);

  /* code and function calls for interrupt service routine */
  ...

  /* restore the AMR for you hand assembly code before exiting */
  RESTORE_AMR(temp_amr);
}
```

If you need to save/restore the SAT bit (i.e. you were performing saturated arithmetic when interrupted into the C interrupt service routine which may also perform some saturated arithmetic) in your C interrupt service routine, it can be done in a similar way as the above example using the SAVE_SAT and RESTORE_SAT macros.

For C6400+, C6740, and C6600, the compiler saves and restores the ILC and RILC control registers if needed.

For floating point architectures, you are responsible for handling the floating point control registers FADCR, FAUCR and FMCR. If you are reading bits out of the floating pointer control registers, and if the interrupt service routine (or any called function) performs floating point operations, then the relevant floating point control registers should be saved and restored. No macros are provided for these registers, as simple assignment to and from an unsigned int temporary will suffice.
7.6.4 Using Assembly Language Interrupt Routines

You can handle interrupts with assembly language code as long as you follow the same register conventions the compiler does. Like all assembly functions, interrupt routines can use the stack, access global C/C++ variables, and call C/C++ functions normally. When calling C/C++ functions, be sure that any registers listed in Table 7-2 are saved, because the C/C++ function can modify them.

7.7 Run-Time-Support Arithmetic Routines

The run-time-support library contains a number of assembly language functions that provide arithmetic routines for C/C++ math operations that the C6000 instruction set does not provide, such as integer division, integer remainder, and floating-point operations.

These routines follow the standard C/C++ calling sequence. The compiler automatically adds these routines when appropriate; they are not intended to be called directly by your programs.

The source code for these functions is in the source library rts.src. The source code has comments that describe the operation of the functions. You can extract, inspect, and modify any of the math functions. Be sure, however, that you follow the calling conventions and register-saving rules outlined in this chapter. Table 7-10 summarizes the run-time-support functions used for arithmetic.

Table 7-10. Summary of Run-Time-Support Arithmetic Functions

<table>
<thead>
<tr>
<th>Type</th>
<th>Function in COFF ABI</th>
<th>Function in EABI</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>float</td>
<td>_cvtdf (double)</td>
<td>__c6xabi_cvtdf (double)</td>
<td>Convert double to float</td>
</tr>
<tr>
<td>int</td>
<td>_fixdi (double)</td>
<td>__c6xabi_fixdi (double)</td>
<td>Convert double to signed integer</td>
</tr>
<tr>
<td>long</td>
<td>_fixdi (double)</td>
<td>__c6xabi_fixdi (double)</td>
<td>Convert double to long</td>
</tr>
<tr>
<td>long long</td>
<td>_fixdll (double)</td>
<td>__c6xabi_fixdll (double)</td>
<td>Convert double to long long</td>
</tr>
<tr>
<td>uint</td>
<td>_fixdll (double)</td>
<td>__c6xabi_fixdll (double)</td>
<td>Convert double to unsigned integer</td>
</tr>
<tr>
<td>ulong</td>
<td>_fix dul (double)</td>
<td>__c6xabi_fixdul (double)</td>
<td>Convert double to unsigned long</td>
</tr>
<tr>
<td>ulong long</td>
<td>_fixdull (double)</td>
<td>__c6xabi_fixdull (double)</td>
<td>Convert double to unsigned long long</td>
</tr>
<tr>
<td>double</td>
<td>_cvtfld (float)</td>
<td>__c6xabi_cvtfld (float)</td>
<td>Convert float to double</td>
</tr>
<tr>
<td>int</td>
<td>_fixfl (float)</td>
<td>__c6xabi_fixfl (float)</td>
<td>Convert float to signed integer</td>
</tr>
<tr>
<td>long</td>
<td>_fixfl (float)</td>
<td>__c6xabi_fixfl (float)</td>
<td>Convert float to long</td>
</tr>
<tr>
<td>long long</td>
<td>_fixfl (float)</td>
<td>__c6xabi_fixfl (float)</td>
<td>Convert float to long long</td>
</tr>
<tr>
<td>uint</td>
<td>_fixfu (float)</td>
<td>__c6xabi_fixfu (float)</td>
<td>Convert float to unsigned integer</td>
</tr>
<tr>
<td>ulong</td>
<td>_fixful (float)</td>
<td>__c6xabi_fixful (float)</td>
<td>Convert float to unsigned long</td>
</tr>
<tr>
<td>ulong long</td>
<td>_fixfull (float)</td>
<td>__c6xabi_fixfull (float)</td>
<td>Convert float to unsigned long long</td>
</tr>
<tr>
<td>double</td>
<td>_fltild (int)</td>
<td>__c6xabi_fltild (int)</td>
<td>Convert signed integer to double</td>
</tr>
<tr>
<td>float</td>
<td>_fltlf (int)</td>
<td>__c6xabi_fltlf (int)</td>
<td>Convert signed integer to float</td>
</tr>
<tr>
<td>double</td>
<td>_fltuid (uint)</td>
<td>__c6xabi_fltuid (uint)</td>
<td>Convert unsigned integer to double</td>
</tr>
<tr>
<td>float</td>
<td>_fltuf (uint)</td>
<td>__c6xabi_fltuf (uint)</td>
<td>Convert unsigned integer to float</td>
</tr>
<tr>
<td>double</td>
<td>_fltlld (long)</td>
<td>__c6xabi_fltlld (long)</td>
<td>Convert signed long to double</td>
</tr>
<tr>
<td>float</td>
<td>_fltllf (long)</td>
<td>__c6xabi_fltllf (long)</td>
<td>Convert signed long to float</td>
</tr>
<tr>
<td>double</td>
<td>_fltulld (ulong)</td>
<td>__c6xabi_fltulld (ulong)</td>
<td>Convert unsigned long to double</td>
</tr>
<tr>
<td>float</td>
<td>_fltullf (ulong)</td>
<td>__c6xabi_fltullf (ulong)</td>
<td>Convert unsigned long to float</td>
</tr>
<tr>
<td>double</td>
<td>_absd (double)</td>
<td>__c6xabi_absd (double)</td>
<td>Double absolute value</td>
</tr>
<tr>
<td>float</td>
<td>_absf (float)</td>
<td>__c6xabi_absf (float)</td>
<td>Float absolute value</td>
</tr>
<tr>
<td>long</td>
<td>_labs (long)</td>
<td>__c6xabi_labs (long)</td>
<td>Long absolute value</td>
</tr>
<tr>
<td>long long</td>
<td>_llabs (long long)</td>
<td>__c6xabi_llabs (long long)</td>
<td>Long long absolute value</td>
</tr>
<tr>
<td>double</td>
<td>_negd (double)</td>
<td>__c6xabi_negd (double)</td>
<td>Double negative value</td>
</tr>
</tbody>
</table>
## Table 7-10. Summary of Run-Time-Support Arithmetic Functions (continued)

<table>
<thead>
<tr>
<th>Type</th>
<th>Function in COFF ABI</th>
<th>Function in EABI</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>float</td>
<td>_negf (float)</td>
<td>__c6xabi_negf (float)</td>
<td>Float negate value</td>
</tr>
<tr>
<td>long long</td>
<td>_negll (long)</td>
<td>__c6xabi_negll (long)</td>
<td>Long long negate value</td>
</tr>
<tr>
<td>long long</td>
<td>_lshl (long long)</td>
<td>__c6xabi_lshl (long long)</td>
<td>Long long shift left</td>
</tr>
<tr>
<td>long long</td>
<td>_lshr (long long)</td>
<td>__c6xabi_lshr (long long)</td>
<td>Long long shift right</td>
</tr>
<tr>
<td>ulong long</td>
<td>_lshru (ulong long)</td>
<td>__c6xabi_lshru (ulong long)</td>
<td>Unsigned long shift right</td>
</tr>
<tr>
<td>double</td>
<td>_adddd (double, double)</td>
<td>__c6xabi_adddd (double, double)</td>
<td>Double addition</td>
</tr>
<tr>
<td>double</td>
<td>_cmpeq (double, double)</td>
<td>__c6xabi_cmpd (double, double)</td>
<td>Double comparison</td>
</tr>
<tr>
<td>double</td>
<td>_divdd (double, double)</td>
<td>__c6xabi_divd (double, double)</td>
<td>Double division</td>
</tr>
<tr>
<td>double</td>
<td>_mpydd (double, double)</td>
<td>__c6xabi_mpyd (double, double)</td>
<td>Double multiplication</td>
</tr>
<tr>
<td>double</td>
<td>_subd (double, double)</td>
<td>__c6xabi_subd (double, double)</td>
<td>Double subtraction</td>
</tr>
<tr>
<td>float</td>
<td>_addff (float, float)</td>
<td>__c6xabi_addf (float, float)</td>
<td>Float addition</td>
</tr>
<tr>
<td>float</td>
<td>_cmpeqf (float, float)</td>
<td>__c6xabi_cmpf (float, float)</td>
<td>Float comparison</td>
</tr>
<tr>
<td>float</td>
<td>_divff (float, float)</td>
<td>__c6xabi_divf (float, float)</td>
<td>Float division</td>
</tr>
<tr>
<td>float</td>
<td>_mpyff (float, float)</td>
<td>__c6xabi_mpyf (float, float)</td>
<td>Float multiplication</td>
</tr>
<tr>
<td>float</td>
<td>_subff (float, float)</td>
<td>__c6xabi_subf (float, float)</td>
<td>Float subtraction</td>
</tr>
<tr>
<td>int</td>
<td>_divi (int, int)</td>
<td>__c6xabi_divi (int, int)</td>
<td>Signed integer division</td>
</tr>
<tr>
<td>int</td>
<td>_remi (int, int)</td>
<td>__c6xabi_remi (int, int)</td>
<td>Signed integer remainder</td>
</tr>
<tr>
<td>uint</td>
<td>_divui (uint, uint)</td>
<td>__c6xabi_divu (uint, uint)</td>
<td>Unsigned integer division</td>
</tr>
<tr>
<td>uint</td>
<td>_remu (uint, uint)</td>
<td>__c6xabi_remu (uint, uint)</td>
<td>Unsigned integer remainder</td>
</tr>
<tr>
<td>long</td>
<td>_divlli (long, long)</td>
<td>__c6xabi_divlli (long, long)</td>
<td>Signed long division</td>
</tr>
<tr>
<td>long</td>
<td>_remlli (long, long)</td>
<td>__c6xabi_remlli (long, long)</td>
<td>Signed long remainder</td>
</tr>
<tr>
<td>ulong</td>
<td>_divull (ulong, ulong)</td>
<td>__c6xabi_divull (ulong, ulong)</td>
<td>Unsigned long division</td>
</tr>
<tr>
<td>ulong</td>
<td>_remull (ulong, ulong)</td>
<td>__c6xabi_remull (ulong, ulong)</td>
<td>Unsigned long remainder</td>
</tr>
</tbody>
</table>
7.8 System Initialization

Before you can run a C/C++ program, you must create the C/C++ run-time environment. The C/C++ boot routine performs this task using a function called c_int00 (or _c_int00). The run-time-support source library, rts.src, contains the source to this routine in a module named boot.c (or boot.asm).

To begin running the system, the c_int00 function can be branched to or called, but it is usually vectored to by reset hardware. You must link the c_int00 function with the other object files. This occurs automatically when you use the --rom_model or --ram_model link option and include a standard run-time-support library as one of the linker input files.

When C/C++ programs are linked, the linker sets the entry point value in the executable output file to the symbol c_int00. This does not, however, set the hardware to automatically vector to c_int00 at reset (see the TMS320C2x DSP CPU and Instruction Set Reference Guide, the TMS320C64x/C64x+ DSP CPU and Instruction Set Reference Guide, the TMS320C67x/C67x+ DSP CPU and Instruction Set Reference Guide, or the TMS320C66x+ DSP CPU and Instruction Set Reference Guide).

The c_int00 function performs the following tasks to initialize the environment:

1. Defines a section called .stack for the system stack and sets up the initial stack pointers
2. Performs C autoinitialization of global/static variables. For more information, see Section 7.8.1 for COFF ABI mode and Section 7.8.2 for EABI mode.
3. Initializes global variables by copying the data from the initialization tables to the storage allocated for the variables in the .bss section. If you are initializing variables at load time (--ram_model option), a loader performs this step before the program runs (it is not performed by the boot routine). For more information, see Section 7.8.1.
4. Calls C++ initialization routines for file scope construction from the global constructor table. For more information, see Section 7.8.2.6 for EABI mode and Section 7.8.1.3 for COFF ABI mode.
5. Calls the function main to run the C/C++ program

You can replace or modify the boot routine to meet your system requirements. However, the boot routine must perform the operations listed above to correctly initialize the C/C++ environment.

7.8.1 COFF ABI Automatic Initialization of Variables

Some global variables must have initial values assigned to them before a C/C++ program starts running. The process of retrieving these variables’ data and initializing the variables with the data is called autoinitialization.

The COFF ABI compiler builds tables in a special section called .cinit that contains data for initializing global and static variables. Each compiled module contains these initialization tables. The linker combines them into a single table (a single .cinit section). The boot routine or a loader uses this table to initialize all the system variables.

### Initializing Variables

**NOTE:** In ANSI/ISO C, global and static variables that are not explicitly initialized must be set to 0 before program execution. The COFF ABI C/C++ compiler does not perform any preinitialization of uninitialized variables. Explicitly initialize any variable that must have an initial value of 0.

Global variables are either autoinitialized at run time or at load time; see Section 7.8.1.1 and Section 7.8.1.2. Also see Section 6.13. In EABI mode, the compiler automatically zero initializes the uninitialized variables. See Section 7.8.2 for details.
7.8.1.1 Autoinitialization of Variables at Run Time

Autoinitializing variables at run time is the default method of autoinitialization. To use this method, invoke the linker with the --rom_model option.

Using this method, the .cinit section is loaded into memory along with all the other initialized sections, and global variables are initialized at run time. The linker defines a special symbol called cinit that points to the beginning of the initialization tables in memory. When the program begins running, the C/C++ boot routine copies data from the tables (pointed to by .cinit) into the specified variables in the .bss section. This allows initialization data to be stored in ROM and copied to RAM each time the program starts.

Figure 7-11 illustrates autoinitialization at run time. Use this method in any system where your application runs from code burned into ROM.

Figure 7-11. Autoinitialization at Run Time

7.8.1.2 Initialization of Variables at Load Time

Initialization of variables at load time enhances performance by reducing boot time and by saving the memory used by the initialization tables. To use this method, invoke the linker with the --ram_model option.

When you use the --ram_model link option, the linker sets the STYP_COPY bit in the .cinit section's header. This tells the loader not to load the .cinit section into memory. (The .cinit section occupies no space in the memory map.) The linker also sets the cinit symbol to -1 (normally, cinit points to the beginning of the initialization tables). This indicates to the boot routine that the initialization tables are not present in memory; accordingly, no run-time initialization is performed at boot time.

A loader (which is not part of the compiler package) must be able to perform the following tasks to use initialization at load time:

- Detect the presence of the .cinit section in the object file
- Determine that STYP_COPY is set in the .cinit section header, so that it knows not to copy the .cinit section into memory
- Understand the format of the initialization tables

Figure 7-12 illustrates the initialization of variables at load time.
Regardless of the use of the --rom_model or --ram_model options, the .pinit section is always loaded and processed at run time.

7.8.1.3 Global Constructors for COFF

All global C++ variables that have constructors must have their constructor called before main. The compiler builds a table in a section called .pinit of global constructor addresses that must be called, in order, before main. The linker combines the .pinit section from each input file to form a single table in the .pinit section. The boot routine uses this table to execute the constructors. (See Section 7.8.2.6 for global constructor details for EABI.)

7.8.2 EABI Automatic Initialization of Variables

Any global variables declared as preinitialized must have initial values assigned to them before a C/C++ program starts running. The process of retrieving these variables' data and initializing the variables with the data is called autoinitialization.

7.8.2.1 Zero Initializing Variables

In ANSI C, global and static variables that are not explicitly initialized, must be set to 0 before program execution. The C/C++ EABI compiler supports preinitialization of uninitialized variables by default. This can be turned off by specifying the linker option --zero_init=off. COFF ABI does not support zero initialization.

7.8.2.2 EABI Direct Initialization

The EABI compiler uses direct initialization to initialize global variables. For example, consider the following C code:

```c
int i = 23;
int a[5] = {1, 2, 3, 4, 5};
```

The compiler allocates the variables 'i' and 'a[]' to .data section and the initial values are placed directly.

```assembly
.globl i
.data
.align 4
i:
.field 23,32 ; i @ 0
.globl a
.data
.align 4
a:
.field 1,32 ; a[0] @ 0
.field 2,32 ; a[1] @ 32
.field 3,32 ; a[2] @ 64
```
Each compiled module that defines static or global variables contains these .data sections. The linker treats the .data section like any other initialized section and creates an output section. In the load-time initialization model, the sections are loaded into memory and used by the program. See Section 7.8.2.5.

In the run-time initialization model, the linker uses the data in these sections to create initialization data and an additional initialization table. The boot routine processes the initialization table to copy data from load addresses to run addresses. See Section 7.8.2.3.

7.8.2.3 Autoinitialization of Variables at Run Time in EABI Mode

Autoinitializing variables at run time is the default method of autoinitialization. To use this method, invoke the linker with the --rom_model option.

Using this method, the linker creates an initialization table and initialization data from the direct initialized sections in the compiled module. The table and data are used by the C/C++ boot routine to initialize variables in RAM using the table and data in ROM.

Figure 7-13 illustrates autoinitialization at run time in EABI Mode. Use this method in any system where your application runs from code burned into ROM.

7.8.2.4 Autoinitialization Tables

In EABI mode, the compiled object files do not have initialization tables. The variables are initialized directly. The linker, when the --rom_model option is specified, creates C auto initialization table and the initialization data. The linker creates both the table and the initialization data in an output section named .cinit.

Migration from COFF to ELF Initialization

NOTE: The name .cinit is used primarily to simplify migration from COFF to ELF format and the .cinit section created by the linker has nothing in common (except the name) with the COFF cinit records.

The autoinitialization table has the following format:
The linker defined symbols _TI_CINIT_Base and _TI_CINT_Limit point to the start and end of the table, respectively. Each entry in this table corresponds to one output section that needs to be initialized.

The initialization data for each output section could be encoded using different encoding.

The load address in the C auto initialization record points to initialization data with the following format:

<table>
<thead>
<tr>
<th>8-bit index</th>
<th>Encoded data</th>
</tr>
</thead>
</table>

The first 8-bits of the initialization data is the handler index. It indexes into a handler table to get the address of a handler function that knows how to decode the following data.

The handler table is a list of 32-bit function pointers.

| 32-bit handler 1 address |
| :                      |
| :                      |
| 32-bit handler n address |

The encoded data that follows the 8-bit index can be in one of the following format types. For clarity the 8-bit index is also depicted for each format.

### 7.8.2.4.2 Zero Initialization Format

<table>
<thead>
<tr>
<th>8-bit index</th>
<th>24-bit padding</th>
<th>32-bit length (N)</th>
<th>N byte initialization data (not compressed)</th>
</tr>
</thead>
</table>

The compiler uses 24-bit padding to align the length field to a 32-bit boundary. The 32-bit length field encodes the length of the initialization data in bytes (N). N byte initialization data is not compressed and is copied to the run address as is.

The run-time support library has a function __TI_zero_init() to process this type of initialization data. The first argument to this function is the address pointing to the byte after the 8-bit index. The second argument is the run address from the C auto initialization record.
7.8.2.4.3 Run Length Encoded (RLE) Format

| 8-bit index | Initialization data compressed using run length encoding |

The data following the 8-bit index is compressed using Run Length Encoded (RLE) format. It uses a simple run length encoding that can be decompressed using the following algorithm:

1. Read the first byte, Delimiter (D).
2. Read the next byte (B).
3. If B != D, copy B to the output buffer and go to step 2.
4. Read the next byte (L).
   (a) If L == 0, then length is either a 16-bit, a 24-bit value, or we've reached the end of the data, read next byte (L).
      (i) If L == 0, length is a 24-bit value or the end of the data is reached, read next byte (L).
      (ii) Else L <= 16, read next two bytes into lower 16 bits of L to complete 24-bit value for L.
      (iii) Else L <= 8, read next byte into lower 8 bits of L to complete 16-bit value for L.
   (b) Else if L > 0 and L < 4, copy D to the output buffer L times. Go to step 2.
   (c) Else, length is 8-bit value (L).
5. Read the next byte (C); C is the repeat character.
6. Write C to the output buffer L times; go to step 2.
7. End of processing.

The run-time support library has a routine `__TI_decompress_rle24()` to decompress data compressed using RLE. The first argument to this function is the address pointing to the byte after the 8-bit index. The second argument is the run address from the C auto initialization record.

---

RLE Decompression Routine

**NOTE:** The previous decompression routine, `__TI_decompress_rle()`, is included in the run-time support library for decompressing RLE encodings that are generated by older versions of the linker.

---

7.8.2.4.4 Lempel-Ziv-Storer-Szymanski Compression (LZSS) Format

| 8-bit index | Initialization data compressed using LZSS |

The data following the 8-bit index is compressed using LZSS compression. The run-time support library has the routine `__TI_decompress_lzss()` to decompress the data compressed using LZSS. The first argument to this function is the address pointing to the byte after the 8-bit index. The second argument is the run address from the C auto initialization record.

7.8.2.4.5 Sample C Code to Process the C Autoinitialization Table

The run-time support boot routine has code to process the C autoinitialization table. The following C code illustrates how the autoinitialization table can be processed on the target.

**Example 7-12. Processing the C Autoinitialization Table**

typedef void (*handler_fptr)(const unsigned char *in,
unsinged char *out);

#define HANDLER_TABLE __TI_Handler_Table_Base
#define HANDLER_TABLE __TI_Handler_Table_Base
#pragma weak HANDLER_TABLE
extern unsigned int HANDLER_TABLE;

---
Example 7-12. Processing the C Autoinitialization Table (continued)

