TMS320C28x Optimizing C/C++ Compiler v6.0

User's Guide

Literature Number: SPRU514D
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About This Manual

The *TMS320C28x Optimizing C/C++ Compiler User's Guide* explains how to use these compiler tools:

- Compiler
- Post-link optimizer
- Library-build process
- 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 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:

cl2000 [*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:

cl2000 --silicon_version=28 --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 TMS320C2800™ core is referred to as TMS320C28x or C28x.

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

C: A Reference Manual (fourth edition), by Samuel P. Harbison, and Guy L. Steele Jr., published by Prentice Hall, Englewood Cliffs, New Jersey

ISO/IEC 9899:1989, International Standard - Programming Languages - C (The 1989 C Standard), International Organization for Standardization

ISO/IEC 9899:1999, International Standard - Programming Languages - C (The C Standard), International Organization for Standardization

ISO/IEC 14882-1998, International Standard - Programming Languages - C++ (The C++ Standard), International Organization for Standardization

Programming Embedded Systems in C and C++, by Michael Barr, Andy Oram (Editor), published by O'Reilly & Associates; ISBN: 1565923545, February 1999

Programming in C, Steve G. Kochan, Hayden Book Company

The C Programming Language (second edition), by Brian W. Kernighan and Dennis M. Ritchie, published by Prentice-Hall, Englewood Cliffs, New Jersey, 1988

The C++ Programming Language (second edition), Bjarne Stroustrup, published by Addison-Wesley Publishing Company, Reading, Massachusetts, 1990

The Annotated C++ Reference Manual, Margaret A. Ellis and Bjarne Stroustrup, published by Addison-Wesley Publishing Company, Reading, Massachusetts, 1990

Tool Interface Standards (TIS) DWARF Debugging Information Format Specification Version 2.0, TIS Committee, 1995

DWARF Debugging Information Format Version 3, DWARF Debugging Information Format Workgroup, Free Standards Group, 2005 (http://dwarfstd.org)

Related Documentation From Texas Instruments

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.

SPRU430— TMS320C28x DSP CPU and Instruction Set Reference Guide describes the central processing unit (CPU) and the assembly language instructions of the TMS320C28x fixed-point digital signal processors (DSPs). It also describes emulation features available on these DSPs.

SPRU513— TMS320C28x Assembly Language Tools User's Guide describes the assembly language tools (assembler and other tools used to develop assembly language code), assembler directives, macros, common object file format, and symbolic debugging directives for the TMS320C28x device.

SPRU566— TMS320x28xx, 28xxx Peripheral Reference Guide describes the peripheral reference guides of the 28x digital signal processors (DSPs).

SPRU625— TMS320C28x DSP/BIOS Application Programming Interface (API) Reference Guide describes development using DSP/BIOS.

Introduction to the Software Development Tools

The TMS320C28x™ is supported by a set of software development tools, which includes an optimizing C/C++ compiler, 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 assembler and linker are discussed in detail in the *TMS320C28x Assembly Language Tools User's Guide*.

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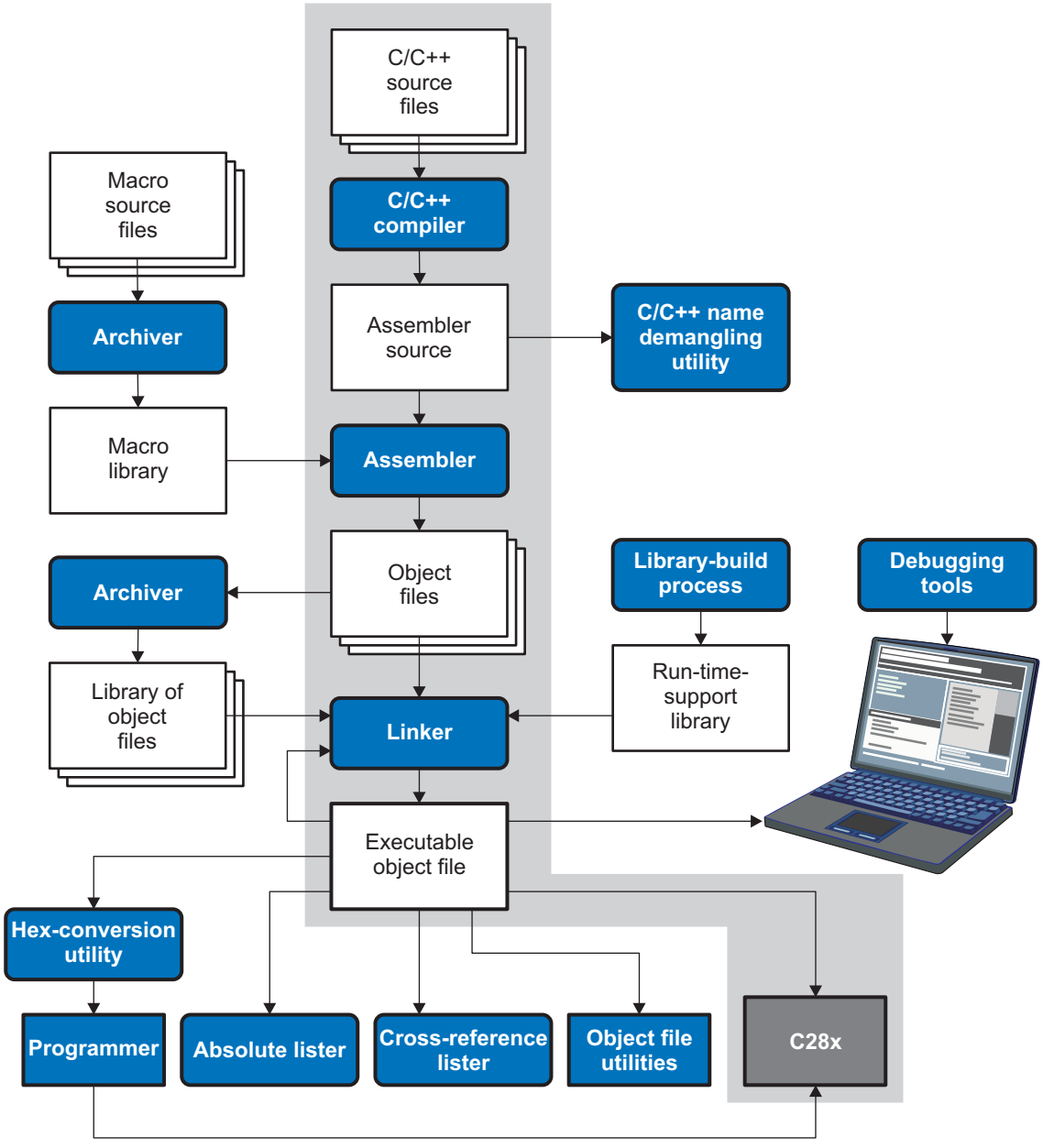
1.1 Software Development Tools Overview

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. TMS320C28x Software Development Flow



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

- The **compiler** accepts C/C++ source code and produces C28x assembly language source code. See Chapter 2.
- The **assembler** translates assembly language source files into machine language object modules. The *TMS320C28x Assembly Language Tools User's Guide* explains how to use the assembler.
- The **linker** combines object files into a single executable object module. As it creates the executable module, it performs relocation and resolves external references. The linker accepts relocatable object files and object libraries as input. See Chapter 4. The *TMS320C28x 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 modules. The *TMS320C28x Assembly Language Tools User's Guide* explains how to use the archiver.
- You can use the **library-build process** to build your own customized run-time-support library. See Section 8.5. Standard run-time-support library functions for C and C++ are provided in the self-contained rtssrc.zip file.

  The **run-time-support libraries** contain the standard ISO run-time-support functions, compiler-utility functions, floating-point arithmetic functions, and C I/O functions that are supported by the compiler. See Chapter 8.
- The **hex conversion utility** converts an object file into other object formats. You can download the converted file to an EPROM programmer. The *TMS320C28x 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 *TMS320C28x 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 *TMS320C28x 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 **post-link optimizer** removes or modifies assembly language instructions to generate better code. The post-link optimizer must be run with the compiler -plink option. See Chapter 5.
- The **disassembler** disassembles object files. The *TMS320C28x Assembly Language Tools User's Guide* explains how to use the disassembler.
- The main product of this development process is a module that can be executed in a **TMS320C28x** device.

1.2 C/C++ Compiler Overview

The following subsections describe the key features of the compiler.

1.2.1 ANSI/ISO Standard

These features pertain to ISO standards:

- **ISO-standard C**

  The C/C++ compiler conforms to the ISO C standard as defined by the ISO specification and described in the second edition of Kernighan and Ritchie's *The C Programming Language* (K&R). The ISO C standard supercedes and is the same as the ANSI C standard.
- **ISO-standard C++**

  The C/C++ compiler supports C++ as defined by the ISO C++ Standard and described in Ellis and Stroustrup's *The Annotated C++ Reference Manual* (ARM). 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 features pertain to output files 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.

1.2.3 Compiler Interface

These features pertain to interfacing with the compiler:

- **Compiler program**

  The compiler tools include a compiler program 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 pertain to the compiler utilities:

- **Library-build process**

  The library-build process 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 (dem2000) is a debugging aid that translates each mangled name it detects 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 files output by the compiler can be converted to EPROM programmer data files by using the hex conversion utility, as described in the *TMS320C28x Assembly Language Tools User's Guide*.

Using the C/C++ Compiler

The compiler translates your source program into machine language object code that the TMS320C28x 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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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 2.3.8 for more information.
- The **linker** combines object files to create an executable object file. The linker is optional, so you can compile and assemble many modules independently and link them later. See Chapter 4 for information about linking the files.

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 *TMS320C28x Assembly Language Tools User's Guide*.

2.2 Invoking the C/C++ Compiler

To invoke the compiler, enter:

cl2000 [*options*] [*filenames*] [**--run_linker** [*link_options*] *object files*]]