```c
extern unsigned char *__TI_CINIT_Base;
extern unsigned char *__TI_CINIT_Limit;

void auto_initialize()
{
    unsigned char **table_ptr;
    unsigned char **table_limit;

    /*------------------------------------------------------------------*/
    /* Check if Handler table has entries. */
    /*------------------------------------------------------------------*/
    if ( & __TI_Handler_Table_Base >= & __TI_Handler_Table_Limit)
        return;

    /*------------------------------------------------------------------*/
    /* Get the Start and End of the CINIT Table. */
    /*------------------------------------------------------------------*/
    table_ptr = (unsigned char **) & __TI_CINIT_Base;
    table_limit = (unsigned char **) & __TI_CINIT_Limit;
    while (table_ptr < table_limit)
    {
        /*------------------------------------------------------------------*/
        /* 1. Get the Load and Run address. */
        /* 2. Read the 8-bit index from the load address. */
        /* 3. Get the handler function pointer using the index from */
        /* handler table. */
        /*------------------------------------------------------------------*/
        unsigned char *load_addr = *table_ptr++;
        unsigned char *run_addr = *table_ptr++;
        unsigned char handler_idx = *load_addr++;
        handler_fptr handler =
            (handler_fptr)( & HANDLER_TABLE)[handler_idx];

        /*------------------------------------------------------------------*/
        /* 4. Call the handler and pass the pointer to the load data */
        /* after index and the run address. */
        /*------------------------------------------------------------------*/
        (*handler)((const unsigned char *)load_addr, run_addr);
    }
}
```

7.8.2.5 Initialization of Variables at Load Time in EABI Mode

Initialization of variables at load time enhances performance by reducing boot time and by saving the memory used by the initialization tables. To use this method, invoke the linker with the --ram_model option.

When you use the --ram_model link option, the linker does not generate C autoinitialization tables and data. The direct initialized sections (.data) in the compiled object files are combined according to the linker command file to generate initialized output sections. The loader loads the initialized output sections into memory. After the load, the variables are assigned their initial values.

Since the linker does not generate the C autoinitialization tables, no boot time initialization is performed.

Figure 7-14 illustrates the initialization of variables at load time in EABI mode.
7.8.2.6 Global Constructors

All global C++ variables that have constructors must have their constructor called before main. The compiler builds a table of global constructor addresses that must be called, in order, before main in a section called .init_array. The linker combines the .init_array section from each input file to form a single table in the .init_array section. The boot routine uses this table to execute the constructors. The linker defines two symbols to identify the combined .init_array table as shown below. This table is not null terminated by the linker.

Figure 7-15. Constructor Table for EABI Mode

<table>
<thead>
<tr>
<th>__TI_INITARRAY_Base:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Address of constructor 1</td>
</tr>
<tr>
<td>Address of constructor 2</td>
</tr>
<tr>
<td>...</td>
</tr>
<tr>
<td>...</td>
</tr>
<tr>
<td>Address of constructor n</td>
</tr>
</tbody>
</table>

| __TI_INITARRAY_Limit: |

7.8.3 Initialization Tables

The tables in the .cinit section consist of variable-size initialization records. Each variable that must be autoinitialized has a record in the .cinit section. Figure 7-16 shows the format of the .cinit section and the initialization records.
The fields of an initialization record contain the following information:

- The first field of an initialization record contains the size (in bytes) of the initialization data.
- The second field contains the starting address of the area within the .bss section where the initialization data must be copied.
- The third field contains the data that is copied into the .bss section to initialize the variable.

Each variable that must be autoinitialized has an initialization record in the .cinit section.

Example 7-13 shows initialized global variables defined in C. Example 7-14 shows the corresponding initialization table. The section .cinit:c is a subsection in the .cinit section that contains all scalar data. The subsection is handled as one record during initialization, which minimizes the overall size of the .cinit section.

**Example 7-13. Initialized Variables Defined in C**

```c
int x;
short i = 23;
int *p =
int a[5] = {1,2,3,4,5};
```
Example 7-14. Initialized Information for Variables Defined in Example 7-13

```
.global _x
.bss _x,4,4
.sect "cinit:c"
.align 8
.field (CIR - $) - 8, 32
.field _I+0,32
.field 23,16 ; _I @ 0
.sect "text"
.global _I
_I: .usect "bss:c",2,2
.sect "cinit:c"
.align 4
.field _x,32 ; _p @ 0
.sect "text"
.global _p
_p: .usect "bss:c",4,4