cl2000	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 2-2 through Table 2-26.
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 4 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:

```
cl2000 -v28 symtab.c file.c seek.asm --run_linker --library=lnk.cmd
       --library=rts2800.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 an online summary of the options, enter **cl2000** 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 C2000_C_OPTION environment variable. For a detailed description of the environment variable, see Section 2.4.1.

Table 2-2 through Table 2-26 summarize all options (including link options). Use the references in the tables for more complete descriptions of the options.

Table 2-1. Basic Options

Option	Alias	Effect	Section
--silicon_version=28	-v28	Specifies TMS320C28x architecture. When not specified defaults to TMS320C27x.	Section 2.3.3
--large_memory_model	-ml	Generates large memory model code and allows conditional compilation of 16-bit code with large memory model code	Section 2.3.3, Section 6.6.1
--unified_memory	-mt	Generates code for the unified memory model	Section 2.3.3
--symdebug:dwarf	-g	Enables symbolic debugging	Section 2.3.4 Section 3.8.1
--symdebug:coff		Enables symbolic debugging using the alternate STABS debugging format.	Section 2.3.4 Section 3.8.1
--symdebug:none		Disables all symbolic debugging	Section 2.3.4
--symdebug:profile_coff		Enables profiling using the alternate STABS debugging format.	Section 2.3.4
--symdebug:skeletal		Enables minimal symbolic debugging that does not hinder optimizations (default behavior)	Section 2.3.4
--opt_level[=0-4]	-O	Optimization level (Default:2)	Section 3.1
--opt_for_space[=0-3]	-ms	Optimize for code size (Default: 0)	Section 3.9

Table 2-2. Control Options

Option	Alias	Effect	Section
--compile_only	-c	Disables linking (negates --run_linker)	Section 4.1.3
--help	-h	Prints (on the standard output device) a description of the options understood by the compiler.	Section 2.3.1
--run_linker	-z	Enables linking	Section 2.3.1
--skip_assembler	-n	Compiles or assembly optimizes only	Section 2.3.1

Table 2-3. Symbolic Debug Options

Option	Alias	Effect	Section
--symdebug:dwarf	-g	Enables symbolic debugging	Section 2.3.4 Section 3.8.1
--symdebug:coff		Enables symbolic debugging using the alternate STABS debugging format.	Section 2.3.4 Section 3.8.1
--symdebug:none		Disables all symbolic debugging	Section 2.3.4
--symdebug:profile_coff		Enables profiling using the alternate STABS debugging format.	Section 2.3.4
--symdebug:skeletal		Enables minimal symbolic debugging that does not hinder optimizations (default behavior)	Section 2.3.4

Table 2-4. Language Options

Option	Alias	Effect	Section
--check_misra={all|required| advisory|none|*rulespec*}		Enables checking of the specified MISRA-C:2004 rules	Section 2.3.2
--cpp_default	-fg	Processes all source files with a C extension as C++ source files.	Section 2.3.6
--embedded_cpp	-pe	Enables embedded C++ mode	Section 6.14.3
--exceptions		Enables C++ exception handling	Section 6.7
--extern_c_can_throw		Allow extern C functions to propagate exceptions	
--gcc		Enables support for GCC extensions	Section 6.15
--gen_asp_raw	-pl	Generates a raw listing file	Section 2.10
--gen_acp_xref	-px	Generates a cross-reference listing file	Section 2.9
--keep_unneeded_statics		Keeps unreferenced static variables.	Section 2.3.2
--kr_compatible	-pk	Allows K&R compatibility	Section 6.14.1
--misra_advisory={error|warning| remark|suppress}		Sets the diagnostic severity for advisory MISRA-C:2004 rules	Section 2.3.2
--misra_required={error|warning| remark|suppress}		Sets the diagnostic severity for required MISRA-C:2004 rules	Section 2.3.2
--multibyte_chars	-pc	Enables multibyte character support.	-
--no_inlining	-pi	Disables definition-controlled inlining (but --opt_level=3 (or -O3) optimizations still perform automatic inlining)	Section 2.11
--no_intrinsics	-pn	Disables intrinsic functions. No predefinition of compiler-supplied intrinsic functions.	-
--program_level_compile	-pm	Combines source files to perform program-level optimization	Section 3.3
--relaxed_ansi	-pr	Enables relaxed mode; ignores strict ISO violations	Section 6.14.2
--rtti	-rtti	Enables run time type information (RTTI)	–
--static_template_instantiation		Instantiate all template entities with internal linkage	–
--strict_ansi	-ps	Enables strict ISO mode (for C/C++, not K&R C)	Section 6.14.2

Table 2-5. Parser Preprocessing Options

Option	Alias	Effect	Section
--preproc_dependency[=*filename*]	-ppd	Performs preprocessing only, but instead of writing preprocessed output, writes a list of dependency lines suitable for input to a standard make utility	Section 2.6.7
--preproc_includes[=*filename*]	-ppi	Performs preprocessing only, but instead of writing preprocessed output, writes a list of files included with the #include directive	Section 2.6.8
--preproc_macros[=*filename*]	-ppm	Performs preprocessing only. Writes list of predefined and user-defined macros to a file with the same name as the input but with a .pp extension.	Section 2.6.9
--preproc_only	-ppo	Performs preprocessing only. Writes preprocessed output to a file with the same name as the input but with a .pp extension.	Section 2.6.3
--preproc_with_comment	-ppc	Performs preprocessing only. Writes preprocessed output, keeping the comments, to a file with the same name as the input but with a .pp extension.	Section 2.6.5

Table 2-5. Parser Preprocessing Options (continued)

Option	Alias	Effect	Section
--preproc_with_compile	-ppa	Continues compilation after preprocessing	Section 2.6.4
--preproc_with_line	-ppl	Performs preprocessing only. Writes preprocessed output with line-control information (#line directives) to a file with the same name as the input but with a .pp extension.	Section 2.6.6

Table 2-6. Predefined Symbols Options

Option	Alias	Effect	Section
--define=*name*[=*def*]	-D	Predefines *name*	Section 2.3.1
--undefine=*name*	-U	Undefines *name*	Section 2.3.1

Table 2-7. Include Options

Option	Alias	Effect	Section
--include_path=*directory*	`-I`	Defines #include search path	Section 2.6.2.1
--preinclude=*filename*		Includes *filename* at the beginning of compilation	Section 2.3.2

Table 2-8. Diagnostics Options

Option	Alias	Effect	Section
--compiler_revision		Prints out the compiler release revision and exits	--
--diag_error=*num*	-pdse	Categorizes the diagnostic identified by *num* as an error	Section 2.7.1
--diag_remark=*num*	-pdsr	Categorizes the diagnostic identified by *num* as a remark	Section 2.7.1
--diag_suppress=*num*	-pds	Suppresses the diagnostic identified by *num*	Section 2.7.1
--diag_warning=*num*	-pdsw	Categorizes the diagnostic identified by *num* as a warning	Section 2.7.1
--display_error_number	-pden	Displays a diagnostic's identifiers along with its text	Section 2.7.1
--emit_warnings_as_errors	-pdew	Treat warnings as errors	Section 2.7.1
--issue_remarks	-pdr	Issues remarks (nonserious warnings)	Section 2.7.1
--no_warnings	-pdw	Suppresses warning diagnostics (errors are still issued)	Section 2.7.1
--quiet	-q	Suppresses progress messages (quiet)	--
--set_error_limit=*num*	-pdel	Sets the error limit to *num*. The compiler abandons compiling after this number of errors. (The default is 100.)	Section 2.7.1
--super_quiet	-qq	Super quiet mode	--
--tool_version	-version	Displays version number for each tool	--
--verbose		Display banner and function progress information	--
--verbose_diagnostics	-pdv	Provides verbose diagnostics that display the original source with line-wrap	Section 2.7.1
--write_diagnostics_file	-pdf	Generates a diagnostics information file. Compiler only option.	Section 2.7.1

Table 2-9. Run-Time Model Options

Option	Alias	Effect	Section
--silicon_version=28	-v28	Specifies TMS320C28x architecture. (When not specified defaults to TMS320C27x.)	Section 2.3.3.
--large_memory_model	-ml	Generates large memory model code and allows conditional compilation of 16-bit code with large memory model code	Section 2.3.3, Section 6.6.1
--unified_memory	-mt	Generates code for the unified memory model	Section 2.3.3
--asm_code_fill=*value*		Specifies assembler fill value for code sections. Default is zero.	Section 2.3.3
--asm_data_fill=*value*		Specifies fill value for data sections. Default is NOP instructions.	Section 2.3.3
--c2xlp_src_compatible	-m20	Accepts C2xLP assembly instructions	Section 2.3.3
--cla_support=cla0		Specifies TMS320C28x CLA accelerator support	Section 2.3.3
--disable_dp_load_opt	-md	Disables DP load optimizations	Section 2.3.3

Table 2-9. Run-Time Model Options (continued)

Option	Alias	Effect	Section
--float_support={fpu32|softlib|fpu64}		Specifies TMS320C28x 32- or 64-bit hardware floating-point support; default is softlib.	Section 2.3.3
--fp_reassoc={on|off}		Enables or disables the reassociation of floating-point arithmetic	Section 2.3.3
--gen_func_subsections={on|off}	-mo	Puts each function in a separate subsection in the object file	Section 4.2.1
--no_fast_branch	-me	Disables generation of fast branch instructions	Section 2.3.3
--no_rpt	-mi	Disables generation of RPT instructions	Section 2.3.3
--optimize_with_debug	-mn	Reenables optimizations disabled with --symdebug:dwarf	Section 3.8.1
-plink		Performs post-link optimization; must follow the --run_linker option	
--profile:power		Enables power profiling	Section 2.3.4 Section 3.8.2
--protect_volatile	-mv	Enables volatile reference protection	Section 2.3.3
--rpt_threshold=*k*		Generates RPT loops that iterate *k* times or less. (k is a constant between 0 and 256.)	Section 2.3.3
--sat_reassoc={on|off}		Enables or disables the reassociation of saturating arithmetic. Default is --sat_reassoc=off.	
--vcu_support[=vcu0]		Specifies C28x VCU coprocessor support; default is vcu0	Section 2.3.3

Table 2-10. Optimization Options[(1)]

Option	Alias	Effect	Section
--opt_level=0	-O0	Optimizes register usage	Section 3.1
--opt_level=1	-O1	Uses -O0 optimizations and optimizes locally	Section 3.1
--opt_level=2	-O2 or -O	Uses -O1 optimizations and optimizes globally (default)	Section 3.1
--opt_level=3	-O3	Uses -O2 optimizations and optimizes the file	Section 3.1 Section 3.2
--opt_level=4	-O4	Uses -O3 optimizations and performs link-time optimization	Section 3.4
--opt_for_space=*n*	-ms	Controls code size on four levels (0, 1, 2, and 3)	Section 3.9
--auto_inline=[*size*]	-oi	Sets automatic inlining size (--opt_level=3 only). If *size* is not specified, the default is 1.	Section 3.6
--call_assumptions=0	-op0	Specifies that the module contains functions and variables that are called or modified from outside the source code provided to the compiler	Section 3.3.1
--call_assumptions=1	-op1	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	Section 3.3.1
--call_assumptions=2	-op2	Specifies that the module contains no functions or variables that are called or modified from outside the source code provided to the compiler (default)	Section 3.3.1
--call_assumptions=3	-op3	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	Section 3.3.1
--gen_opt_info=0	-on0	Disables the optimization information file	Section 3.2.2
--gen_opt_info=1	-on1	Produces an optimization information file	Section 3.2.2
--gen_opt_info=2	-on2	Produces a verbose optimization information file	Section 3.2.2
--opt_for_speed=*n*	-mf	Optimizes for speed over space (0-5 range)	Section 3.9
--optimizer_interlist	-os	Interlists optimizer comments with assembly statements	Section 3.7
--remove_hooks_when_inlining		Removes entry/exit hooks for auto-inlined functions	Section 2.13
--single_inline		Inlines functions that are only called once	
--aliased_variables	-ma	Assumes called functions create hidden aliases (rare)	Section 3.5.2.2

(1) **Note:** Machine-specific options (see Table 2-9) can also affect optimization.

Table 2-11. Entry/Exit Hook Options

Option	Alias	Effect	Section
--entry_hook[=*name*]		Enables entry hooks	Section 2.13
--entry_parm={none|name|address}		Specifies the parameters to the function to the --entry_hook option	Section 2.13
--exit_hook[=*name*]		Enables exit hooks	Section 2.13
--exit_parm={none|name|address}		Specifies the parameters to the function to the --exit_hook option	Section 2.13

Table 2-12. Library Function Assumptions Options

Option	Alias	Effect	Section
--printf_support={nofloat|full|minimal}		Enables support for smaller, limited versions of the printf and sprintf run-time-support functions.	Section 2.3.2
--std_lib_func_defined	-ol1 or -oL1	Informs the optimizer that your file declares a standard library function	Section 3.2.1
--std_lib_func_not_defined	-ol2 or -oL2	Informs the optimizer that your file does not declare or alter library functions. Overrides the -ol0 and -ol1 options (default).	Section 3.2.1
--std_lib_func_redefined	-ol0 or -oL0	Informs the optimizer that your file alters a standard library function	Section 3.2.1

Table 2-13. Assembler Options

Option	Alias	Effect	Section
--keep_asm	-k	Keeps the assembly language (.asm) file	Section 2.3.10
--asm_listing	-al	Generates an assembly listing file	Section 2.3.10
--c_src_interlist	-ss	Interlists C source and assembly statements	Section 2.12 Section 3.7
--src_interlist	-s	Interlists optimizer comments (if available) and assembly source statements; otherwise interlists C and assembly source statements	Section 2.3.1
--absolute_listing	-aa	Enables absolute listing	Section 2.3.10
--asm_code_fill=*value*		Specifies fill value for code sections. Default is zero.	Section 2.3.10
--asm_data_fill=*value*		Specifies fill value for data sections. Default is NOP instructions.	Section 2.3.10
--asm_define=*name*[=*def*]	-ad	Sets the *name* symbol	Section 2.3.10
--asm_dependency	-apd	Performs preprocessing; lists only assembly dependencies	Section 2.3.10
--asm_includes	-api	Performs preprocessing; lists only included #include files	Section 2.3.10
--asm_remarks	-mw	Enables additional assembly-time checking	Section 2.3.10
--asm_undefine=*name*	-au	Undefines the predefined constant *name*	Section 2.3.10
--cdebug_asm_data	-mg	Produces C-type symbolic debugging for assembly variables	Section 2.3.10
--copy_file=*filename*	-ahc	Copies the specified file for the assembly module	Section 2.3.10
--cross_reference	-ax	Generates the cross-reference file	Section 2.3.10
--flash_prefetch_warn		Assembler warnings for F281X BF flash prefetch issue	Section 2.3.10
--include_file=*filename*	-ahi	Includes the specified file for the assembly module	Section 2.3.10
--no_const_clink		Stops generation of .clink directives for const global arrays.	Section 2.3.2
--output_all_syms	-as	Puts labels in the symbol table	Section 2.3.10
--preproc_asm	-mx	Preprocesses assembly source, expands assembly macros	Section 2.3.10
--syms_ignore_case	-ac	Makes case insignificant in assembly source files	Section 2.3.10

Table 2-14. File Type Specifier Options

Option	Alias	Effect	Section
--asm_file=*filename*	-fa	Identifies *filename* as an assembly source file regardless of its extension. By default, the compiler and assembler treat .asm files as assembly source files.	Section 2.3.6
--c_file=*filename*	-fc	Identifies *filename* as a C source file regardless of its extension. By default, the compiler treats .c files as C source files.	Section 2.3.6
--cpp_file=*filename*	-fp	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.	Section 2.3.6
--obj_file=*filename*	-fo	Identifies *filename* as an object code file regardless of its extension. By default, the compiler and linker treat .obj files as object code files.	Section 2.3.6

Table 2-15. Directory Specifier Options

Option	Alias	Effect	Section
--abs_directory=*directory*	-fb	Specifies an absolute listing file directory. By default, the compiler uses the .obj directory.	Section 2.3.9
--asm_directory=*directory*	-fs	Specifies an assembly file directory. By default, the compiler uses the current directory.	Section 2.3.9
--list_directory=*directory*	-ff	Specifies an assembly listing file and cross-reference listing file directory By default, the compiler uses the .obj directory.	Section 2.3.9
--obj_directory=*directory*	-fr	Specifies an object file directory. By default, the compiler uses the current directory.	Section 2.3.9
--output_file=*filename*	-fe	Specifies a compilation output file name; can override --obj_directory.	Section 2.3.9
--pp_directory=*dir*		Specifies a preprocessor file directory. By default, the compiler uses the current directory.	Section 2.3.9
--temp_directory=*directory*	-ft	Specifies a temporary file directory. By default, the compiler uses the current directory.	Section 2.3.9

Table 2-16. Default File Extensions Options

Option	Alias	Effect	Section
--asm_extension=[.]*extension*	-ea	Sets a default extension for assembly source files	Section 2.3.8
--c_extension=[.]*extension*	-ec	Sets a default extension for C source files	Section 2.3.8
--cpp_extension=[.]*extension*	-ep	Sets a default extension for C++ source files	Section 2.3.8
--listing_extension=[.]*extension*	-es	Sets a default extension for listing files	Section 2.3.8
--obj_extension=[.]*extension*	-eo	Sets a default extension for object files	Section 2.3.8

Table 2-17. Command Files Options

Option	Alias	Effect	Section
--cmd_file=*filename*	-@	Interprets contents of a file as an extension to the command line. Multiple -@ instances can be used.	Section 2.3.1

The following tables list the linker options. See the *TMS320C28x Assembly Language Tools User's Guide* for details on these options.

Table 2-18. Linker Basic Options Summary

Option	Alias	Description
--output_file=*file*	-o	Names the executable output module. The default filename is a.out.
--map_file=*file*	-m	Produces a map or listing of the input and output sections, including holes, and places the listing in *filename*
--heap_size=*size*	[-]-heap	Sets heap size (for the dynamic memory allocation in C) to *size* words and defines a global symbol that specifies the heap size. Default = 1K words
--stack_size=*size*	[-]-stack	Sets C system stack size to *size* words and defines a global symbol that specifies the stack size. Default = 1K words

Table 2-19. Command File Preprocessing Options Summary

Option	Alias	Description
--define=*name*=*value*		Predefines *name* as a preprocessor macro.
--undefine=*name*		Removes the preprocessor macro *name*.
--disable_pp		Disables preprocessing for command files

Table 2-20. Diagnostic Options Summary

Option	Alias	Description
--diag_error=*num*		Categorizes the diagnostic identified by *num* as an error
--diag_remark=*num*		Categorizes the diagnostic identified by *num* as a remark
--diag_suppress=*num*		Suppresses the diagnostic identified by *num*
--diag_warning=*num*		Categorizes the diagnostic identified by *num* as a warning
--display_error_number		Displays a diagnostic's identifiers along with its text
--emit_warnings_as_errors	-pdew	Treat warnings as errors
--issue_remarks		Issues remarks (nonserious warnings)
--no_demangle		Disables demangling of symbol names in diagnostics
--no_warnings		Suppresses warning diagnostics (errors are still issued)
--set_error_limit=*count*		Sets the error limit to *count*. The linker abandons linking after this number of errors. (The default is 100.)
--verbose_diagnostics		Provides verbose diagnostics that display the original source with line-wrap
--warn_sections	-w	Displays a message when an undefined output section is created

Table 2-21. File Search Path Options Summary

Option	Alias	Description
--library=*file*	-l	Names an archive library or link command *file* as linker input
--search_path=*pathname*	`-I`	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.
--disable_auto_rts		Disables the automatic selection of a run-time-support library
--priority	-priority	Satisfies unresolved references by the first library that contains a definition for that symbol
--reread_libs	-x	Forces rereading of libraries, which resolves back references

Table 2-22. Linker Output Options Summary

Option	Alias	Description
--output_file=*file*	-o	Names the executable output module. The default filename is a.out.
--map_file=*file*	-m	Produces a map or listing of the input and output sections, including holes, and places the listing in *filename*
--absolute_exe	-a	Produces an absolute, executable module. This is the default; if neither --absolute_exe nor --relocatable is specified, the linker acts as if --absolute_exe were specified.
--mapfile_contents=*attribute*		Controls the information that appears in the map file.
--relocatable	-r	Produces a nonexecutable, relocatable output module
--rom		Creates a ROM object
--run_abs	-abs	Produces an absolute listing file
--xml_link_info=*file*		Generates a well-formed XML *file* containing detailed information about the result of a link

Table 2-23. Symbol Management Options Summary

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

Table 2-24. Run-Time Environment Options Summary

Option	Alias	Description
--heap_size=*size*	[-]-heap	Sets heap size (for the dynamic memory allocation in C) to *size* words and defines a global symbol that specifies the heap size. Default = 1K words
--stack_size=*size*	[-]-stack	Sets C system stack size to *size* words and defines a global symbol that specifies the stack size. Default = 1K words
--arg_size=*size*	--args	Reserve *size* bytes for the argc/argv memory area
--far_heapsize	-farheap	Sets far heap size (words).
--fill_value=*value*	-f	Sets default fill value for holes within output sections
--ram_model	-cr	Initializes variables at load time
--rom_model	-c	Autoinitializes variables at run time

Table 2-25. Link-Time Optimization Options Summary[(1)]

Option	Alias	Description
--no_postlink_across_calls	-nf	Disable post-link optimizations across functions.
--postlink_exclude	-ex	Exclude files from post-link pass
--postlink_opt	-plink	Post-link optimizations (only after -z)

(1) See Chapter 5 for details.

Table 2-26. Miscellaneous Options Summary

Option	Alias	Description
--disable_clink	-j	Disables conditional linking of COFF object modules
--linker_help	[-]-help	Displays information about syntax and available options
--preferred_order=*function*		Prioritizes placement of functions
--strict_compatibility[=off|on]		Performs more conservative and rigorous compatibility checking of input object files. Default is on.

Table 2-27. Dynamic Linking Options Summary

Option	Description
--dynamic[=exe|lib]]	Generates dynamic executable or a dynamic library. Default is .exe.
--export=*symbol*	Specifies *symbol* exported
--fini=*symbol*	Specifies *symbol* name of termination code
--forced_static_binding[=off|on]	Forces all import references to bind during static linking; defaults to on
--import=*symbol*	Specifies *symbol* imported
--init=*symbol*	Specifies *symbol* name of termination code
--rpath=*dir*	Adds directory to beginning of library search path
--runpath=*dir*	Adds directory to end of library search path
--soname=*soname*	Specifies shared object file name

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 3.7. 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:

```
cl2000 -v28 --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 C2000_C_OPTION environment variable and you do not want to link. See Section 4.1.3.

--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.

--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 4.1.

--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 --fp_mode=relaxed is specified, --fp_reassoc=on is set automatically. 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 floating point values. Supports all format specifiers except %f, %g, %G, %e, and %E.
- minimal: Supports the printing 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 TMS320C28x toolset. See the referenced sections for more information.

--asm_code_fill=*value* Specifies fill value to fill the holes in code sections created by the assembler. You can specify a 16-bit value in decimal, octal, or hexadecimal format.

--asm_data_fill=*value* Specifies fill value to fill the holes in data sections created by the assembler. You can specify a 16-bit value in decimal, octal, or hexadecimal format.

--c2xlp_src_compatible Accepts C2xLP assembly instructions and encodes them as equivalent C28x instructions.

--cla_support	Specifies TMS320C28x Control Law Accelerator (CLA) version 0 support. This option is useful only if the source is assembly code, written for the CLA. The option is ignored for C/C++ code. This option does not need any special library support at the linker; the libraries used for C28x with/without FPU support should be sufficient.
--disable_dp_load_opt	Disables the compiler from optimizing redundant loads of the DP register when using DP direct addressing.
--float_support={fpu32|fpu64}	Specifies TMS320C28x with hardware floating-point support and generates large memory model code. Using --float_support=fpu32 specifies the C28x architecture with 32-bit hardware floating-point support. Using --float_support=fpu64 specifies the C28x architecture with 64-bit hardware floating-point support.
--large_memory_model	Generates large memory model code. This forces the compiler to view the architecture as having a flat 22-bit address space. All pointers are considered to be 22-bit pointers. The main use of --large_memory_model is with C++ code to access memory beyond 16 bits. Also allows conditional compilation of 16-bit code with large memory model. Defines the LARGE_MODEL symbol and sets it to true. For more information, see Section 6.6.1.
--no_fast_branch	Prevents the compiler from generating TMS320C28x fast branch instructions (BF). Fast branch instructions are generated by the compiler by default when possible.
--no_rpt	Prevents the compiler from generating repeat (RPT) instructions. By default, repeat instructions are generated for certain memcpy operations and certain division operations. However, repeat instructions are not interruptible.
--protect_volatile=*num*	Enables volatile reference protection. Pipeline conflicts may occur between non-local variables that have been declared volatile. A conflict can occur between a write to one volatile variable that is followed by a read from a different volatile variable. The --protect_volatile option allows at least *num* instructions to be placed between the two volatile references to ensure the write occurs before the read. The num is optional. If no num is given, the default value is 2. For example, if --protect_volatile=4 is used, volatile writes and volatile reads are protected by at least 4 instructions. The peripheral pipeline protection hardware protects all internal peripherals and XINTF zone 1. If you connect peripherals to Xintf zone 0, 2, 6, 7 then you may need to use the --protect_volatile option. Hardware protection or using this option is not required for memories.
--rpt_threshold=*k*	Generates RPT loops that iterate *k* times or less (k is a constant between 0 and 256). Multiple RPT's may be generated for the same loop, if iteration count is more than k and if code size does not increase too much. Using this option when optimizing for code size disables RPT loop generation for loops whose iteration count can be greater than k.
--silicon_version=28	Generates code for the TMS320C28x architecture.
--unified_memory	Use the -mt option if your memory map is configured as a single unified space; this allows the compiler to generate RPT PREAD instructions for most memcpy calls and structure assignments. This also allows MAC instructions to be generated. The --unified_memory option also allows more efficient data memory instructions to be used to access switch tables.
--vcu_support[=vcu0]	Specifies support for the Viterbi, Complex Math and CRC Unit (VCU), version 0. This option is useful only if the source is in assembly code, written for the VCU. The option is ignored for C/C++ code. This option does not need any special library support at the linker; the libraries used for C28x with/without VCU support should be sufficient.

2.3.4 Symbolic Debugging and Profiling Options

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

--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.

--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 3.8.1).

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

--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.

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 2.3.12 for a list of deprecated symbolic debugging options.

2.3.5 Specifying Filenames

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

Extension	File Type
.asm, .abs, or .s* (extension begins with s)	Assembly source
.c	C source
.C	Depends on operating system
.cpp, .cxx, .cc	C++ source
.obj .o* .dll .so	Object

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 2.3.6. 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 2.3.9.

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:

```
cl2000 -v28 *.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.

2.3.6 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:

--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:

```
cl2000 -v28 --c_file=file.s --asm_file=assy
```

You cannot use the filename options with wildcard specifications.

2.3.7 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 2.3.8 for more information about filename extension conventions.

2.3.8 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:

--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:

```
cl2000 -v28 --asm_extension=.rrr --obj_extension=.o fit.rrr
```

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

```
cl2000 -v28 --asm_extension=rrr --obj_extension=o fit.rrr
```

2.3.9 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: `cl2000 -v28 --abs_directory=d:\abso_list`
--asm_directory=*directory*	Specifies a directory for assembly files. For example: `cl2000 -v28 --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: `cl2000 -v28 --list_directory=d:\listing`
--obj_directory=*directory*	Specifies a directory for object files. For example: `cl2000 -v28 --obj_directory=d:\object`
--output_file=*filename*	Specifies a compilation output file name; can override --obj_directory . For example: `cl2000 -v28 output_file=transfer`
--pp_directory=*directory*	Specifies a preprocessor file directory for object files (default is .). For example: `cl2000 -v28 --pp_directory=d:\preproc`
--temp_directory=*directory*	Specifies a directory for temporary intermediate files. For example: `cl2000 -v28 --temp_directory=d:\temp`

2.3.10 Assembler Options

Following are assembler options that you can use with the compiler. For more information, see the *TMS320C28x 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_remarks Enables additional assembly-time checking. A warning is generated if a .bss allocation size is greater than 64 words, or a 16-bit immediate operand value resides outside of the -32 768 to 65 535 range.

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

--cdebug_asm_data Produces C-type symbolic debugging for assembly variables defined in assembly source code using data directives. This support is for basic C types, structures, and arrays.

--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.

--flash_prefetch_warn Need more information than "Assembler warnings for F281X BF flash prefetch issue."

--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.

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

--preproc_asm Expands macros in an assembly file and assembles the expanded file. Expanding macros helps you to debug the assembly file. The --preproc_asm option affects only the assembly file. When --preproc_asm is used, the compiler first invokes the assembler with the --large_memory_model option to generate the macro-expanded source .exp file. Then the .exp file is assembled to generate the object file. The debugger uses the .exp file for debugging. The .exp file is an intermediate file and any update to this file will be lost. You need to make any updates to the original assembly file.

--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).

2.3.11 Dynamic Linking

The C28x v?.? Code Generation Tools (CGT) support dynamic linking. For details on dynamic linking with the C28x CGT, see the *TMS320C28x Assembly Language Tools User's Guide*.

Table 2-28 provides a brief summary of the linker options that are related to support for the Dynamic Linking Model in the C28x CGT.

Table 2-28. Linker Options For Dynamic Linking

Option	Description
--dynamic[=exe]	Specifies that the result of a link will be a lightweight dynamic executable.
--dynamic=*lib*	Specifies that the result of a link will be a dynamic library.
--export=*symbol*	Specifies that *symbol* is exported by the ELF object that is generated for this link.
--fini=*symbol*	Specifies the *symbol* name of the termination code for the output file currently being linked.
--import=*symbol*	Specifies that *symbol* is imported by the ELF object that is generated for this link.
--init=*symbol*	Specifies the *symbol* name of the initialization code for the output file currently being linked.
--rpath=*dir*	Adds a directory to the beginning of the dynamic library search path.
--runpath=*dir*	Adds a directory to the end of the dynamic library search path.
--soname=*string*	Specifies shared object name to be used to identify this ELF object to the any downstream ELF object consumers.

2.3.12 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 2-29 lists the deprecated options and the options that have replaced them.

Table 2-29. Compiler Backwards-Compatibility Options Summary

Old Option	Effect	New Option
-gp	Allows function-level profiling of optimized code	--symdebug:dwarf or -g
-gt	Enables symbolic debugging using the alternate STABS debugging format	--symdebug:coff
-gw	Enables symbolic debugging using the DWARF debugging format	--symdebug:dwarf or -g

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).

The --opt_for_size option has been replaced by the --opt_for_space and --opt_for_speed options. The --disable_pcd and --out_as_uout options are now obsolete.

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 (C2000_C_OPTION)

You might find it useful to set the compiler, assembler, and linker default options using the C2000_C_OPTION environment variable. If you do this, the compiler uses the default options and/or input filenames that you name C2000_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 C2000_C_OPTION environment variable and processes it.

The table below shows how to set the C2000_C_OPTION environment variable. Select the command for your operating system:

Operating System	Enter
UNIX (Bourne shell)	**C2000_C_OPTION="** *option*$_1$ [*option*$_2$ . . .]**"; export C2000_C_OPTION**
Windows	**set C2000_C_OPTION=** *option*$_1$ [;*option*$_2$ . . .]

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 C2000_C_OPTION environment variable as follows:

```
set C2000_C_OPTION=--quiet --src_interlist --run_linker
```

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 C2000_C_OPTION are passed to the linker. Thus, you can use the C2000_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 C2000_C_OPTION is set as shown above:

```
cl2000 -v28 *c                        ; compiles and links
cl2000 -v28 --compile_only *.c        ; only compiles
cl2000 -v28 *.c --run_linker lnk.cmd  ; compiles and links using a command file
cl2000 -v28 --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 *TMS320C28x Assembly Language Tools User's Guide*.