.sect "cinit"
.align 8
.field IR_1,32
.field _a+0,32
.field 1,32 ; _a[0] @ 0
.field 2,32 ; _a[1] @ 32
.field 3,32 ; _a[2] @ 64
.field 4,32 ; _a[3] @ 96
.field 5,32 ; _a[4] @ 128
IR_1: .set 20
.sect "text"
.global _a
.bss _a,20,4
;**********************************************************************
;* MARK THE END OF THE SCALAR INIT RECORD IN CINIT:C *
;**********************************************************************
CIR: .sect "cinit:c"
```

The .cinit section must contain only initialization tables in this format. When interfacing assembly language modules, do not use the .cinit section for any other purpose.

The table in the .pinit section simply consists of a list of addresses of constructors to be called (see Figure 7-17). The constructors appear in the table after the .cinit initialization.
When you use the --rom_model or --ram_model option, the linker combines the .cinit sections from all the C/C++ modules and appends a null word to the end of the composite .cinit section. This terminating record appears as a record with a size field of 0 and marks the end of the initialization tables.

Likewise, the --rom_model or --ram_model link option causes the linker to combine all of the .pinit sections from all C/C++ modules and append a null word to the end of the composite .pinit section. The boot routine knows the end of the global constructor table when it encounters a null constructor address.

The const-qualified variables are initialized differently; see Section 6.5.1.
7.9 Support for Multi-Threaded Applications

The compiler supports various features for multi-threaded applications. These features assume an underlying runtime operating system that provides thread management services.

7.9.1 Compiling with OpenMP

The compiler implements support for the OpenMP 3.0 API. To enable support for OpenMP use the --openmp or --omp compiler option.

OpenMP is the industry standard for shared memory parallel programming. It provides portable high-level programming constructs that enable users to easily expose a program's task and loop level parallelism in an incremental fashion. With OpenMP, users specify the parallelization strategy for a program at a high level by annotating the program code with compiler directives that specify how a region of code is executed by a team of threads. The compiler works out the detailed mapping of the computation to the machine. The OpenMP programming API enables the programmer to perform the following:

- Create and manage threads
- Assign and distribute work (tasks) to threads
- Specify which data is shared among threads and which data is private
- Coordinate thread access to shared data

OpenMP is a thread-based programming language. The master thread executes the sequential parts of a program. When the master thread encounters a parallel region, it forks a team of worker threads that along with the master thread execute in parallel.

The OpenMP API is made up of directives(#pragmas), function calls, and environment variables. The compiler translates the OpenMP API into multi-threaded code with calls to a custom runtime library that implements support for thread management, shared memory and synchronization. For further details on the OpenMP API (including the API specification), please refer to http://www.openmp.org.

The OpenMP runtime for SYS/BIOS (OMP) library implements the OpenMP solution stack. Currently, OpenMP is supported on TI DSPs only for SYS/BIOS operating system. All OpenMP programs must be linked with the OMP run-time library found in the BIOS-MCSDK 2.1.

7.9.2 Multi-Threading Runtime Support

7.9.2.1 Runtime Thread Safety

Thread safety involves creation, initialization, maintenance, and destruction of thread-private data. It also requires that accesses to data that is shared between threads must be protected. That is, only one thread should be allowed to access a piece of shared data at a given time. An additional issue that needs to be addressed on C6000 multi-core devices that have a private data cache (L1D cache on C6600 devices, for example) is that copies of shared data that exist among private data caches and shared memory must be kept coherent. This means that if a thread reads a piece of shared data into the private data cache on a processor, it must invalidate any local copies of that data that exist in the local data cache before accessing or modifying the data. This ensures that the currently executing thread will only access the latest available copy of the shared data.

7.9.2.1.1 Thread Creation, Initialization, and Termination

Thread libraries are responsible for allocating a thread-local area of memory when a thread is created, then initializing any thread-private data objects that reside in that thread-local area, and when the thread is terminated, the thread library must free the thread-local area that was allocated for thread-private data.
7.9.2.1.2 Thread Local Storage (TLS)

The compiler now supports the __thread qualifier to identify a data object that is to be given thread-private storage. To access a variable that has been identified as thread-local, the compiler will rely on support of the runtime operating system's thread library to find the run-time location of a thread-local variable. Specifically, the thread library must provide an implementation of the __c6xabi_get_tlp() function. The runtime operating system's thread library will provide the address of a TLS block that has been allocated on behalf of the currently executed thread and then the compiler can access data in the TLS block with knowledge of where a given thread-local variable exists within the TLS block. Further information about TLS data objects can be found in the "Thread Local Storage Specification for C6000 EABI" document (C6000_TLS.docx in the 'doc' sub-directory where your C6000 CGT is installed).

7.9.2.1.3 Accessing Shared Data

Accesses to shared data objects must be protected within a critical region which prevents a second thread from entering the critical region of code while the first thread is accessing a shared data object. We also need to be concerned about data coherency between copies of shared data that may exist in both shared memory and in private data caches as mentioned above in Section 7.9.2.1.
Some of the features of C/C++ (such as I/O, dynamic memory allocation, string operations, and trigonometric functions) are provided as an ANSI/ISO C/C++ standard library, rather than as part of the compiler itself. The TI implementation of this library is the run-time-support library (RTS). The C/C++ compiler implements the complete ISO standard library except for those facilities that handle signal and locale issues (properties that depend on local language, nationality, or culture). Using the ANSI/ISO standard library ensures a consistent set of functions that provide for greater portability.

In addition to the ANSI/ISO-specified functions, the run-time-support library includes routines that give you processor-specific commands and direct C language I/O requests. These are detailed in Section 8.1 and Section 8.2.

A library-build utility is provided with the code generation tools that lets you create customized run-time-support libraries. This process is described in Section 8.5.
8.1 C and C++ Run-Time Support Libraries

TMS320C6000 compiler releases include pre-built run-time libraries that provide all the standard capabilities. Separate libraries are provided for each target CPU version, big and little endian support, each ABI, and C++ exception support. See Section 8.5 for information on the library-naming conventions.

The run-time-support library contains the following:

- ANSI/ISO C/C++ standard library
- C I/O library
- Low-level support functions that provide I/O to the host operating system
- Fundamental arithmetic routines
- System startup routine, _c_int00
- Functions and macros that allow C/C++ to access specific instructions

The run-time-support libraries do not contain functions involving signals and locale issues.

The C++ library supports wide chars, in that template functions and classes that are defined for char are also available for wide char. For example, wide char stream classes wios, wistream, wstreambuf and so on (corresponding to char classes ios, iostream, streambuf) are implemented. However, there is no low-level file I/O for wide chars. Also, the C library interface to wide char support (through the C++ headers <cwchar> and <cwctype>) is limited as described in Section 6.1.

The C++ library included with the compiler is licensed from Dinkumware, Ltd. The Dinkumware C++ library is a fully conforming, industry-leading implementation of the standard C++ library.

TI does not provide documentation that covers the functionality of the C++ library. TI suggests referring to one of the following sources:

- Dinkumware's online reference at [http://dinkumware.com/manuals](http://dinkumware.com/manuals)

8.1.1 Linking Code With the Object Library

When you link your program, you must specify the object library as one of the linker input files so that references to the I/O and run-time-support functions can be resolved. You can either specify the library or allow the compiler to select one for you. See Section 5.3.1 for further information.

When a library is linked, the linker includes only those library members required to resolve undefined references. For more information about linking, see the *TMS320C6000 Assembly Language Tools User's Guide*.

C, C++, and mixed C and C++ programs can use the same run-time-support library. Run-time-support functions and variables that can be called and referenced from both C and C++ will have the same linkage.
8.1.2 Header Files

You must use the header files provided with the compiler run-time support when using functions from C/C++ standard library. Set the C6X_C_DIR environment variable to the include directory where the tools are installed.

8.1.3 Modifying a Library Function

You can inspect or modify library functions by unzipping the source file (rtssrc.zip), changing the specific function file, and rebuilding the library. When extracted (with any standard unzip tool on windows, linux, or unix), this zip file recreates the run-time source tree for the run-time library.

The source for the libraries is included in the rtssrc.zip file. See Section 8.5 for details on rebuilding.

You can also build a new library this way, rather than rebuilding into rts6200.lib. See Section 8.5.

8.1.4 Minimal Support for Internationalization

The library now includes the header files <locale.h>, <wchar.h>, and <wctype.h>, which provide APIs to support non-ASCII character sets and conventions. Our implementation of these APIs is limited in the following ways:

- The library has minimal support for wide and multi-byte characters. The type wchar_t is implemented as int. The wide character set is equivalent to the set of values of type char. The library includes the header files <wchar.h> and <wctype.h> but does not include all the functions specified in the standard. So-called multi-byte characters are limited to single characters. There are no shift states. The mapping between multi-byte characters and wide characters is simple equivalence; that is, each wide character maps to and from exactly a single multi-byte character having the same value.

- The C library includes the header file <locale.h> but with a minimal implementation. The only supported locale is the C locale. That is, library behavior that is specified to vary by locale is hardcoded to the behavior of the C locale, and attempting to install a different locale via a call to setlocale() will return NULL.

8.1.5 Allowable Number of Open Files

In the <stdio.h> header file, the value for the macro FOPEN_MAX has been changed from 12 to the value of the macro _NFILE, which is set to 10. The impact is that you can only have 10 files simultaneously open at one time (including the pre-defined streams - stdin, stdout, stderr).

The C standard requires that the minimum value for the FOPEN_MAX macro is 8. The macro determines the maximum number of files that can be opened at one time. The macro is defined in the stdio.h header file and can be modified by changing the value of the _NFILE macro.
8.1.6 Library Naming Conventions

By default, the linker uses automatic library selection to select the correct run-time-support library (see Section 5.3.1.1) for your application. If you select the library manually, you must select the matching library according to the following naming scheme:

\texttt{rtstrg[\textit{endian}][\textit{abi}][\textit{eh}].lib}

- \textit{trg} The device family of the C6000 architecture that the library was built for. This can be one of the following: 6200, 6400, 64plus, 6600, 6700, 6740, 67plus.
- \textit{endian} Indicates endianness:
  - (blank) Little-endian library
  - \texttt{e} Big-endian library
- \textit{abi} Indicates the application binary interface (ABI) used:
  - (blank) COFF ABI
  - \texttt{_elf} EABI
- \textit{eh} Indicates whether the library has exception handling support:
  - (blank) exception handling not supported
  - \texttt{_eh} exception handling support

For information on the C6700 FastMath source library, fastmathc67x.src, see Section 8.4.

8.2 The C I/O Functions

The C I/O functions make it possible to access the host’s operating system to perform I/O. The capability to perform I/O on the host gives you more options when debugging and testing code.

The I/O functions are logically divided into layers: high level, low level, and device-driver level.

With properly written device drivers, the C-standard high-level I/O functions can be used to perform I/O on custom user-defined devices. This provides an easy way to use the sophisticated buffering of the high-level I/O functions on an arbitrary device.

---

\textbf{Debugger Required for Default HOST}

\textbf{NOTE:} For the default HOST device to work, there must be a debugger to handle the C I/O requests; the default HOST device cannot work by itself in an embedded system. To work in an embedded system, you will need to provide an appropriate driver for your system.

---

\textbf{NOTE: C I/O Mysteriously Fails}

If there is not enough space on the heap for a C I/O buffer, operations on the file will silently fail. If a call to print() mysteriously fails, this may be the reason. The heap needs to be at least large enough to allocate a block of size BUFSIZ (defined in stdio.h) for every file on which I/O is performed, including stdout, stdin, and stderr, plus allocations performed by the user’s code, plus allocation bookkeeping overhead. Alternately, declare a char array of size BUFSIZ and pass it to setvbuf to avoid dynamic allocation. To set the heap size, use the --heap_size option when linking (refer to the Linker Description chapter in the TMS320C6000 Assembly Language Tools User’s Guide).
**NOTE:** Open Mysteriously Fails

The run-time support limits the total number of open files to a small number relative to general-purpose processors. If you attempt to open more files than the maximum, you may find that the open will mysteriously fail. You can increase the number of open files by extracting the source code from rts.src and editing the constants controlling the size of some of the C I/O data structures. The macro `_NFILE` controls how many FILE (`fopen`) objects can be open at one time (stdin, stdout, and stderr count against this total). (See also `FOPEN_MAX`.) The macro `_NSTREAM` controls how many low-level file descriptors can be open at one time (the low-level files underlying stdin, stdout, and stderr count against this total). The macro `_NDEVICE` controls how many device drivers are installed at one time (the HOST device counts against this total).

### 8.2.1 High-Level I/O Functions

The high-level functions are the standard C library of stream I/O routines (`printf`, `scanf`, `fopen`, `getchar`, and so on). These functions call one or more low-level I/O functions to carry out the high-level I/O request. The high-level I/O routines operate on FILE pointers, also called streams.

Portable applications should use only the high-level I/O functions.

To use the high-level I/O functions, include the header file `stdio.h`, or `cstdio` for C++ code, for each module that references a C I/O function.

For example, given the following C program in a file named `main.c`:

```c
#include <stdio.h>

void main()
{
  FILE *fid;

  fid = fopen("myfile","w");
  fprintf(fid,"Hello, world\n");
  fclose(fid);

  printf("Hello again, world\n");
}
```

Issuing the following compiler command compiles, links, and creates the file `main.out` from the run-time-support library:

```sh
c16x main.c -z --heap_size=1000 --output_file=main.out
```

Executing `main.out` results in

```
Hello, world
```

being output to a file and

```
Hello again, world
```

being output to your host's `stdout` window.
8.2.2 Overview of Low-Level I/O Implementation

The low-level functions are comprised of seven basic I/O functions: open, read, write, close, lseek, rename, and unlink. These low-level routines provide the interface between the high-level functions and the device-level drivers that actually perform the I/O command on the specified device.

The low-level functions are designed to be appropriate for all I/O methods, even those which are not actually disk files. Abstractly, all I/O channels can be treated as files, although some operations (such as lseek) may not be appropriate. See Section 8.2.3 for more details.

The low-level functions are inspired by, but not identical to, the POSIX functions of the same names.

The low-level functions operate on file descriptors. A file descriptor is an integer returned by open, representing an opened file. Multiple file descriptors may be associated with a file; each has its own independent file position indicator.

open — Open File for I/O

Syntax

```c
#include <file.h>

int open (const char * path , unsigned flags , int file_descriptor );
```

Description

The open function opens the file specified by `path` and prepares it for I/O.

- The `path` is the filename of the file to be opened, including an optional directory path and an optional device specifier (see Section 8.2.5).

- The `flags` are attributes that specify how the file is manipulated. The flags are specified using the following symbols:

  - O_RDONLY (0x0000) /* open for reading */
  - O_WRONLY (0x0001) /* open for writing */
  - O_RDWR (0x0002) /* open for read & write */
  - O_APPEND (0x0008) /* append on each write */
  - O_CREAT (0x0200) /* open with file create */
  - O_TRUNC (0x0400) /* open with truncation */
  - O_BINARY (0x8000) /* open in binary mode */

Low-level I/O routines allow or disallow some operations depending on the flags used when the file was opened. Some flags may not be meaningful for some devices, depending on how the device implements files.

- The `file_descriptor` is assigned by open to an opened file.

  The next available file descriptor is assigned to each new file opened.

Return Value

The function returns one of the following values:

- non-negative file descriptor if successful
- -1 on failure
close  

### Close File for I/O

#### Syntax

```c
#include <file.h>

int close (int file_descriptor);
```

#### Description

The close function closes the file associated with `file_descriptor`. The `file_descriptor` is the number assigned by open to an opened file.

#### Return Value

The return value is one of the following:

- 0 if successful
- -1 on failure

---

read  

### Read Characters from a File

#### Syntax

```c
#include <file.h>

int read (int file_descriptor, char *buffer, unsigned count);
```

#### Description

The read function reads `count` characters into the `buffer` from the file associated with `file_descriptor`.

- The `file_descriptor` is the number assigned by open to an opened file.
- The `buffer` is where the read characters are placed.
- The `count` is the number of characters to read from the file.

#### Return Value

The function returns one of the following values:

- 0 if EOF was encountered before any characters were read
- # number of characters read (may be less than `count`)
- -1 on failure

---

write  

### Write Characters to a File

#### Syntax

```c
#include <file.h>

int write (int file_descriptor, const char *buffer, unsigned count);
```

#### Description

The write function writes the number of characters specified by `count` from the `buffer` to the file associated with `file_descriptor`.

- The `file_descriptor` is the number assigned by open to an opened file.
- The `buffer` is where the characters to be written are located.
- The `count` is the number of characters to write to the file.

#### Return Value

The function returns one of the following values:

- # number of characters written if successful (may be less than `count`)
- -1 on failure
**Iseek — Set File Position Indicator**

**Syntax for C**