2.4.2 Naming an Alternate Directory (C2000_C_DIR)

The linker uses the C2000_C_DIR environment variable to name alternate directories that contain object libraries. The command syntaxes for assigning the environment variable are:

Operating System	Enter
UNIX (Bourne shell)	**C2000_C_DIR="** *pathname*$_1$ **;** *pathname*$_2$ **;..."; export C2000_C_DIR**
Windows	**set C2000_C_DIR=** *pathname*$_1$ **;** *pathname*$_2$ **;...**

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 C2000_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 C2000_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:

Operating System	Enter
UNIX (Bourne shell)	`unset C2000_C_DIR`
Windows	`set C2000_C_DIR=`

2.5 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:

```
#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 2-30.

Table 2-30. Predefined C28x Macro Names

Macro Name	Description
_ _DATE_ _ (1)	Expands to the compilation date in the form *mmm dd yyyy*
_ _FILE_ _ (1)	Expands to the current source filename
_ _LARGE_MODEL_ _	Defined if large-model code is selected (the -ml option is used); otherwise, it is undefined.
_ _LINE_ _ (1)	Expands to the current line number
_ _STDC_ _ (1)	Defined to indicate that compiler conforms to ISO C Standard. See Section 6.1 for exceptions to ISO C conformance.
_ _STDC_VERSION_ _	C standard macro
_ _TI_COMPILER_VERSION_ _	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.
_ _TI_GNU_ATTIBUTE_SUPPORT_ _	Defined if GCC extensions are enabled (the --gcc option is used); otherwise, it is undefined.
_ _TI_STRICT_ANSI_MODE__	Defined if strict ANSI/ISO mode is enabled (the --strict_ansi option is used); otherwise, it is undefined.
_ _TIME_ _ (1)	Expands to the compilation time in the form "*hh:mm:ss*"

(1) Specified by the ISO standard

Table 2-30. Predefined C28x Macro Names (continued)

Macro Name	Description
_ _TMS320C2000_ _	Defined for C28x or C27x processor
_ _TMS320C28XX_ _	Defined if target is C28x
_ _TMS320C28XX_FPU32_ _	Expands to 1 (identifies the C28x processor with 32-bit hardware floating-point support)
_ _TMS320C28XX_FPU64_ _	Expands to 1 (identifies the C28x processor with 64-bit hardware floating-point support)
_INLINE	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.

You can use the names listed in Table 2-30 in the same manner as any other defined name. For example,

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

translates to a line such as:

```
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 C2000_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 C2000_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:

--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:

```
#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:

Operating System	Enter
UNIX	`cl2000 -v28 --include_path=/tools/files source.c`
Windows	`cl2000 -v28 --include_path=c:\tools\files source.c`

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 C2000_C_DIR environment variable.

For example, if you set up C2000_C_DIR with the following command:

```
C2000_C_DIR "/usr/include;/usr/ucb"; export C2000_C_DIR
```

or invoke the compiler with the following command:

```
cl2000 -v28 --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 as 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.

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.
--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.

```
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 2-31.

Table 2-31. Raw Listing File Identifiers

Identifier	Definition
N	Normal line of source
X	Expanded line of source. It appears immediately following the normal line of source if nontrivial preprocessing occurs.
S	Skipped source line (false #if clause)
L	Change in source position, given in the following format: L *line number filename key* 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: 1 = entry into an include file 2 = exit from an include file

The --gen_acp_raw option also includes diagnostic identifiers as defined in Table 2-32.

Table 2-32. Raw Listing File Diagnostic Identifiers

Diagnostic Identifier	Definition
E	Error
F	Fatal
R	Remark
W	Warning

Diagnostic raw listing information is displayed in the following format:

S filename line number column number diagnostic

S	One of the identifiers in Table 2-32 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.

2.11.1 Inlining Intrinsic Operators

There are many intrinsic operators for the C28x. 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 7.4.5.

2.11.2 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

```
inline float volume_sphere(float r)
{
   return 4.0/3.0 * PI * r * r * r;
}
int foo(...)
{
   ...
   volume = volume_sphere(radius);
   ...
}
```

2.11.3 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

```
/*****************************************************************************/
/* string.h  vx.xx                                                           */
/* Copyright (c) 1993-2006 Texas Instruments Incorporated                    */
/* Excerpted ...                                                             */
/*****************************************************************************/
#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

```
/*****************************************************************************/
/*  strlen                                                                   */
/*****************************************************************************/
#undef _INLINE

#include <string>
_CODE_ACCESS size_t strlen(cont char * string)
{
   size_t      n = (size_t)-1;
   const char *s = string - 1;

   do n++; while (*++s);
   return n;
}
```

2.12 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:

```
cl2000 -v28 --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 3.7.

Example 2-4. An Interlisted Assembly Language File

```
;------------------------------------------------------------------------
; 1 | int main()
;------------------------------------------------------------------------

;****************************************************************
;* FNAME: _main                          FR SIZE: 0             *
;*                                                              *
;* FUNCTION ENVIRONMENT                                         *
;*                                                              *
;* FUNCTION PROPERTIES                                          *
;*                           0 Parameter, 0 Auto, 0 SOE         *
;****************************************************************

_main:
;------------------------------------------------------------------------
; 3 | printf("Hello World\n");
;------------------------------------------------------------------------
        MOVL    XAR4,#SL1               ; |3|
        LCR     #_printf                ; |3|
        ; call occurs [#_printf] ; |3|
;------------------------------------------------------------------------
; 4 | return 0;
;------------------------------------------------------------------------

;****************************************************************
;* STRINGS *
;****************************************************************

        .sect   ".const"
SL1:    .string "Hello World",10,0
;****************************************************************
;* UNDEFINED EXTERNAL REFERENCES *
;****************************************************************
.global _printf
```

2.13 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 6.10.13 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.

Topic **Page**

3.1 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*n* 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 loop optimizations
  - Eliminates global common subexpressions
  - Eliminates global unused assignments
  - 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 3.2 and Section 3.3 for more information.
- **--opt_level=4** or **-O4**

  Performs link-time optimization. See Section 3.4 for details.

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.

3.2 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 3-1. Options That You Can Use With --opt_level=3

If You ...	Use this Option	See
Have files that redeclare standard library functions	--std_lib_func_defined --std_lib_func_redefined	Section 3.2.1
Want to create an optimization information file	--gen_opt_level=*n*	Section 3.2.2
Want to compile multiple source files	--program_level_compile	Section 3.3

3.2.1 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 3-2. Selecting a File-Level Optimization Option

If Your Source File...	Use this Option
Declares a function with the same name as a standard library function	--std_lib_func_redefined
Contains but does not alter functions declared in the standard library	--std_lib_func_defined
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.	--std_lib_func_not_defined

3.2.2 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 3-3. Selecting a Level for the --gen_opt_info Option

If you...	Use this option
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.	--gen_opt_level=0
Want to produce an optimization information file	--gen_opt_level=1
Want to produce a verbose optimization information file	--gen_opt_level=2

3.3 Performing Program-Level Optimization (--program_level_compile and --opt_level=3 options)

You can specify program-level optimization by using the --program_level_compile option with the --opt_level=3 option (aliased as -O3). With program-level optimization, all of your source files are compiled into one intermediate file called a *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 main(), the compiler removes the function.

To see which program-level optimizations the compiler is applying, use the --gen_opt_level=2 option to generate an information file. See Section 3.2.2 for more information.

In Code Composer Studio, when the --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 --program_level_compile and --keep_asm Options

NOTE: If you compile all files with the --program_level_compile and --keep_asm options, the compiler produces only one .asm file, not one for each corresponding source file.

3.3.1 Controlling Program-Level Optimization (--call_assumptions Option)

You can control program-level optimization, which you invoke with --program_level_compile --opt_level=3, by using the --call_assumptions option. Specifically, the --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 --call_assumptions indicates the level you set for the module that you are allowing to be called or modified. The --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 --call_assumptions option.

Table 3-4. Selecting a Level for the --call_assumptions Option

If Your Module …	Use this Option
Has functions that are called from other modules and global variables that are modified in other modules	--call_assumptions=0
Does not have functions that are called by other modules but has global variables that are modified in other modules	--call_assumptions=1
Does not have functions that are called by other modules or global variables that are modified in other modules	--call_assumptions=2
Has functions that are called from other modules but does not have global variables that are modified in other modules	--call_assumptions=3

In certain circumstances, the compiler reverts to a different --call_assumptions level from the one you specified, or it might disable program-level optimization altogether. Table 3-5 lists the combinations of --call_assumptions levels and conditions that cause the compiler to revert to other --call_assumptions levels.

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

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

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 3.3.2 for information about these situations.

3.3.2 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 6.10.9) 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 3.3.1).

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 3.3.1 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 3.3.1 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.

3.4 Link-Time Optimization (--opt_level=4 Option)

Link-time optimization is an optimization mode that allows the compiler to have visibility of the entire program. The optimization occurs at link-time instead of compile-time like other optimization levels.

Link-time optimization is invoked by using the --opt_level=4 option. This option must be used in both the compilation and linking steps. At compile time, the compiler embeds an intermediate representation of the file being compiled into the resulting object file. At link-time this representation is extracted from every object file which contains it, and is used to optimize the entire program.

Link-time optimization provides the same optimization opportunities as program level optimization (Section 3.3), with the following benefits:

- Each source file can be compiled separately. One issue with program-level compilation is that it requires all source files to be passed to the compiler at one time. This often requires significant modification of a customer's build process. With link-time optimization, all files can be compiled separately.
- References to C/C++ symbols from assembly are handled automatically. When doing program-level compilation, the compiler has no knowledge of whether a symbol is referenced externally. When performing link-time optimization during a final link, the linker can determine which symbols are referenced externally and prevent eliminating them during optimization.
- Third party object files can participate in optimization. If a third party vendor provides object files that were compiled with the --opt_level=4 option, those files participate in optimization along with user-generated files. This includes object files supplied as part of the TI run-time support. Object files that were not compiled with –opt_level=4 can still be used in a link that is performing link-time optimization. Those files that were not compiled with –opt_level=4 do not participate in the optimization.
- Source files can be compiled with different option sets. With program-level compilation, all source files must be compiled with the same option set. With link-time optimization files can be compiled with different options. If the compiler determines that two options are incompatible, it issues an error.

3.4.1 Option Handling

When performing link-time optimization, source files can be compiled with different options. When possible, the options that were used during compilation are used during link-time optimization. For options which apply at the program level, --auto_inline for instance, the options used to compile the main function are used. If main is not included in link-time optimization, the option set used for the first object file specified on the command line is used. Some options, --opt_for_speed for instance, can effect a wide range of optimizations. For these options, the program-level behavior is derived from main, and the local optimizations are obtained from the original option set.

Some options are incompatible when performing link-time optimization. These are usually options which conflict on the command line as well, but can also be options that cannot be handled during link-time optimization.

3.4.2 Incompatible Types

During a normal link, the linker does not check to make sure that each symbol was declared with the same type in different files. This is not necessary during a normal link. When performing link-time optimization, however, the linker must ensure that all symbols are declared with compatible types in different source files. If a symbol is found which has incompatible types, an error is issued. The rules for compatible types are derived from the C and C++ standards.

3.5 Special Considerations When Using Optimization

The compiler is designed to improve your ANSI/ISO-conforming C and C++ programs while maintaining their correctness. However, when you write code for optimization, you should note the special considerations discussed in the following sections to ensure that your program performs as you intend.

3.5.1 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.

3.5.2 Use the Volatile Keyword for Necessary Memory Accesses

The compiler analyzes data flow to avoid memory accesses whenever possible. If you have code that depends on memory accesses exactly as written in the C/C++ code, you must use the volatile keyword to identify these accesses. The compiler does not optimize out any references to volatile variables.

In the following example, the loop waits for a location to be read as 0xFF:

```
unsigned int *ctrl;
while (*ctrl !=0xFF);
```

In this example, *ctrl is a loop-invariant expression, so the loop is optimized down to a single memory read. To correct this, declare ctrl as:

```
volatile unsigned int *ctrl
```

3.5.2.1 Use Caution When Accessing Aliased Variables

Aliasing occurs when a single object can be accessed 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 still preserving the correctness of the program. The compiler behaves conservatively.

The compiler assumes that if the address of a local variable is passed to a function, the function might change the local by writing through the pointer, but that it will not make its address available for use elsewhere after returning. For example, the called function cannot assign the local's address to a global variable or return it. In cases where this assumption is invalid, use the -ma compiler option to force the compiler to assume worst-case aliasing. In worst-case aliasing, any indirect reference (that is, using a pointer) can refer to such a variable.

3.5.2.2 Use the --aliased_variables Option to Indicate That the Following Technique Is Used

The compiler, when invoked with optimization, assumes that any variable whose address is passed as an argument to a function will not be 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

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:

```
int *glob_ptr;

g()
{
    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;
}
```

3.5.2.3 On FPU Targets Only: Use restrict Keyword to Indicate That Pointers Are Not Aliased

On FPU targets, with --opt_level=2, the optimizer performs dependency analysis. 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 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. This can improve performance and code size, as more FPU operations can be parallelized.

As shown in Example 3-1 and Example 3-2 you can use the restrict keyword to tell the compiler that a and b never point to the same object in foo. Furthermore, the compiler is assured that the objects pointed to by a and b do not overlap in memory.

Example 3-1. Use of the restrict Type Qualifier With Pointers

```
void foo(float * restrict a, float * restrict b)
{
   /* foo's code here */
}
```

Example 3-2. Use of the restrict Type Qualifier With Pointers

```
void foo(float c[restrict], float d[restrict])
{
   /* foo's code here */
}
```

3.6 Automatic Inline Expansion (--auto_inline Option)

When optimizing with the --opt_level=3 option (aliased as -O3), the compiler automatically inlines small functions. A command-line option, --auto_inline=*size*, specifies the size threshold. Any function larger than the *size* threshold is not automatically inlined. You can use the --auto_inline=*size* option in the following ways:

- If you set the *size* parameter to 0 (--auto_inline=0), automatic inline expansion is disabled.
- If you set the *size* parameter to a nonzero integer, the compiler uses this size threshold as a limit to the size of the functions it automatically inlines. The compiler multiplies the number of times the function is inlined (plus 1 if the function is externally visible and its declaration cannot be safely removed) by the size of the function.

The compiler inlines the function only if the result is less than the size parameter. The compiler measures the size of a function in arbitrary units; however, the optimizer information file (created with the --gen_opt_level=1 or --gen_opt_level=2 option) reports the size of each function in the same units that the --auto_inline option uses.

The --auto_inline=*size* option controls only the inlining of functions that are not explicitly declared as inline. If you do not use the --auto_inline=*size* option, the compiler inlines very small functions.

Optimization Level 3 and Inlining

NOTE: In order to turn on automatic inlining, you must use the --opt_level=3 option. If you desire the --opt_level=3 optimizations, but not automatic inlining, use --auto_inline=0 with the --opt_level=3 option.

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.

3.7 Using the Interlist Feature With Optimization

You control the output of the interlist feature when compiling with optimization (the --opt_level=*n* or -O*n* 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 and --optimizer_interlist options 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 3-4 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 3-5 shows the function from Example 3-4 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.

Example 3-3. C Code for Interlist Illustration

```
int copy (char *str, const char *s, int n)
{
   int i;

   for (i = 0; i < n; i ++)
      *str++ = *s++;
}
```

Example 3-4. The Function From Example 3-3 Compiled With the -O2 and --optimizer_interlist Options

```
;****************************************************************
;* FNAME: _copy                         FR SIZE: 0              *
;*                                                              *
;* FUNCTION ENVIRONMENT                                         *
;*                                                              *
;* FUNCTION PROPERTIES                                          *
;*                            0 Parameter, 0 Auto, 0 SOE        *
;****************************************************************

_copy:
;*** 6  ----------------------    if ( n <= 0 ) goto g4;
        CMPB      AL,#0                 ; |6|
        B         L2,LEQ                ; |6|
        ; branch occurs ; |6|
;***    ----------------------    #pragma MUST_ITERATE(1, 4294967295, 1)
:***    ----------------------    L$1 = n-1;
        ADDB      AL,#-1
        MOVZ      AR6,AL
L1:
;***    ----------------------g3:
;*** 7  ----------------------    *str++ = *s++;
;*** 7  ----------------------    if ( (--L$1) != (-1) ) goto g3;
        MOV       AL,*XAR5++            ; |7|
        MOV       *XAR4++,AL            ; |7|
        BANZ      L1,AR6--
        ; branch occurs ; |7|
;***    ----------------------g4:
;***    ----------------------    return;
L2:
        LRETR
        ; return occurs
```

Example 3-5. The Function From Example 3-3 Compiled with the --opt_level=2, --optimizer_interlist, and --c_src_interlist Options

```
;----------------------------------------------------------------------
;   2 | int copy (char *str, const char *s, int n)
;----------------------------------------------------------------------

;******************************************************************
;* FNAME: _copy                         FR SIZE:   0              *
;*                                                                 *
;* FUNCTION ENVIRONMENT                                            *
;*                                                                 *
;* FUNCTION PROPERTIES                                             *
;* FUNCTION PROPERTIES                                             *
;*                            0 Parameter,  0 Auto,  0 SOE         *
;******************************************************************

_copy
;* AR4   assigned to _str
;* AR5   assigned to _s
;* AL    assigned to _n
;* AL    assigned to _n
;* AR5   assigned to _s
;* AR4   assigned to _str
;* AR6   assigned to L$1
;*** 6  ----------------------    if ( n <= 0 ) goto g4;
;----------------------------------------------------------------------
;   4 | int i;
;----------------------------------------------------------------------
;----------------------------------------------------------------------
;   6 | for (i = 0; i < n; i++)
;----------------------------------------------------------------------
        CMPB      AL,#0                 ; |6|
        B         L2,LEQ                ; |6|
        ; branch occurs ; |6|
;***    ----------------------    #pragma MUST_ITERATE(1, 4294967295, 1)
:***    ----------------------    L$1 = n-1;
        ADDB      AL,#-1
        MOVZ      AR6,AL
        NOP
L1:
;*** 7  ----------------------    *str++ = *s++;
;*** 7  ----------------------    if ( (--L$1) != (-1) ) goto g3;
;----------------------------------------------------------------------
;   7 | *str++ = *s++;
;----------------------------------------------------------------------
        MOV       AL,*XAR5++            ; |7|
        MOV       *XAR4++,AL            ; |7|
        BANZ      L1,AR6--
        ; branch occurs ; |7|
;***    ----------------------g4:
;***    ----------------------    return;
L2:
        LRETR
        ; return occurs
```

3.8 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.

3.8.1 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 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 optionsthis option for debugging only. Using --symdebug:dwarf or --symdebug:coff when profiling is not recommended.

3.8.2 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.

3.9 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. However, the default behavior of the compiler is as if --opt_for_speed=1 were specified.

The initial mechanism for controlling code space, the --opt_for_space option, has the following equivalences with the --opt_for_speed option:

--opt_for_space	--opt_for_speed
none	=4
=0	=3
=1	=2
=2	=1
=3	=0

A fast branch (BF) instruction is generated by default when the --opt_for_speed option is used. When --opt_for_speed is not used, the compiler generates BF instruction only when the condition code is one of NEQ, EQ, NTC and TC. The reason is that BF with these condition codes can be optimized to SBF. There is a code size penalty to use BF instruction when the condition code is NOT one of NEQ, EQ, NTC and TC.

The --no_fast_branch option does not control the BF instruction generated under the -opt_for_speed option. That is, --opt_for_speed overrides --no_fast_branch. The --no_fast_branch option affects only the BF instruction generated by default for one of NEQ, EQ, NTC and TC.

3.10 Increasing Code-Size Optimizations (--opt_for_size Option)

The --opt_for_size option increases the level of code-size optimizations performed by the compiler. These optimizations are done at the expense of performance. The optimizations include procedural abstraction where common blocks of code are replaced with function calls. For example, prolog and epilog code, certain intrinsics, and other common code sequences, can be replaced with calls to functions that are defined in the run-time library. It is necessary to link with the supplied run-time library when using the --opt_for_size option. It is not necessary to use optimization to invoke the --opt_for_size option.

To illustrate how the --opt_for_size option works, the following describes how prolog and epilog code can be replaced. This code is changed to function calls depending on the number of SOE registers, the size of the frame, and whether a frame pointer is used. These functions are defined in each file with the --opt_for_size option, as shown below:

```
_prolog_c28x_1
_prolog_c28x_2
_prolog_c28x_3
_epilog_c28x_1
_epilog_c28x_2
```

Example 3-6 provides an example of C code to be compiled with the --opt_for_size option. The resulting output is shown in Example 3-7.

Example 3-6. C Code to Show Code-Size Optimizations

```
extern int x, y, *ptr;
extern int foo();

int main(int a, int b, int c)
{

   ptr[50] = foo();
   y = ptr[50] + x + y + a +b + c;
}
```

Example 3-7. Example 3-6 Compiled With the --opt_for_size Option

```
FP      .set    XAR2
        .global _prolog_c28x_1
        .global _prolog_c28x_2
        .global _prolog_c28x_3
        .global _epilog_c28x_1
        .global _epilog_c28x_2
        .sect   ".text"
        .global _main

;****************************************************************
;* FNAME: _main                          FR SIZE:   6           *
;*                                                              *
;* FUNCTION ENVIRONMENT                                         *
;*                                                              *
;* FUNCTION PROPERTIES                                          *
;*                            0 Parameter,  0 Auto,  6 SOE      *
;****************************************************************

_main:

        FFC       XAR7,_prolog_c28x_1
        MOVZ      AR3,AR4               ; |5|
        MOVZ      AR2,AH                ; |5|
        MOVZ      AR1,AL                ; |5|
        LCR       #_foo                 ; |6|
        ; call occurs [#_foo] ; |6|
        MOVW      DP,#_ptr
        MOVL      XAR6,@_ptr            ; |6|
        MOVB      XAR0,#50              ; |6|
        MOVW      DP,#_y
        MOV       *+XAR6[AR0],AL        ; |6|
        MOV       AH,@_y                ; |7|
        MOVW      DP,#_x
        ADD       AH,AL                 ; |7|
        ADD       AH,@_x                ; |7|
        ADD       AH,AR3                ; |7|
        ADD       AH,AR1                ; |7|
        ADD       AH,AR2                ; |7|
        MOVB      AL,#0
        MOVW      DP,#_y
        MOV       @_y,AH                ; |7|
        FFC       XAR7,_epilog_c28x_1
        LRETR
        ; return occurs
```

3.11 What Kind of Optimization Is Being Performed?

The TMS320C28x 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:

Optimization	See
Cost-based register allocation	Section 3.11.1
Alias disambiguation	Section 3.11.1
Branch optimizations and control-flow simplification	Section 3.11.3
Data flow optimizations • Copy propagation • Common subexpression elimination • Redundant assignment elimination	Section 3.11.4
Expression simplification	Section 3.11.5
Inline expansion of functions	Section 3.11.6
Function Symbol Aliasing	Section 3.11.7
Induction variable optimizations and strength reduction	Section 3.11.8
Loop-invariant code motion	Section 3.11.9
Loop rotation	Section 3.11.10
Instruction scheduling	Section 3.11.11

C28x-Specific Optimization	See
Register variables	Section 3.11.12
Register tracking/targeting	Section 3.11.13
Tail merging	Section 3.11.14
Autoincrement addressing	Section 3.11.15
Removing comparisons to zero	Section 3.11.16
RPTB generation (for FPU targets only)	Section 3.11.17

3.11.1 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.

3.11.2 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.

3.11.3 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.

3.11.4 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.

3.11.5 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.

3.11.6 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.

3.11.7 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:

```
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.

3.11.8 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.

3.11.9 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.

3.11.10 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.

3.11.11 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.

3.11.12 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.

3.11.13 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.

3.11.14 Tail Merging

If you are optimizing for code size, tail merging can be very effective for some functions. Tail merging finds basic blocks that end in an identical sequence of instructions and have a common destination. If such a set of blocks is found, the sequence of identical instructions is made into its own block. These instructions are then removed from the set of blocks and replaced with branches to the newly created block. Thus, there is only one copy of the sequence of instructions, rather than one for each block in the set.

3.11.15 Autoincrement Addressing

For pointer expressions of the form *p++, the compiler uses efficient C28x autoincrement addressing modes. In many cases, where code steps through an array in a loop such as below, the loop optimizations convert the array references to indirect references through autoincremented register variable pointers.

```
for (I = 0; I <N; ++I) a(I)...
```

3.11.16 Removing Comparisons to Zero

Because most of the 32-bit instructions and some of the 16-bit instructions can modify the status register, explicit comparisons to 0 may be unnecessary. The C28x C/C++ compiler removes comparisons to 0 if a previous instruction can be modified to set the status register appropriately.