```
#include <file.h>

off_t lseek (int file_descriptor, off_t offset, int origin);
```

**Description**

The lseek function sets the file position indicator for the given file to a location relative to the specified origin. The file position indicator measures the position in characters from the beginning of the file.

- The `file_descriptor` is the number assigned by open to an opened file.
- The `offset` indicates the relative offset from the `origin` in characters.
- The `origin` is used to indicate which of the base locations the `offset` is measured from. The `origin` must be one of the following macros:
  - `SEEK_SET` (0x0000) Beginning of file
  - `SEEK_CUR` (0x0001) Current value of the file position indicator
  - `SEEK_END` (0x0002) End of file

**Return Value**

The return value is one of the following:

- `new value of the file position indicator` if successful
- `(off_t)-1` on failure

---

**unlink** — **Delete File**

**Syntax**

```
#include <file.h>

int unlink (const char * path);
```

**Description**

The unlink function deletes the file specified by `path`. Depending on the device, a deleted file may still remain until all file descriptors which have been opened for that file have been closed. See Section 8.2.3.

The `path` is the filename of the file, including path information and optional device prefix. (See Section 8.2.5.)

**Return Value**

The function returns one of the following values:

- `0` if successful
- `-1` on failure
rename — Rename File

Syntax for C

```c
#include <stdio.h> | <file.h>

int rename (const char * old_name, const char * new_name);
```

Syntax for C++

```cpp
#include <cstdio> | <file.h>

int std::rename (const char * old_name, const char * new_name);
```

Description

The rename function changes the name of a file.
- The `old_name` is the current name of the file.
- The `new_name` is the new name for the file.

**NOTE:**
The optional device specified in the new name must match the device of the old name. If they do not match, a file copy would be required to perform the rename, and rename is not capable of this action.

Return Value

The function returns one of the following values:

<table>
<thead>
<tr>
<th>Value</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Successful</td>
</tr>
<tr>
<td>-1</td>
<td>Failure</td>
</tr>
</tbody>
</table>

**NOTE:** Although rename is a low-level function, it is defined by the C standard and can be used by portable applications.

### 8.2.3 Device-Driver Level I/O Functions

At the next level are the device-level drivers. They map directly to the low-level I/O functions. The default device driver is the HOST device driver, which uses the debugger to perform file operations. The HOST device driver is automatically used for the default C streams stdin, stdout, and stderr.

The HOST device driver shares a special protocol with the debugger running on a host system so that the host can perform the C I/O requested by the program. Instructions for C I/O operations that the program wants to perform are encoded in a special buffer named `_CIOBUF_` in the `.cio` section. The debugger halts the program at a special breakpoint (`$IO$`), reads and decodes the target memory, and performs the requested operation. The result is encoded into `_CIOBUF_`, the program is resumed, and the target decodes the result.

The HOST device is implemented with seven functions, HOSTopen, HOSTclose, HOSTread, HOSTwrite, HOSTlseek, HOSTunlink, and HOSTrename, which perform the encoding. Each function is called from the low-level I/O function with a similar name.

A device driver is composed of seven required functions. Not all function need to be meaningful for all devices, but all seven must be defined. Here we show the names of all seven functions as starting with DEV, but you may choose any name except for HOST.
**DEV_open**

---

**Open File for I/O**

### Syntax

```c
int DEV_open (const char *path, unsigned flags, int llv_fd);
```

### Description

This function finds a file matching `path` and opens it for I/O as requested by `flags`.

- The `path` is the filename of the file to be opened. If the name of a file passed to `open` has a device prefix, the device prefix will be stripped by `open`, so `DEV_open` will not see it. (See Section 8.2.5 for details on the device prefix.)

- The `flags` are attributes that specify how the file is manipulated. The flags are specified using the following symbols:

  - `O_RDONLY` (0x0000) /* open for reading */
  - `O_WRONLY` (0x0001) /* open for writing */
  - `O_RDWR` (0x0002) /* open for read & write */
  - `O_APPEND` (0x0008) /* append on each write */
  - `O_CREAT` (0x0200) /* open with file create */
  - `O_TRUNC` (0x0400) /* open with truncation */
  - `O_BINARY` (0x8000) /* open in binary mode */

  See POSIX for further explanation of the flags.

- The `llv_fd` is treated as a suggested low-level file descriptor. This is a historical artifact; newly-defined device drivers should ignore this argument. This differs from the low-level I/O open function.

This function must arrange for information to be saved for each file descriptor, typically including a file position indicator and any significant flags. For the HOST version, all the bookkeeping is handled by the debugger running on the host machine. If the device uses an internal buffer, the buffer can be created when a file is opened, or the buffer can be created during a read or write.

### Return Value

This function must return -1 to indicate an error if for some reason the file could not be opened; such as the file does not exist, could not be created, or there are too many files open. The value of `errno` may optionally be set to indicate the exact error (the HOST device does not set `errno`). Some devices might have special failure conditions; for instance, if a device is read-only, a file cannot be opened `O_WRONLY`.

On success, this function must return a non-negative file descriptor unique among all open files handled by the specific device. It need not be unique across devices. Only the low-level I/O functions will see this device file descriptor; the low-level function `open` will assign its own unique file descriptor.
DEV_close — Close File for I/O

Syntax
int DEV_close (int dev_fd);

Description
This function closes a valid open file descriptor.
On some devices, DEV_close may need to be responsible for checking if this is the last
file descriptor pointing to a file that was unlinked. If so, it is responsible for ensuring that
the file is actually removed from the device and the resources reclaimed, if appropriate.

Return Value
This function should return -1 to indicate an error if the file descriptor is invalid in some
way, such as being out of range or already closed, but this is not required. The user
should not call close() with an invalid file descriptor.

DEV_read — Read Characters from a File

Syntax
int DEV_read (int dev_fd, char * bu, unsigned count);

Description
The read function reads count bytes from the input file associated with dev_fd.
• The dev_fd is the number assigned by open to an opened file.
• The bu is where the read characters are placed.
• The count is the number of characters to read from the file.

Return Value
This function must return -1 to indicate an error if for some reason no bytes could be
read from the file. This could be because of an attempt to read from a O_WRONLY file,
or for device-specific reasons.
If count is 0, no bytes are read and this function returns 0.
This function returns the number of bytes read, from 0 to count. 0 indicates that EOF
was reached before any bytes were read. It is not an error to read less than count bytes;
this is common if the are not enough bytes left in the file or the request was larger than
an internal device buffer size.

DEV_write — Write Characters to a File

Syntax
int DEV_write (int dev_fd, const char * bu, unsigned count);

Description
This function writes count bytes to the output file.
• The dev_fd is the number assigned by open to an opened file.
• The buffer is where the write characters are placed.
• The count is the number of characters to write to the file.

Return Value
This function must return -1 to indicate an error if for some reason no bytes could be
written to the file. This could be because of an attempt to read from a O_RDONLY file,
or for device-specific reasons.
DEV_lseek — Set File Position Indicator

Syntax

```c
off_t lseek (int dev_fd, off_t offset, int origin);
```

Description

This function sets the file's position indicator for this file descriptor as `lseek`.

If `lseek` is supported, it should not allow a seek to before the beginning of the file, but it should support seeking past the end of the file. Such seeks do not change the size of the file, but if it is followed by a write, the file size will increase.

Return Value

If successful, this function returns the new value of the file position indicator.

This function must return -1 to indicate an error if for some reason no bytes could be written to the file. For many devices, the `lseek` operation is nonsensical (e.g. a computer monitor).

---

DEV_unlink — Delete File

Syntax

```c
int DEV_unlink (const char * path);
```

Description

Remove the association of the pathname with the file. This means that the file may no longer by opened using this name, but the file may not actually be immediately removed.

Depending on the device, the file may be immediately removed, but for a device which allows open file descriptors to point to unlinked files, the file will not actually be deleted until the last file descriptor is closed. See Section 8.2.3.

Return Value

This function must return -1 to indicate an error if for some reason the file could not be unlinked (delayed removal does not count as a failure to unlink.)

If successful, this function returns 0.

---

DEV_rename — Rename File

Syntax

```c
int DEV_rename (const char * old_name, const char * new_name);
```

Description

This function changes the name associated with the file.

- The `old_name` is the current name of the file.
- The `new_name` is the new name for the file.

Return Value

This function must return -1 to indicate an error if for some reason the file could not be renamed, such as the file doesn't exist, or the new name already exists.

NOTE: It is inadvisable to allow renaming a file so that it is on a different device. In general this would require a whole file copy, which may be more expensive than you expect.

If successful, this function returns 0.
8.2.4 Adding a User-Defined Device Driver for C I/O

The function add_device allows you to add and use a device. When a device is registered with add_device, the high-level I/O routines can be used for I/O on that device.

You can use a different protocol to communicate with any desired device and install that protocol using add_device; however, the HOST functions should not be modified. The default streams stdin, stdout, and stderr can be remapped to a file on a user-defined device instead of HOST by using freopen() as in Example 8-1. If the default streams are reopened in this way, the buffering mode will change to _IOFBF (fully buffered). To restore the default buffering behavior, call setvbuf on each reopened file with the appropriate value (_IOLBF for stdin and stdout, _IONBF for stderr).

The default streams stdin, stdout, and stderr can be mapped to a file on a user-defined device instead of HOST by using freopen() as shown in Example 8-1. Each function must set up and maintain its own data structures as needed. Some function definitions perform no action and should just return.

Example 8-1. Mapping Default Streams to Device

```c
#include <stdio.h>
#include <file.h>
#include "mydevice.h"

void main()
{
    add_device("mydevice", _MSA,
        MYDEVICE_open, MYDEVICE_close,
        MYDEVICE_read, MYDEVICE_write,
        MYDEVICE_lseek, MYDEVICE_unlink, MYDEVICE_rename);

    /*-----------------------------------------------------------------------*/
    /* Re-open stderr as a MYDEVICE file */
    /*-----------------------------------------------------------------------*/
    if (!freopen("mydevice:stderrfile", "w", stderr))
    {
        puts("Failed to freopen stderr");
        exit(EXIT_FAILURE);
    }

    /*-----------------------------------------------------------------------*/
    /* stderr should not be fully buffered; we want errors to be seen as */
    /* soon as possible. Normally stderr is line-buffered, but this example */
    /* doesn't buffer stderr at all. This means that there will be one call */
    /* to write() for each character in the message. */
    /*-----------------------------------------------------------------------*/
    if (setvbuf(stderr, NULL, _IONBF, 0))
    {
        puts("Failed to setvbuf stderr");
        exit(EXIT_FAILURE);
    }

    /*-----------------------------------------------------------------------*/
    /* Try it out! */
    /*-----------------------------------------------------------------------*/
    printf("This goes to stdout\n");
    fprintf(stderr, "This goes to stderr\n");
}
```
Use the low-level function add_device() to add your device to the device_table. The device table is a statically defined array that supports \( n \) devices, where \( n \) is defined by the macro \_NDEVICE found in stdio.h/cstdio.

The first entry in the device table is predefined to be the host device on which the debugger is running. The low-level routine add_device() finds the first empty position in the device table and initializes the device fields with the passed-in arguments. For a complete description, see the add_device function.

### 8.2.5 The device Prefix

A file can be opened to a user-defined device driver by using a device prefix in the pathname. The device prefix is the device name used in the call to add_device followed by a colon. For example:

```c
FILE *fptr = fopen("mydevice:file1", "r");
int fd = open("mydevice:file2", O_RDONLY, 0);
```

If no device prefix is used, the HOST device will be used to open the file.

#### add_device — Add Device to Device Table

Syntax for C

```c
#include <file.h>

int add_device(char * name,
               unsigned flags,
               int (* dopen)(const char *path, unsigned flags, int llv_fd),
               int (* dclose)(int dev_fd),
               int (* dread)(int dev_fd, char *buf, unsigned count),
               int (* dwrite)(int dev_fd, const char *buf, unsigned count),
               off_t (* dlseek)(int dev_fd, off_t ioffset, int origin),
               int (* dunlink)(const char *path),
               int (* drename)(const char *old_name, const char *new_name));
```

Defined in lowlev.c in rtssrc.zip

Description

The add_device function adds a device record to the device table allowing that device to be used for I/O from C. The first entry in the device table is predefined to be the HOST device on which the debugger is running. The function add_device() finds the first empty position in the device table and initializes the fields of the structure that represent a device.

To open a stream on a newly added device use fopen( ) with a string of the format devicename : filename as the first argument.

- The `name` is a character string denoting the device name. The name is limited to 8 characters.
- The `flags` are device characteristics. The flags are as follows:
  - \_SSA Denotes that the device supports only one open stream at a time
  - \_MSA Denotes that the device supports multiple open streams

  More flags can be added by defining them in file.h.

- The `dopen`, `dclose`, `dread`, `dwrite`, `dlseek`, `dunlink`, and `drename` specifiers are function pointers to the functions in the device driver that are called by the low-level functions to perform I/O on the specified device. You must declare these functions with the interface specified in Section 8.2.2. The device driver for the HOST that the TMS320C6000 debugger is run on are included in the C I/O library.

Return Value

The function returns one of the following values:

- 0 if successful
- -1 on failure
Example 8-2 does the following:

- Adds the device mydevice to the device table
- Opens a file named test on that device and associates it with the FILE pointer fid
- Writes the string Hello, world into the file
- Closes the file

Example 8-2 illustrates adding and using a device for C I/O:

**Example 8-2. Program for C I/O Device**

```c
#include <stdio.h>

extern int MYDEVICE_open(const char *path, unsigned flags, int fno);
extern int MYDEVICE_close(int fno);
extern int MYDEVICE_read(int fno, char *buffer, unsigned count);
extern int MYDEVICE_write(int fno, const char *buffer, unsigned count);
extern off_t MYDEVICE_lseek(int fno, off_t offset, int origin);
extern int MYDEVICE_unlink(const char *path);
extern int MYDEVICE_rename(const char *old_name, char *new_name);

main()
{
    FILE *fid;
    add_device("mydevice", _MSA, MYDEVICE_open, MYDEVICE_close, MYDEVICE_read,
               MYDEVICE_write, MYDEVICE_lseek, MYDEVICE_unlink, MYDEVICE_rename);
    fid = fopen("mydevice:test","w");
    fprintf(fid,"Hello, world\n");
    fclose(fid);
}
```
8.3 Handling Reentrancy (_register_lock() and _register_unlock() Functions)

The C standard assumes only one thread of execution, with the only exception being extremely narrow support for signal handlers. The issue of reentrancy is avoided by not allowing you to do much of anything in a signal handler. However, BIOS applications have multiple threads which need to modify the same global program state, such as the CIO buffer, so reentrancy is a concern.

Part of the problem of reentrancy remains your responsibility, but the run-time-support environment does provide rudimentary support for multi-threaded reentrancy by providing support for critical sections. This implementation does not protect you from reentrancy issues such as calling run-time-support functions from inside interrupts; this remains your responsibility.

The run-time-support environment provides hooks to install critical section primitives. By default, a single-threaded model is assumed, and the critical section primitives are not employed. In a multi-threaded system such as BIOS, the kernel arranges to install semaphore lock primitive functions in these hooks, which are then called when the run-time-support enters code that needs to be protected by a critical section.

Throughout the run-time-support environment where a global state is accessed, and thus needs to be protected with a critical section, there are calls to the function _lock(). This calls the provided primitive, if installed, and acquires the semaphore before proceeding. Once the critical section is finished, _unlock() is called to release the semaphore.

Usually BIOS is responsible for creating and installing the primitives, so you do not need to take any action. However, this mechanism can be used in multi-threaded applications which do not use the BIOS LCK mechanism.

You should not define the functions _lock() and _unlock() functions directly; instead, the installation functions are called to instruct the run-time-support environment to use these new primitives:

```c
void _register_lock (void (*lock)());
void _register_unlock(void (*unlock)());
```

The arguments to _register_lock() and _register_unlock() should be functions which take no arguments and return no values, and which implement some sort of global semaphore locking:

```c
extern volatile sig_atomic_t *sema = SHARED_SEMAPHORE_LOCATION;
static int sema_depth = 0;
static void my_lock(void)
{
    while (ATOMIC_TEST_AND_SET(sema, MY_UNIQUE_ID) != MY_UNIQUE_ID);
    sema_depth++;
}
static void my_unlock(void)
{
    if (!--sema_depth) ATOMIC_CLEAR(sema);
}
```

The run-time-support nests calls to _lock(), so the primitives must keep track of the nesting level.
8.4 C6700 FastMath Library

The C6700 FastMath Library provides hand-coded assembly-optimized versions of certain math functions. These implementations are two to three times faster than those found in the standard run-time-support library. However, these functions gain speed improvements at the cost of accuracy in the result.

The C6700 FastMath library contains these files:

- fastmath67x.lib—object library for use with little-endian C/C++ code
- fastmath67xe.lib—object library for use with big-endian C/C++ code
- fastmath67x.h—header file to be included with C/C++ code

To use the C67x FastMath library, specify it before the standard run-time-support library when linking your program. For example:

```
c6x -mv6700 --run_linker myprogram.obj --library=lnk.cmd --library=fastmath67x.lib --library=rts6700.lib
```

If you are using Code Composer Studio, include the C6700 FastMath library in your project, and ensure it appears before the standard run-time-support library in the Link Order tab in the Build Options dialog box.

For details, refer to the TMS320C67x FastRTS Library Programmer's Reference (SPRU100).
8.5 Library-Build Process

When using the C/C++ compiler, you can compile your code under a large number of different configurations and options that are not necessarily compatible with one another. Because it would be infeasible to include all possible run-time-support library variants, compiler releases pre-build only a small number of very commonly-used libraries such as rts6200.lib.

To provide maximum flexibility, the run-time-support source code is provided as part of each compiler release. You can build the missing libraries as desired. The linker can also automatically build missing libraries. This is accomplished with a new library build process, the core of which is the executable mklib, which is available beginning with CCS 5.1.

8.5.1 Required Non-Texas Instruments Software

To use the self-contained run-time-support build process to rebuild a library with custom options, the following are required:

- sh (Bourne shell)
- unzip (InfoZIP unzip 5.51 or later, or equivalent)
  You can download the software from http://www.info-zip.org.
- gmake (GNU make 3.81 or later)
  More information is available from GNU at http://www.gnu.org/software/make. GNU make (gmake) is also available in earlier versions of Code Composer Studio. GNU make is also included in some Unix support packages for Windows, such as the MKS Toolkit, Cygwin, and Interix. The GNU make used on Windows platforms should explicitly report "This program build for Windows32" when the following is executed from the Command Prompt window:

  gmake -h

All three of these programs are provided as a non-optional feature of CCS 5.1. They are also available as part of the optional XDC Tools feature if you are using an earlier version of CCS.

The mklib program looks for these executables in the following order:

1. in your PATH
2. in the directory getenv("CCS_UTILS_DIR")/cygwin
3. in the directory getenv("CCS_UTILS_DIR")/bin
4. in the directory getenv("XDCROOT")
5. in the directory getenv("XDCROOT")/bin

If you are invoking mklib from the command line, and these executables are not in your path, you must set the environment variable CCS_UTILS_DIR such that getenv("CCS_UTILS_DIR")/bin contains the correct programs.

8.5.2 Using the Library-Build Process

You should normally let the linker automatically rebuild libraries as needed. If necessary, you can run mklib directly to populate libraries. See Section 8.5.2.2 for situations when you might want to do this.

8.5.2.1 Automatic Standard Library Rebuilding by the Linker

The linker looks for run-time-support libraries primarily through the C6X_C_DIR environment variable. Typically, one of the pathnames in C6X_C_DIR is your install directory/lib, which contains all of the pre-built libraries, as well as the index library libc.a. The linker looks in C6X_C_DIR to find a library that is the best match for the build attributes of the application. The build attributes are set indirectly according to the command-line options used to build the application. Build attributes include things like CPU revision. If the library is explicitly named (e.g. rts6200.lib), run-time support looks for that library exactly; otherwise, it uses the index library libc.a to pick an appropriate library.
The index library describes a set of libraries with different build attributes. The linker will compare the build attributes for each potential library with the build attributes of the application and will pick the best fit. For details on the index library, see the archiver chapter in the *TMS320C6000 Assembly Language Tools User's Guide*.

Now that the linker has decided which library to use, it checks whether the run-time-support library is present in C6X_C_DIR. The library must be in exactly the same directory as the index library libc.a. If the library is not present, the linker will invoke mklib to build it. This happens when the library is missing, regardless of whether the user specified the name of the library directly or allowed the linker to pick the best library from the index library.

The mklib program builds the requested library and places it in 'lib' directory part of C6X_C_DIR in the same directory as the index library, so it is available for subsequent compilations.

Things to watch out for:

- The linker invokes `mklib` and waits for it to finish before finishing the link, so you will experience a one-time delay when an uncommonly-used library is built for the first time. Build times of 1-5 minutes have been observed. This depends on the power of the host (number of CPUs, etc).
- In a shared installation, where an installation of the compiler is shared among more than one user, it is possible that two users might cause the linker to rebuild the same library at the same time. The `mklib` program tries to minimize the race condition, but it is possible one build will corrupt the other. In a shared environment, all libraries which might be needed should be built at install time; see Section 8.5.2.2 for instructions on invoking `mklib` directly to avoid this problem.
- The index library must exist, or the linker is unable to rebuild libraries automatically.
- The index library must be in a user-writable directory, or the library is not built. If the compiler installation must be installed read-only (a good practice for shared installation), any missing libraries must be built at installation time by invoking `mklib` directly.
- The `mklib` program is specific to a certain version of a certain library; you cannot use one compiler version's run-time support's `mklib` to build a different compiler version's run-time support library.

### 8.5.2.2 Invoking mklib Manually

You may need to invoke `mklib` directly in special circumstances:

- The compiler installation directory is read-only or shared.
- You want to build a variant of the run-time-support library that is not pre-configured in the index library libc.a or known to mklib. (e.g. a variant with source-level debugging turned on.)

#### 8.5.2.2.1 Building Standard Libraries

You can invoke mklib directly to build any or all of the libraries indexed in the index library libc.a. The libraries are built with the standard options for that library; the library names and the appropriate standard option sets are known to mklib.

This is most easily done by changing the working directory to be the compiler run-time-support library directory 'lib' and invoking the `mklib` executable there:

```
mklib --pattern=rts6200.lib
```

#### 8.5.2.2.2 Shared or Read-Only Library Directory

If the compiler tools are to be installed in shared or read-only directory, mklib cannot build the standard libraries at link time; the libraries must be built before the library directory is made shared or read-only.

At installation time, the installing user must build all of the libraries which will be used by any user. To build all possible libraries, change the working directory to be the compiler RTS library directory 'lib' and invoke the mklib executable there:

```
mklib --all
```

Some targets have many libraries, so this step can take a long time. To build a subset of the libraries, invoke mklib individually for each desired library.
8.5.2.2.3 Building Libraries With Custom Options

You can build a library with any extra custom options desired. This is useful for building a debugging version of the library, or with silicon exception workarounds enabled. The generated library is not a standard library, and must not be placed in the "lib" directory. It should be placed in a directory local to the project which needs it. To build a debugging version of the library rts6200.lib, change the working directory to the "lib" directory and run the command:

```
mklib --pattern=rts6200.lib --name=rts6200_debug.lib --install_to=$Project/Debug --extra_options="-g"
```

8.5.2.2.4 The mklib Program Option Summary

Run the following command to see the full list of options. These are described in Table 8-1.

```
mklib --help
```

<table>
<thead>
<tr>
<th>Option</th>
<th>Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>--index=filename</td>
<td>The index library (libc.a) for this release. Used to find a template library for custom builds, and to find the source files (rtssrc.zip). REQUIRED.</td>
</tr>
<tr>
<td>--pattern=filename</td>
<td>Pattern for building a library. If neither --extra_options nor --options are specified, the library will be the standard library with the standard options for that library. If either --extra_options or --options are specified, the library is a custom library with custom options. REQUIRED unless --all is used.</td>
</tr>
<tr>
<td>--all</td>
<td>Build all standard libraries at once.</td>
</tr>
<tr>
<td>--install_to=directory</td>
<td>The directory into which to write the library. For a standard library, this defaults to the same directory as the index library (libc.a). For a custom library, this option is REQUIRED.</td>
</tr>
<tr>
<td>--compiler_bin_dir=directory</td>
<td>The directory where the compiler executables are. When invoking mklib directly, the executables should be in the path, but if they are not, this option must be used to tell mklib where they are. This option is primarily for use when mklib is invoked by the linker.</td>
</tr>
<tr>
<td>--name=filename</td>
<td>File name for the library with no directory part. Only useful for custom libraries.</td>
</tr>
<tr>
<td>--options='str'</td>
<td>Options to use when building the library. The default options (see below) are replaced by this string. If this option is used, the library will be a custom library.</td>
</tr>
<tr>
<td>--extra_options='str'</td>
<td>Options to use when building the library. The default options (see below) are also used. If this option is used, the library will be a custom library.</td>
</tr>
<tr>
<td>--list_libraries</td>
<td>List the libraries this script is capable of building and exit. ordinary system-specific directory.</td>
</tr>
<tr>
<td>--log=filename</td>
<td>Save the build log as filename.</td>
</tr>
<tr>
<td>--tmpdir=directory</td>
<td>Use directory for scratch space instead of the ordinary system-specific directory.</td>
</tr>
<tr>
<td>--gmake=filename</td>
<td>Gmake-compatible program to invoke instead of &quot;gmake&quot;</td>
</tr>
<tr>
<td>--parllele=N</td>
<td>Compile N files at once (&quot;gmake -j N&quot;).</td>
</tr>
<tr>
<td>--query=filename</td>
<td>Does this script know how to build FILENAME?</td>
</tr>
<tr>
<td>--help or --h</td>
<td>Display this help.</td>
</tr>
<tr>
<td>--quiet or --q</td>
<td>Operate silently.</td>
</tr>
<tr>
<td>--verbose or -v</td>
<td>Extra information to debug this executable.</td>
</tr>
</tbody>
</table>

Examples:

To build all standard libraries and place them in the compiler's library directory:

```
mklib --all --index=$C_DIR/lib
```

To build one standard library and place it in the compiler's library directory:

```
mklib --pattern=rts6200.lib --index=$C_DIR/lib
```

To build a custom library that is just like rts6200.lib, but has symbolic debugging support enabled:

```
mklib --pattern=rts6200.lib --extra_options="-g" --index=$C_DIR/lib --install_to=$Project/Debug --name=rts6200_debug.lib
```
8.5.3 Extending mklib

The mklib API is a uniform interface that allows Code Composer Studio to build libraries without needing to know exactly what underlying mechanism is used to build it. Each library vendor (e.g. the TI compiler) provides a library-specific copy of 'mklib' in the library directory that can be invoked, which understands a standardized set of options, and understands how to build the library. This allows the linker to automatically build application-compatible versions of any vendor's library without needing to register the library in advance, as long as the vendor supports mklib.

8.5.3.1 Underlying Mechanism

The underlying mechanism can be anything the vendor desires. For the compiler run-time-support libraries, mklib is just a wrapper which knows how to unpack Makefile from rtssrc.zip and invoke gmake with the appropriate options to build each library. If necessary, mklib can be bypassed and Makefile used directly, but this mode of operation is not supported by TI, and the you are responsible for any changes to Makefile. The format of the Makefile and the interface between mklib and the Makefile is subject to change without notice. The mklib program is the forward-compatible path.

8.5.3.2 Libraries From Other Vendors

Any vendor who wishes to distribute a library that can be rebuilt automatically by the linker must provide:

- An index library (like 'libc.a', but with a different name)
- A copy of mklib specific to that library
- A copy of the library source code (in whatever format is convenient)

These things must be placed together in one directory that is part of the linker's library search path (specified either in C6X_C_DIR or with the linker --search_path option).

If mklib needs extra information that is not possible to pass as command-line options to the compiler, the vendor will need to provide some other means of discovering the information (such as a configuration file written by a wizard run from inside CCS).

The vendor-supplied mklib must at least accept all of the options listed in Table 8-1 without error, even if they do not do anything.
The C++ compiler implements function overloading, operator overloading, and type-safe linking by encoding a function's prototype and namespace in its link-level name. The process of encoding the prototype into the linkname is often referred to as name mangling. When you inspect mangled names, such as in assembly files, disassembler output, or compiler or linker diagnostics, it can be difficult to associate a mangled name with its corresponding name in the C++ source code. The C++ name demangler is a debugging aid that translates each mangled name it detects to its original name found in the C++ source code.

These topics tell you how to invoke and use the C++ name demangler. The C++ name demangler reads in input, looking for mangled names. All unmangled text is copied to output unaltered. All mangled names are demangled before being copied to output.

<table>
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<td>9.3 Sample Usage of the C++ Name Demangler</td>
<td>270</td>
</tr>
</tbody>
</table>
9.1 Invoking the C++ Name Demangler

The syntax for invoking the C++ name demangler is:

\[
\text{dem6x}\ [\text{options}]\ [\text{filenames}]
\]

\textbf{dem6x} Command that invokes the C++ name demangler.

\textit{options} Options affect how the name demangler behaves. Options can appear anywhere on the command line. (Options are discussed in Section 9.2.)

\textit{filenames} Text input files, such as the assembly file output by the compiler, the assembler listing file, the disassembly file, and the linker map file. If no filenames are specified on the command line, dem6x uses standard input.

By default, the C++ name demangler outputs to standard output. You can use the -o file option if you want to output to a file.

9.2 C++ Name Demangler Options

The following options apply only to the C++ name demangler:

\[\text{-abi=abi}\] Demangles EABI identifiers

\[\text{-h}\] Prints a help screen that provides an online summary of the C++ name demangler options

\[\text{-o file}\] Outputs to the given file rather than to standard out

\[\text{-u}\] Specifies that external names do not have a C++ prefix

\[\text{-v}\] Enables verbose mode (outputs a banner)
9.3 Sample Usage of the C++ Name Demangler

The examples in this section illustrate the demangling process. Example 9-1 shows a sample C++ program. Example 9-2 shows the resulting assembly that is output by the compiler. In this example, the linknames of all the functions are mangled; that is, their signature information is encoded into their names.

Example 9-1. C++ Code for calories_in_a_banana

class banana {
public:
    int calories(void);
    banana();
    ~banana();
};
int calories_in_a_banana(void)
{
    banana x;
    return x.calories();
}

Example 9-2. Resulting Assembly for calories_in_a_banana

_execing the C++ name demangler demangles all names that it believes to be mangled. Enter:
dem6x calories_in_a_banana.asm
The result is shown in Example 9-3. The linknames in Example 9-2 ___ct__6bananaFv, _calories__6bananaFv, and ___dt__6bananaFv are demangled.

Example 9-3. Result After Running the C++ Name Demangler

calories_in_a_banana():
;** ----------------------------------------------------------------------*
    CALL .S1 banana::banana() ; |10|
    STW .D2T2 B3,*SP--(16) ; |9|
    MVKL .S2 RL0,B3 ; |10|
    MVKH .S2 RL0,B3 ; |10|
    ADD .S1X 8,SP,A4 ; |10|
    NOP 1
RL0: ; CALL OCCURS ; |10|
    CALL .S1 banana::calories() ; |12|
    MVKL .S2 RL1,B3 ; |12|
    ADD .S1X 8,SP,A4 ; |12|
    MVKH .S2 RL1,B3 ; |12|
    NOP 2
RL1: ; CALL OCCURS ; |12|
    CALL .S1 banana::~banana() ; |13|
    STW .D2T1 A4,**SP(4) ; |12|
    ADD .S1X 8,SP,A4 ; |13|
    MVKL .S2 RL2,B3 ; |13|
    MVX .S2 0x2,B4 ; |13|
    MVKH .S2 RL2,B3 ; |13|
RL2: ; CALL OCCURS ; |13|
    LDW .D2T1 **SP(4),A4 ; |12|
    LDW .D2T2 **SP(16),B3 ; |13|
    NOP 4
    RET .S2 B3 ; |13|
    NOP 5
; BRANCH OCCURS ; |13|
absolute lister — A debugging tool that allows you to create assembler listings that contain absolute addresses.

assignment statement — A statement that initializes a variable with a value.

autoinitialization — The process of initializing global C variables (contained in the .cinit section) before program execution begins.

autoinitialization at run time — An autoinitialization method used by the linker when linking C code. The linker uses this method when you invoke it with the --rom_model link option. The linker loads the .cinit section of data tables into memory, and variables are initialized at run time.

alias disambiguation — A technique that determines when two pointer expressions cannot point to the same location, allowing the compiler to freely optimize such expressions.

aliasing — The ability for a single object to be accessed in more than one way, such as when two pointers point to a single object. It can disrupt optimization, because any indirect reference could refer to any other object.

allocation — A process in which the linker calculates the final memory addresses of output sections.

ANSI — American National Standards Institute; an organization that establishes standards voluntarily followed by industries.

archive library — A collection of individual files grouped into a single file by the archiver.

archiver — A software program that collects several individual files into a single file called an archive library. With the archiver, you can add, delete, extract, or replace members of the archive library.

assembler — A software program that creates a machine-language program from a source file that contains assembly language instructions, directives, and macro definitions. The assembler substitutes absolute operation codes for symbolic operation codes and absolute or relocatable addresses for symbolic addresses.

assignment statement — A statement that initializes a variable with a value.

autoinitialization — The process of initializing global C variables (contained in the .cinit section) before program execution begins.

autoinitialization at run time — An autoinitialization method used by the linker when linking C code. The linker uses this method when you invoke it with the --rom_model link option. The linker loads the .cinit section of data tables into memory, and variables are initialized at run time.

big endian — An addressing protocol in which bytes are numbered from left to right within a word. More significant bytes in a word have lower numbered addresses. Endian ordering is hardware-specific and is determined at reset. See also little endian

block — A set of statements that are grouped together within braces and treated as an entity.

.bss section — One of the default object file sections. You use the assembler .bss directive to reserve a specified amount of space in the memory map that you can use later for storing data. The .bss section is uninitialized.

byte — Per ANSI/ISO C, the smallest addressable unit that can hold a character.
C/C++ compiler— A software program that translates C source statements into assembly language source statements.

code generator— A compiler tool that takes the file produced by the parser or the optimizer and produces an assembly language source file.

COFF— Common object file format; a system of object files configured according to a standard developed by AT&T. These files are relocatable in memory space.

command file— A file that contains options, filenames, directives, or commands for the linker or hex conversion utility.

comment— A source statement (or portion of a source statement) that documents or improves readability of a source file. Comments are not compiled, assembled, or linked; they have no effect on the object file.

compiler program— A utility that lets you compile, assemble, and optionally link in one step. The compiler runs one or more source modules through the compiler (including the parser, optimizer, and code generator), the assembler, and the linker.

configured memory— Memory that the linker has specified for allocation.

constant— A type whose value cannot change.

cross-reference listing— An output file created by the assembler that lists the symbols that were defined, what line they were defined on, which lines referenced them, and their final values.

.data section— One of the default object file sections. The .data section is an initialized section that contains initialized data. You can use the .data directive to assemble code into the .data section.

direct call— A function call where one function calls another using the function's name.

directives— Special-purpose commands that control the actions and functions of a software tool (as opposed to assembly language instructions, which control the actions of a device).

disambiguation— See alias disambiguation

dynamic memory allocation— A technique used by several functions (such as malloc, calloc, and realloc) to dynamically allocate memory for variables at run time. This is accomplished by defining a large memory pool (heap) and using the functions to allocate memory from the heap.

ELF— Executable and Linkable Format; a system of object files configured according to the System V Application Binary Interface specification.

emulator— A hardware development system that duplicates the TMS320C6000 operation.

entry point— A point in target memory where execution starts.

environment variable— A system symbol that you define and assign to a string. Environmental variables are often included in Windows batch files or UNIX shell scripts such as .cshrc or .profile.

epilog— The portion of code in a function that restores the stack and returns. See also pipelined-loop epilog.

executable object file— A linked, executable object file that is downloaded and executed on a target system.

expression— A constant, a symbol, or a series of constants and symbols separated by arithmetic operators.

external symbol— A symbol that is used in the current program module but defined or declared in a different program module.
file-level optimization— A level of optimization where the compiler uses the information that it has about the entire file to optimize your code (as opposed to program-level optimization, where the compiler uses information that it has about the entire program to optimize your code).

function inlining— The process of inserting code for a function at the point of call. This saves the overhead of a function call and allows the optimizer to optimize the function in the context of the surrounding code.

global symbol— A symbol that is either defined in the current module and accessed in another, or accessed in the current module but defined in another.

high-level language debugging— The ability of a compiler to retain symbolic and high-level language information (such as type and function definitions) so that a debugging tool can use this information.

indirect call— A function call where one function calls another function by giving the address of the called function.

initialization at load time— An autoinitlization method used by the linker when linking C/C++ code. The linker uses this method when you invoke it with the --ram_model link option. This method initializes variables at load time instead of run time.

initialized section— A section from an object file that will be linked into an executable object file.

input section— A section from an object file that will be linked into an executable object file.

integrated preprocessor— A C/C++ preprocessor that is merged with the parser, allowing for faster compilation. Stand-alone preprocessing or preprocessed listing is also available.

interlist feature— A feature that inserts as comments your original C/C++ source statements into the assembly language output from the assembler. The C/C++ statements are inserted next to the equivalent assembly instructions.

intrinsics— Operators that are used like functions and produce assembly language code that would otherwise be inexpressible in C, or would take greater time and effort to code.

ISO— International Organization for Standardization; a worldwide federation of national standards bodies, which establishes international standards voluntarily followed by industries.

kernel— The body of a software-pipelined loop between the pipelined-loop prolog and the pipelined-loop epilog.

K&R C— Kernighan and Ritchie C, the de facto standard as defined in the first edition of *The C Programming Language* (K&R). Most K&R C programs written for earlier, non-ISO C compilers should correctly compile and run without modification.

label— A symbol that begins in column 1 of an assembler source statement and corresponds to the address of that statement. A label is the only assembler statement that can begin in column 1.

linker— A software program that combines object files to form an executable object file that can be allocated into system memory and executed by the device.

listing file— An output file, created by the assembler, that lists source statements, their line numbers, and their effects on the section program counter (SPC).

little endian— An addressing protocol in which bytes are numbered from right to left within a word. More significant bytes in a word have higher numbered addresses. Endian ordering is hardware-specific and is determined at reset. See also big endian

loader— A device that places an executable object file into system memory.

loop unrolling— An optimization that expands small loops so that each iteration of the loop appears in your code. Although loop unrolling increases code size, it can improve the performance of your code.
macro—A user-defined routine that can be used as an instruction.

macro call—The process of invoking a macro.

macro definition—A block of source statements that define the name and the code that make up a macro.

macro expansion—The process of inserting source statements into your code in place of a macro call.

map file—An output file, created by the linker, that shows the memory configuration, section composition, section allocation, symbol definitions and the addresses at which the symbols were defined for your program.

memory map—A map of target system memory space that is partitioned into functional blocks.

name mangling—A compiler-specific feature that encodes a function name with information regarding the function's arguments return types.

object file—An assembled or linked file that contains machine-language object code.

object library—An archive library made up of individual object files.

operand—An argument of an assembly language instruction, assembler directive, or macro directive that supplies information to the operation performed by the instruction or directive.

optimizer—A software tool that improves the execution speed and reduces the size of C programs. See also assembly optimizer.

options—Command-line parameters that allow you to request additional or specific functions when you invoke a software tool.

output section—A final, allocated section in a linked, executable module.

parser—A software tool that reads the source file, performs preprocessing functions, checks the syntax, and produces an intermediate file used as input for the optimizer or code generator.

partitioning—The process of assigning a data path to each instruction.

pipelining—A technique where a second instruction begins executing before the first instruction has been completed. You can have several instructions in the pipeline, each at a different processing stage.

pop—An operation that retrieves a data object from a stack.

pragma—A preprocessor directive that provides directions to the compiler about how to treat a particular statement.

preprocessor—A software tool that interprets macro definitions, expands macros, interprets header files, interprets conditional compilation, and acts upon preprocessor directives.

program-level optimization—An aggressive level of optimization where all of the source files are compiled into one intermediate file. Because the compiler can see the entire program, several optimizations are performed with program-level optimization that are rarely applied during file-level optimization.

prolog—The portion of code in a function that sets up the stack. See also pipelined-loop prolog.

push—An operation that places a data object on a stack for temporary storage.

quiet run—An option that suppresses the normal banner and the progress information.

raw data—Executable code or initialized data in an output section.

relocation—A process in which the linker adjusts all the references to a symbol when the symbol's address changes.
run-time environment— The run time parameters in which your program must function. These parameters are defined by the memory and register conventions, stack organization, function call conventions, and system initialization.

run-time-support functions— Standard ISO functions that perform tasks that are not part of the C language (such as memory allocation, string conversion, and string searches).

run-time-support library— A library file, rts.src, that contains the source for the run time-support functions.

section— A relocatable block of code or data that ultimately will be contiguous with other sections in the memory map.

sign extend— A process that fills the unused MSBs of a value with the value's sign bit.

simulator— A software development system that simulates TMS320C6000 operation.

source file— A file that contains C/C++ code or assembly language code that is compiled or assembled to form an object file.

stand-alone preprocessor— A software tool that expands macros, #include files, and conditional compilation as an independent program. It also performs integrated preprocessing, which includes parsing of instructions.

static variable— A variable whose scope is confined to a function or a program. The values of static variables are not discarded when the function or program is exited; their previous value is resumed when the function or program is reentered.

storage class— An entry in the symbol table that indicates how to access a symbol.

string table— A table that stores symbol names that are longer than eight characters (symbol names of eight characters or longer cannot be stored in the symbol table; instead they are stored in the string table). The name portion of the symbol's entry points to the location of the string in the string table.

structure— A collection of one or more variables grouped together under a single name.

subsection— A relocatable block of code or data that ultimately will occupy continuous space in the memory map. Subsections are smaller sections within larger sections. Subsections give you tighter control of the memory map.

symbol— A string of alphanumeric characters that represents an address or a value.

symbolic debugging— The ability of a software tool to retain symbolic information that can be used by a debugging tool such as a simulator or an emulator.

target system— The system on which the object code you have developed is executed.

.text section— One of the default object file sections. The .text section is initialized and contains executable code. You can use the .text directive to assemble code into the .text section.

trigraph sequence— A 3-character sequence that has a meaning (as defined by the ISO 646-1983 Invariant Code Set). These characters cannot be represented in the C character set and are expanded to one character. For example, the trigraph ??' is expanded to ^.

trip count— The number of times that a loop executes before it terminates.

unconfigured memory— Memory that is not defined as part of the memory map and cannot be loaded with code or data.

uninitialized section— A object file section that reserves space in the memory map but that has no actual contents. These sections are built with the .bss and .usect directives.

unsigned value— A value that is treated as a nonnegative number, regardless of its actual sign.

variable— A symbol representing a quantity that can assume any of a set of values.
**word**— A 32-bit addressable location in target memory
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