3.11.17 RPTB Generation (for FPU Targets Only)

When the target has hardware floating-point support, some loops can be converted to hardware loops called repeat blocks (RPTB). Normally, a loop looks like this:

```
Label:
   ...loop body...
   SUB loop_count
   CMP
   B    Label
```

The same loop, when converted to a RPTB loop, looks like this:

```
   RPTB   end_label, loop_count
   ...loop body...
end_label:
```

A repeat block loop is loaded into a hardware buffer and executed for the specified number of iterations. This kind of loop has minimal or zero branching overhead, and can improve performance. The loop count is stored in a special register RB (repeat block register), and the hardware seamlessly decrements the count without any explicit subtractions. Thus, there is no overhead due to the subtract, the compare, and the branch. The only overhead is due to the RPTB instruction that executes once before the loop. The RPTB instruction takes one cycle if the number of iterations is a constant, and 4 cycles otherwise. This overhead is incurred once per loop.

There are limitations on the minimum and maximum loop size for a loop to qualify for becoming a repeat block, due to the presence of the buffer. Also, the loop cannot contain any inner loops or function calls.

Linking C/C++ Code

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 *TMS320C28x Assembly Language Tools User's Guide*.

Topic **Page**

4.1 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.

4.1.1 Invoking the Linker Separately

This is the general syntax for linking C/C++ programs as a separate step:

cl2000 -v28 --run_linker {**--rom_model | --ram_model**} *filenames*
[*options*] [**--output_file=** *name.out*] **--library=** *library* [*lnk.cmd*]

cl2000 -v28 --run_linker	The command that invokes the linker. The -v28 is the alias for --silicon_version=28.
--rom_model | **--ram_model**	Options that tell the linker to use special conventions defined by the C/C++ environment. When you use cl2000 -v28 --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 *TMS320C28x 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 *TMS320C28x Assembly Language Tools User's Guide*.

You can link a C/C++ program consisting of modules prog1.obj, prog2.obj, and prog3.obj, with an executable filename of prog.out with the command:

```
cl2000 --silicon_version=28 --run_linker --rom_model prog1 prog2 prog3
     --output_file=prog.out --library=rts28.lib
```

4.1.2 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:

cl2000 -v28*filenames* [*options*] **--run_linker** {**--rom_model | --ram_model**} *filenames*
[*options*] [**--output_file=** *name.out*] **--library=** *library* [*lnk.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 4.1.1.

All arguments that precede --run_linker on the command line are compiler arguments. These arguments can be C/C++ source files, assembly files, or compiler options. These arguments are described in Section 2.2.

You can compile and link a C/C++ program consisting of modules prog1.c, prog2.c, and prog3.c, with an executable filename of prog.out with the command:

```
cl2000 -v28 prog1.c prog2.c prog3.c --run_linker --rom_model --output_file=prog.out
     --library=rts28.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 C2000_C_OPTION environment variable

4.1.3 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 C2000_C_OPTION environment variable and want to selectively disable linking with the --compile_only option on the command line.

4.2 Linker Code Optimizations

4.2.1 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.

4.3 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 *TMS320C28x Assembly Language Tools User's Guide*

4.3.1 Including the Run-Time-Support Library

You must include a run-time-support library in the linker process. The following sections describe two methods for including the run-time-support library.

4.3.1.1 Manual Run-Time-Support Library Selection

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. You must use the --library linker option to specify which C28x run-time-support library to use. The --library option also tells the linker to look at the --search_path options and then the C2000_C_DIR environment variable to find an archive path or object file. To use the --library linker option, type on the command line:

cl2000 -v28 --run_linker {**--rom_model** | **--ram_model**} *filenames* **--library=** *libraryname*

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.

4.3.1.2 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 as if it was specified with the --library option last on the command line. Alternatively, you can always 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 4-1. Using the --issue_remarks Option

```
cl2000 -v28 --issue_remarks main.c --run_linker --rom_model

<Linking>

remark: linking in "libc.a"

remark: linking in "rts2800-eh.lib" in place of "libc.a"
```

4.3.2 Run-Time Initialization

You must link all C/C++ programs with code to initialize and execute the program called a bootstrap routine. The bootstrap routine is responsible for the following tasks:

1. Set up status and configuration registers
2. Set up the stack and secondary system stack
3. Process the .cinit run-time initialization table to autoinitialize global variables (when using the --rom_model option)
4. Call all global object constructors (.pinit)
5. Call main
6. Call exit when main returns

A sample bootstrap routine is _c_int00, provided in boot.obj in rts2800.lib. 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.

4.3.3 Initialization by the Interrupt Vector

If your program is expected to run from RESET, you must set up the reset vector to branch to _c_int00. Referring to _c_int00 causes boot.obj to be loaded from the library. The _c_int00 routine will initialize the program's state. The boot.obj code places the address of _c_int00 into a section named .reset. The section can then be allocated at the reset vector location using the linker.

A sample interrupt vector is provided in vectors.obj in rts2800.lib. For C28x, the first few lines of the vector are:

```
        .def  _Reset
        .ref  _c_int00
_Reset: .vec _c_int00, USE_RETA
```

4.3.4 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 main( ) is called. Global destructors are invoked during exit( ), similar to functions registered through atexit( ).

Section 7.8.6 discusses the format of the global constructor table.

4.3.5 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. 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 7.8.4).
- Global variables are initialized at *load time*. Use the --ram_model linker option (see Section 7.8.5).

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 4.1). The following list outlines the linking conventions 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.

4.3.6 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 4-1 summarizes the initialized sections. Table 4-2 summarizes the uninitialized sections.

Table 4-1. Initialized Sections Created by the Compiler

Name	Contents	Restrictions
.cinit	Tables for explicitly initialized global and static variables	Program
.const	Global and static const variables that are explicitly initialized and contain string literals	Low 64K
.econst	Far constant variables	Anywhere in data
.pinit	Table of constructors to be called at startup	Program
.switch	Jump tables for large switch statements	Program with -mt option Data without -mt option
.text	Executable code and constants	Program

Table 4-2. Uninitialized Sections Created by the Compiler

Name	Contents	Restrictions
.bss	Global and static variables	Low 64K
.ebss	Far global/static variables	Anywhere in data
.stack	Stack	Low 64K
.sysmem	Memory for malloc functions (heap)	Low 64K
.esysmem	Memory for far_malloc functions	Anywhere in data

The C/C++ run-time environment supports placing the system heap (.esysmem section) in far memory by providing far_malloc routines.

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 .text, 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 *TMS320C28x Assembly Language Tools User's Guide*.

4.3.7 A Sample Linker Command File

Example 4-2 shows a typical linker command file that links a C program. The command file in this example is named lnk.cmd. It links three object files (a.obj, b.obj, and c.obj) and creates a program (prog.out) and a map file (prog.map).

To link the program, enter the following:

```
cl2000 -v28 --run_linker lnk.cmd
```

The MEMORY and possibly the SECTIONS directives, might require modification to work with your system. See the *TMS320C28x Assembly Language Tools User's Guide* for more information on these directives.

Example 4-2. Linker Command File

```
a.obj b.obj c.obj         /* Input filenames */
--output_file=prog.out    /* Options */
--map_file=prog.map
--library=rts2800.lib     /* Get run-time support */

MEMORY                    /* MEMORY directive */
{
   RAM:  origin = 100h     length = 0100h
   ROM:  origin = 01000h   length = 0100h
}

SECTIONS                  /* SECTIONS directive */
{
   .text:   > ROM
   .data:   > ROM
   .bss:    > RAM
   .pinit:  > ROM
   .cinit:  > ROM
   .switch: > ROM
   .const:  > RAM
   .stack:  > RAM
   .sysmem: > RAM
```

4.4 Linking C28x and C2XLP Code

The error in the C28x linker to prevent linking code with a 64-word page size (C28x) and a 128-word page size (C2XLP) has been changed to a warning. It is possible to call a C2XLP assembly function from C28x C/C++ code. One possible way is to replace the call to the C2XLP function with a veneer function that correctly sets up the arguments and call stack for the C2XLP code. For example, to make a call to a C2XLP function expecting five integer arguments, change the C28x code to:

```
extern void foo_veneer(int, int, int, int, int);
void bar()
{
   /* replace the C2XLP call with a veneer call */
   /* foo(1, 2, 3, 4, 5); */
   foo_veneer(1, 2, 3, 4, 5);
}
```

Example 4-3 illustrates how the veneer function might look:

Example 4-3. Veneer Function for Linking C2xx and C2XLP Code

```
        .sect ".text"
        .global _foo_veneer
        .global _foo
_foo_veneer:
        ;save registers
        PUSH AR1:AR0
        PUSH AR3:AR2
        PUSH AR5:AR4

        ;set the size of the C2XLP frame (including args size)
        ADDB SP,#10

        ;push args onto the C2XLP frame
        MOV *-SP[10],AL ;copy arg 1
        MOV *-SP[9],AH  ;copy arg 2
        MOV *-SP[8],AR4 ;copy arg 3
        MOV *-SP[7],AR5 ;copy arg 4
        MOV AL,*-SP[19]
        MOV *-SP[6],AL  ;copy arg 5

        ;save the return address
        MOV *-SP[5],#_label

        ;set AR1,ARP
        MOV AL,SP
        SUBB AL,#3
        MOV AR1,AL
        NOP *ARP1

        ;jump to C2XLP function
        LB _foo
_label:

        ;restore register
        POP AR5:AR4
        POP AR3:AR2
        POP AR1:AR0LRETR
```

Since the veneer function frame will act as the frame for all C2XLP calls, it is necessary to add sufficient size to the frame for any subsequent calls made by the first C2XLP function.

Global variables will be placed in the .bss sections for C28x C/C++ code. A C2XLP .bss section is not guaranteed to begin on a 128-word boundary when linked with C28x code. To avoid this problem, define a new section, change the C2XLP globals to the new section, and update the linker command file to ensure this new section begins at a 128-word boundary.

Post-Link Optimizer

The TMS320C28x post-link optimizer removes or modifies assembly language instructions to generate better code. The post-link optimizer examines the final addresses of symbols determined by linking and uses this information to make code changes.

Post-link optimization requires the -plink compiler option. The -plink compiler option invokes added passes of the tools that include running the absolute lister and rerunning the assembler and linker. You must use the -plink option following the --run_linker option.

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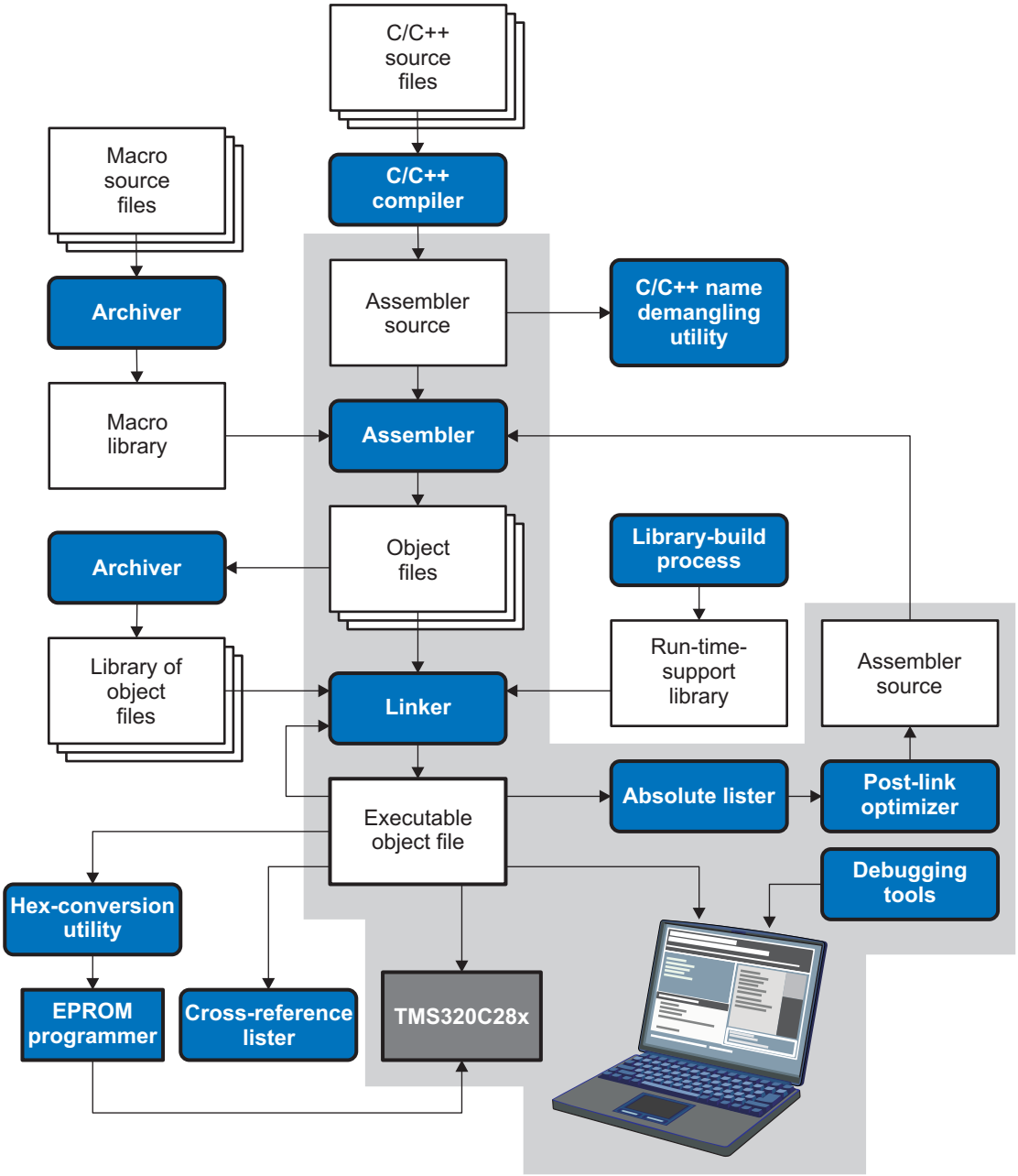
5.1 The Post-Link Optimizer's Role in the Software Development Flow

The post-link optimizer is not part of the normal development flow. Figure 5-1 shows the flow including the post-link optimizer; this flow occurs only when you use the compiler and the -plink option.

Figure 5-1. The Post-Link Optimizer in the TMS320C28x Software Development Flow



As the flow shows, the absolute lister (abs2000) is also part of the post-link optimizing process. The absolute lister outputs the absolute addresses of all globally defined symbols and coff sections. The post-link optimizer takes .abs files as input and uses these addresses to perform optimizations. The output is a .pl file, which is an optimized version of the original .asm file. The flow then reruns the assembler and linker to produce a final output file.

The described flow is supported only when you use the compiler (cl2000 -v28) and the -plink option. If you use a batch file to invoke each tool individually, you must adapt the flow to use the compiler instead. In addition, you must use the --output_file option to specify an output file name when using the -plink option. See Section 5.8 for more details.

For example, replace these lines:

```
cl2000 -v28 file1.asm file1.obj
cl2000 -v28 file2.asm file2.obj
cl2000 -v28 --run_linker file1.obj file2.obj lnk.cmd --output_file=prog.out
```

with this line:

```
cl2000 -v28 file1.asm file2.asm --run_linker lnk.cmd --output_file=prog.out -plink
```

Post-link optimization is not supported for FPU targets.

5.2 Removing Redundant DP Loops

Post-link optimization reduces the difficulty of managing the DP register by removing redundant DP loads. It does this by tracking the current value of the DP and determining whether the address in a MOV DP,#address instruction is located on the same 64-word page to which the DP is currently pointing. If the address can be accessed using the current DP value, the instruction is redundant and can be removed. For example, consider the following code segment:

```
MOVZ      DP,#name1
ADD       @name1,#10
MOVZ      DP,#name2
ADD       @name2,#10
```

If name1 and name2 are linked to the same page, the post-link optimizer determines that loading DP with the address of name2 is not necessary, and it comments out the redundant load.

```
MOVZ      DP,#name1
ADD       @name1,#10
 ; <<REDUNDANT>>          MOVZ      DP,#name2
ADD       @name2,#10
```

This optimization can be used on C files as well. Even though the compiler manages the DP for all global variable references that are defined within a module, it conservatively emits DP loads for any references to global variables that are externally defined. Using the post-link optimizer can help reduce the number of DP loads in these instances.

5.3 Tracking DP Values Across Branches

In order to track DP values across branches, the post-link optimizer requires that there are no indirect calls or branches, and all possible branch destinations have labels. If an indirect branch or call is encountered, the post-link optimizer will only track the DP value within a basic block. Branch destinations without labels may cause incorrect output from the post-link optimizer.

If the post-link optimizer encounters indirect calls or branches, it issues the following warning:

```
NO POST LINK OPTIMIZATION DONE ACROSS BRANCHES
Branch/Call must have labeled destination
```

This warning is issued so that if the file is a hand written assembly file, you can try to change the indirect call/branch to a direct one to obtain the best optimization from the post linker.

5.4 Tracking DP Values Across Function Calls

The post-link optimizer optimizes DP loads after a call to a function if the function is defined in the same file scope. For example, consider the following post-link optimized code:

```
_main:
    LCR    #_foo
    MOVB    AL, #0
;<<REDUNDANT>>    MOVZ    DP,#_g2
    MOV    @_g2, #20
    LRETR

    .global    _foo
_foo:
    MOVZ    DP, #g1
    MOV      @_g1, #10
    LRETR
```

The MOVZ DP after the function call to _foo is removed by the post-link optimizer as the variables _g1 and _g2 are in the same page and the function _foo already set the DP.

In order for the post-link optimizer to optimize across the function calls, the functions should have only one return statement. If you are running the post-link optimizer on hand written assembly that has more that one return statement per function, the post-link optimization output can be incorrect. You can turn off the optimization across function calls by specifying the -nf option after the -plink option.

5.5 Other Post-Link Optimizations

An externally defined symbol used as a constant operand forces the assembler to choose a 16-bit encoding to hold the immediate value. Since the post-link optimizer has access to the externally defined symbol value, it replaces a 16-bit encoding with an 8-bit encoding when possible. For example:

```
.ref ext_sym ; externally defined to be 4
:
:
ADD AL, #ext_sym ; assembly will encode ext_sym with 16 bits
```

Since ext_sym is externally defined, the assembler chooses a 16-bit encoding for ext_sym. The post-link optimizer changes the encoding of ext_sym to an 8-bit encoding:

```
.ref ext_sym
:
:
; << ADD=>ADDB>> ADD AL,#ext_sym
ADDB AL, #ext_sym
```

Similarly the post-link optimizer attempts to reduce the following 2-word instructions to 1-word instructions:

2-Word Instructions	1-Word Instructions
ADD ACC, *#imm*	ADDB ACC, *#imm*
ADD AL, *#imm*	ADDB AL, *#imm*
AND AL, *#imm*	ANDB AL, *#imm*
CMP AL, *#imm*	CMPB AL, *#imm*
MOVL XARn, *#imm*	MOVB XARn, *#imm*
OR AL, *#imm*	ORB AL, *#imm*
SUB ACC, *#imm*	SUBB ACC, *#imm*
SUB AL, *#imm*	SUBB AL, *#imm*
XOR AL, *#imm*	XORB AL, *#imm*

5.6 Controlling Post-Link Optimizations

There are three ways to control post-link optimizations: by excluding files, by inserting specific comments within an assembly file, and by manually editing the post-link optimization file.

5.6.1 Excluding Files (-ex Option)

Specific files can be excluded from the post-link optimization process by using the −ex option. The files to be excluded must follow the −ex option and include file extensions. The −ex option must be used after the −plink option and no other option may follow. For example:

```
cl2000 -v28 file1.asm file2.asm file3.asm --keep_asm --run_linker lnk.cmd -plink -o=prog.out -
ex=file3.asm
```

The file3.asm will be excluded from the post-link optimization process.

5.6.2 Controlling Post-Link Optimization Within an Assembly File

Within an assembly file, post-link optimizations can be disabled or enabled by using two specially formatted comment statements:

```
;//NOPLINK//
;//PLINK//
```

Assembly statements following the NOPLINK comment are not optimized. Post-link optimization can be reenabled using the //PLINK// comment.

The PLINK and NOPLINK comment format is not case sensitive. There can be white space between the semicolon and PLINK delimiter. The PLINK and NOPLINK comments must appear on a separate line, alone, and must begin in column 1. For example:

```
;     //PLINK//
```

5.6.3 Retaining Post-Link Optimizer Output (--keep_asm Option)

The --keep_asm option allows you to retain any post-link files (.pl) and .absolute listing files (.abs) generated by the −plink option. Using the --keep_asm option lets you view any changes the post-link optimizer makes.

The .pl files contain the commented out statement shown with <<REDUNDANT>> or any improvements to instructions, such as <<ADD=>ADDB>>. The .pl files are assembled and linked again to exclude the commented out lines.

5.6.4 Disable Optimization Across Function Calls (-nf Option)

The −nf option disables the post-link optimization across function calls. The post-link optimizer recognizes the function end by the return statement and assumes there is only one return statement per function. In some hand written assembly code, it is possible to have more than one return statement per function. In such cases, the output of the post-link optimization can be incorrect. You can turn off the optimization across function calls by using the− nf option. This option affects all the files.

5.7 Restrictions on Using the Post-Link Optimizer

The following restrictions affect post-link optimization:

- Post-link optimization is not supported on FPU targets.
- Branches or calls to unlabeled destinations invalidate DP load optimizations. All branch destinations must have labels.
- If the position of the data sections depends on the size of the code sections, the data page layout information used to decide which DP load instructions to remove may no longer be valid.

  For example, consider the following link command file:

```
SECTIONS
{
    .text    > MEM,
    .mydata  > MEM,}
```

  A change in the size of the .text section after optimizing causes the .mydata section to shift. Ensuring that all output data sections are aligned on a 64-word boundary removes this shifting issue. For example, consider the following link command file:

```
SECTIONS
{
    .text > MEM,
    .mydata align = 64 > MEM,}
```

5.8 Naming the Outfile (--output_file Option)

When using the -plink option, you must include the --output_file option. If the output filename is specified in a linker command file, the compiler does not have access to the filename to pass it along to other phases of post-link optimization, and the process will fail. For example:

```
cl2000 -v28 file1.c file2.asm --run_linker --output_file=prog.out lnk.cmd -plink
```

Because the post-link optimization flow uses the absolute lister, abs2000, it must be included in your path.

TMS320C28x C/C++ Language Implementation

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 (IS0).

The C++ language supported by the C28x is defined by the ANSI/ISO/IEC 14882:1998 standard with certain exceptions.

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6.1 Characteristics of TMS320C28x 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 TMS320C28x C++

The C28x 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 6.7.
- 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 <complex> header and its functions are not included in the library.
- The 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, 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.
- 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.
- 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 6.10.1.
- RESET_MISRA pragma resets the specified MISRA-C:2004 rules to the state they were before any CHECK_MISRA pragmas were processed. See Section 6.10.14.

The syntax of the option and pragmas are:

--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 C28x compiler. Many of the range values are available as standard macros in the header file limits.h.

Table 6-1. TMS320C28x C/C++ Data Types

			Range	
Type	**Size**	**Representation**	**Minimum**	**Maximum**
char, signed char	16 bits	ASCII	-32 768	32 767
unsigned char	16 bits	ASCII	0	65 535
short	16 bits	2s complement	-32 768	32 767
unsigned short	16 bits	Binary	0	65 535
int, signed int	16 bits	2s complement	-32 768	32 767
unsigned int	16 bits	Binary	0	65 535
long, signed long	32 bits	2s complement	-2 147 483 648	2 147 483 647
unsigned long	32 bits	Binary	0	4 294 967 295
long long, signed long long	64 bits	2s complement	-9 223 372 036 854 775 808	9 223 372 036 854 775 807
unsigned long long	64 bits	Binary	0	18 446 744 073 709 551 615
enum	16 bits	2s complement	-32 768	32 767
float	32 bits	IEEE 32-bit	1.19 209 290e-38(1)	3.40 282 35e+38
double	32 bits	IEEE 32-bit	1.19 209 290e-38(1)	3.40 282 35e+38
long double	64 bits	IEEE 64-bit	2.22 507 385e-308(1)	1.79 769 313e+308
pointers	16 bits	Binary	0	0xFFFF
far pointers	22 bits	Binary	0	0x3FFFFF

(1) Figures are minimum precision.

NOTE: TMS320C28x Byte is 16 Bits

By ANSI/ISO C definition, the sizeof operator yields the number of bytes required to store an object. ANSI/ISO further stipulates that when sizeof is applied to char, the result is 1. Since the TMS320C28x char is 16 bits (to make it separately addressable), a byte is also 16 bits. This yields results you may not expect; for example, size of (int) = = 1 (not 2). TMS320C28x bytes and words are equivalent (16 bits). To access data in increments of 8 bits, use the __byte() and __mov_byte() intrinsics described in Section 7.4.5.

6.4.1 Support for 64-Bit Integers

The TMS320C28x compiler supports the long long and unsigned long long data types. The range values are available as standard macros in the header file limits.h.

The long long data types are stored in register pairs. In memory they are stored as 64-bit objects at word (32-bit) aligned addresses.

A long long integer constant can have an ll or LL suffix. Without the suffix the value of the constant determines the type of the constant.

The formatting rules for long long in C I/O require ll in the format string. For example:

```
printf("%lld", 0x0011223344556677);
printf("%llx", 0x0011223344556677);
```

The run-time-support library functions, llabs(), strtoll() and strtoull(), are added.

6.4.2 C28x long double Floating-Point Type Change

When compiling C/C++ code for the TMS320C28x only, the long double floating point type is now IEEE 64-bit double precision. No other floating-point types have changed formats. C28x floating point types are:

Type	Format
float	IEEE 32-bit single precision
double	IEEE 32-bit single precision
long double	IEEE 64-bit double precision

When you initialize a long double to a constant, you must use the l or L suffix. The constant is treated as a double type without the suffix and the run-time support double-to-long conversion routine is called for the initialization. This could result in the loss of precision. For example:

```
long double a = 12.34L; /* correctly initializes to double precision */
long double b = 56.78;  /* converts single precision value to double precision */
```

The formatting rules for long doubles in C I/O require a capital 'L' in the format string. For example:

```
printf("%Lg", 1.23L);
printf("%Le", 3.45L);
```

In response to the change in the long double type to 64-bit IEEE double-precision format, the C28x calling conventions have changed.

All long double arguments are passed by reference. A long double return value is returned by reference. The first two long double arguments will pass their addresses in XAR4 and XAR5. All other long double arguments will have their addresses passed on the stack. It is necessary to assume that these long double address will be in far memory. Therefore, the called function will always read 32-bits for the addresses of long double arguments.

If a function returns a long double, the function making that call will place the return address in XAR6. For example:

```
long double foo(long double a, long double b, long double c)
{
   long double d = a + b + c;
   return d;
}
long double a = 1.2L;
long double b = 2.2L;
long double c = 3.2L;
long double d;

void bar()
{
   d = foo(a, b, c);
}
```

In function bar(), at the call to foo(), the register values are:

Register	Equals
XAR4	The address of a
XAR5	The address of b
*−SP[2]	The address of c
XAR6	The address of d

The run-time-support library has been updated to include the necessary long double arithmetic operations and conversion functions. All C27x/C28x floating-point run-time-support routines have had their names updated. For example, a previous call to the floating point add routine was:

```
   LCR F$$ADD
```

This has been updated to:

```
   LCR FS$$ADD  ; single-precision add
   LCR FD$$ADD  ; double-precision add
```

Any C28x routine that calls floating-point arithmetic or conversion routines will need to be recompiled.

6.5 Keywords

The C28x C/C++ compiler supports the standard const, register, and volatile keywords. In addition, the C/C++ compiler extends the C/C++ language through the support of the cregister and interrupt keywords. In C mode, the C/C++ compiler supports the far keyword. The compiler also supports the restrict keyword for FPU targets; for other targets restrict is ignored.

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 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 (function scope).

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:

```
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:

```
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 C28x (see Table 6-2). 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 6-2. Valid Control Registers

Register	Description
IER	Interrupt enable register
IFR	Interrupt flag register

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 6-2, you must declare each register as follows. The c28x.h include file defines all the control registers through this syntax:

extern cregister volatile unsigned int *register* **;**

Once you have declared the register, you can use the register name directly, though in a limited manner. IFR is read only and can be set only by using the | (OR) operation with an immediate. IFR can be cleared only by using the & (AND) operation with an immediate. For example:

```
IFR |= 0x4;
IFR &= 0x0800
```

The IER register also can be used in an assignment other than OR and AND. Since the C28x architecture has limited instructions to manipulate these registers, the compiler terminates with the following message if illegal use of these registers is found:

```
>>> Illegal use of control register
```

See Example 6-1 for an example that declares and uses control registers.

Example 6-1. Define and Use Control Registers

```
extern cregister volatile unsigned int IFR;
extern cregister volatile unsigned int IER;
extern int x;

main()
{
   IER = x;
   IER |= 0x100;
   printf("IER = %x\n", IER);

   IFR &= 0x100;
   IFR |= 0x100;
```

6.5.3 The far Keyword

The default address space of the C/C++ compiler is limited to the low 64K of memory. All pointers have a default size of 16 bits. The TMS320C28x supports addressing beyond 16 bits. In C, the compiler can access up to four megawords of data by extending the C language with the use of the far type qualifier. A far pointer has a 22-bit size.

Far support in C++

NOTE: The TMS320C/C++ compiler does not support the far keyword in C++. Access to far objects in C++ is available through the use of the large memory model option or through intrinsics. For more information, see Section 6.6.

6.5.3.1 Semantics

Declaring an object far designates that the object be placed in far memory. This is accomplished by reserving space for that object in a different section than the default .bss. Global variables declared far are placed in a section called .ebss. This section can then be linked anywhere in the TMS320C28x data address space. const objects declared far are similarly placed in the .econst section.

Pointers that are declared to point at far objects have a size of 22 bits. They require two memory locations to store and require the XAR registers to perform addressing.

Pointer Distinction

NOTE: There is a distinction between declaring a pointer that points at far data (far int *pf) and declaring the pointer itself as far (int*far fp;).

Only global and static variables can be declared far. Nonstatic variables defined in a function (automatic storage class) cannot be far because these variables are allocated on the stack. The compiler will issue a warning and treat these variables as near.

It is meaningless to declare structure members as far. A structure declared far implies that all of its members are far.

6.5.3.2 Syntax

The compiler recognizes far or _ _far as synonymous keywords. The far keyword acts as a type qualifier. When declaring variables, far is used similarly to the type qualifiers const and volatile. Example 6-2 shows the correct way to declare variables.

Example 6-2. Declaring Variables

```
int far sym;        // sym is located in far memory.
far int sym;        // sym is located in far memory.

struct S far s1;    // Likewise for structure s1.

int far *ptr;       // This declares a pointer that points to a far int.
                    // The variable ptr is itself near.

int * far ptr;      // This declares a pointer to a near int. The variable
                    // ptr, however, is located in far memory.

int far * far ptr;  // The pointer and the object it points to are both far.

int far *func();    // Function that returns a pointer to a far int.

int far *memcpy_ff(far void *dest, const far void *src, int count);
                    // Function that takes two far pointers as arguments
                    // and returns a far pointer.

int *far func()     // ERROR: Declares the function as far. Since the
                    // program address space is flat 22-bit, this has no
                    // meaning. Far applies to data only.

int func();
{
int far x;          // ERROR: Far only applies to global/static variables.
:                   // Auto variables on the stack are required to be near
:

int far *ptr        // Ok, since the pointer is on the stack, but points
                    // to far
}

struct S            // Declaring structure members as far is meaningless,
}                   // unless it's a pointer to far.  Structure objects
int a;              // can, of course, be declared far.
int far b;
int far *ptr;
};
```

6.5.3.3 far Run-Time Library Support

The run-time library has been extended to include far versions of most run-time-support functions that have pointers as arguments, return values, or that reference run-time-support global variables. There is also support for managing a far heap. Far run-time-support does not include the C I/O routines or any functions that reference C I/O routines. For more information about far run-time support, see Section 8.2.

6.5.3.4 far Pointer Math

The ANSI/ISO standard states that valid pointer operations are assignment of pointers of the same type, adding or subtracting a pointer and an integer, subtracting or comparing two pointers to members of the same array, and assigning or comparing to zero. All other pointer arithmetic is illegal.

These rules apply to far pointers. The result of subtracting two far pointers is a 16-bit integer type. This implies that the compiler does not support pointer subtraction for arrays larger than 64K words in size.

6.5.3.5 far String Constants

For information about placing string constants in far memory, see Section 7.1.8 and Section 7.1.9.

6.5.3.6 Allocating .econst to Program Memory

For information about how to copy the .econst section from program to data memory at boot time, see Section 7.1.3.

6.5.4 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:

```
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).

HWI Objects and the interrupt Keyword

NOTE: The interrupt keyword 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.

6.5.5 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 6-3, 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 6-3. Use of the restrict Type Qualifier With Pointers

```
void func1(int * restrict a, int * restrict b)
{
  /* func1's code here */
}
```

Example 6-4 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 6-4. Use of the restrict Type Qualifier With Arrays

```
void func2(int c[restrict], int d[restrict])
{
  int i;

  for(i = 0; i < 64; i++)
  {
    c[i] += d[i];
    d[i] += 1;
  }
}
```

At this time the restrict keyword is useful only for FPU targets. For non-FPU targets restrict is ignored.

6.5.6 The volatile Keyword

The compiler analyzes data flow to avoid memory accesses whenever possible. If you have code that depends on memory accesses exactly as written in the C/C++ code, you must use the volatile keyword to identify these accesses. A variable qualified with a volatile keyword is allocated to an uninitialized section (as opposed to a register). The compiler does not optimize out any references to volatile variables.

In the following example, the loop intends to wait for a location to be read as 0xFF:

```
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:

```
volatile unsigned int *ctrl;
```

Here the *ctrl pointer is intended to reference a hardware location, such as an interrupt flag.

6.6 Accessing far Memory From C++

Accessing far memory is handled differently with C and C++ code. The following sections describe accessing far memory from C++ using the -ml option or intrinsics. See Section 6.5.3 for information on using the far keyword to access far memory from C code.

6.6.1 Using the Large Memory Model (--large_memory_model Option)

Since there is no support for the far keyword in C++ code, the large memory model option is provided. The --large_memory_model option forces the compiler to view the TMS320C28x architecture as having a flat 22-bit address space. When you compile with the --large_memory_model option, all pointers are considered to be 22-bit pointers. There is no 64K word limit on a data type size.

The assembler --large_memory_model option is used to allow conditional compilation of 16-bit code with large memory model code. The LARGE_MODEL symbol is predefined by the assembler and automatically set to false unless the --large_memory_model option is used. When compiling for FPU targets, large memory model is assumed. The compiler aborts with an error message if the small model is specified with --float_support={fpu32|fpu64}.

The run-time-support libraries support the large memory model through conditional compilation. When compiling the run-time-support libraries, the LARGE_MODEL symbol must be defined. This symbol is needed if any of the run-time-support functions that pass a size_t argument or return a size_t argument are accessed in your code. This symbol is also needed if the run-time-support va_arg or offsetof( ) macro is used. Therefore, you should use the --define compiler option (see Section 2.3.1) to predefine the LARGE_MODEL symbol when compiling under the large memory model.

6.6.2 Using Intrinsics to Access far Memory in C++

The far keyword extends the C language only. There is no support for the far keyword in C++. Intrinsics are provided to allow access to far memory in C++, along with heap management support routines in the C++ run-time-support library if the large memory model is not used. The intrinsics accept a long integer type that represents an address. The return value of the intrinsic is an implicit far pointer that can be dereferenced to provide access to these basic data types: word, long, float, long long, and long double.

- __farptr_to_word (long address)
- __farptr_to_long (long address)
- __farptr_to_float (long address)
- __farptr_to_llong (long address)
- __farptr_to_ldouble (long address)

There are two methods used for generating long addresses that can access far memory:

- You can use the C++ run-time-support library heap management functions which are provided in the C++ run-time-support library:
  - long far_calloc (unsigned long num, unsigned long size)
  - long far_malloc (unsigned long size)
  - long far_realloc (long ptr, unsigned long size)
  - void far_free (long ptr)

  These functions allocate memory in the far heap. The intrinsics can then be used to access that memory. For example:

```
#include <stdlib.h>;

extern int x;
extern long y;
extern float z;

extern void func1 (int a);
extern void func2 (long b);
extern void func3 (float c);

//create a far object on the heap
long farint = far_malloc (sizeof (int))
long farlong = far_malloc (sizeof (long));
long farfloat = far_malloc (sizeof (float));
```

```
//assign a value to the far object
*__farptr_to_word (farint) = 1;
*__farptr_to_word (farint) = x;
*__farptr_to_long (farlong) = 78934;
*__farptr_to_long (farlong) = y;
*__farptr_to_float (farfloat) = 4.56;
*__farptr_to_float (farfloat) = z;

//use far object in expression
x = *__farprt_to_word (farint) + x;
y = *__farptr_to_long (farlong) + y;
z = *__farptr_to_float (farfloat) + z;

//use as argument to function
func1 (*__farptr_to_word (farint));
func2 (*__farptr_to_long (farlong));
func3 (*__farptr_to_float (farfloat));

//free the far object
far_free (farint);
far_free (farlong);
far_free (farfloat);
```

- The DATA_SECTION pragma can be used along with inline assembly to place variables in a data section that is linked in far memory. The in-line assembly is used to create a long address to those variables. The intrinsics can then be used to access those variables. For example:

```
#pragma DATA_SECTION (var, ".mydata")
int var;
extern const long var_addr;
asm ("\t .sect .const");
asm ("var_addr .long var");
int x;
x = *__farptr_to_word (var_addr);
```

6.7 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. Also, when using --exceptions, you need to link with run-time-support libraries whose name contains _eh. These libraries contain functions that implement exception handling.

Using --exceptions causes

Using --exceptions causes the compiler to insert exception handling code. This code will increase the code size of the programand execution time, even if no exceptions are thrown.

See Section 8.1 for details on the run-time libraries.

6.8 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 7.2.

6.9 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 *asm* statement. The asm (or __asm) statement provides access to hardware features that C/C++ cannot provide. The asm statement is syntactically like a call to a function named asm, with one string constant argument:

asm(" *assembler text* **");**

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:

```
asm("STR: .byte \"abc\"");
```

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 *TMS320C28x Assembly Language Tools User's Guide*.

The 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 __asm("assembler text") if you are writing code for strict ANSI/ISO C mode (using the --strict_ansi option).

NOTE: Avoid Disrupting the C/C++ Environment With asm Statements

Be careful not to disrupt the C/C++ environment with 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 asm statements. Although the compiler cannot remove asm statements, it can significantly rearrange the code order near them and cause undesired results.

NOTE: Use Single asm Statement for the RPT Instruction

When adding a C28x RPT instruction, do not use a separate asm statement for RPT and the repeated instruction. The compiler could insert debug directives between asm directives and the assembler does not allow any directives between the RPT and the repeated instruction. For example, to insert a RPT MAC instruction, use the following:

```
asm("\tRPT #10\n\t||MAC P, *XAR4++, *XAR7++");
```

6.10 Pragma Directives

Pragma directives tell the compiler how to treat a certain function, object, or section of code. The C28x C/C++ compiler supports the following pragmas:

- CHECK_MISRA
- CLINK
- CODE_ALIGN
- CODE_SECTION
- DATA_SECTION
- DIAG_SUPPRESS, DIAG_REMARK, DIAG_WARNING, DIAG_ERROR, and DIAG_DEFAULT
- FAST_FUNC_CALL
- FUNC_EXT_CALLED
- FUNCTION_OPTIONS
- INTERRUPT
- MUST_ITERATE
- RESET_MISRA
- RETAIN
- UNROLL

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.

6.10.1 The CHECK_MISRA Pragma

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 6.10.14.

6.10.2 The CLINK Pragma

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 6.10.15 for more details.

6.10.3 The CODE_ALIGN Pragma

The CODE_ALIGN pragma aligns *func* along the specified alignment. The alignment *constant* must be a power of 2. The CODE_ALIGN pragma is useful if you have functions that you want to start at a certain boundary.

The syntax of the pragma in C is:

#pragma CODE_ALIGN (*func***,** *constant* **);**

The syntax of the pragma in C++ is:

#pragma CODE_ALIGN (*constant* **);**

6.10.4 The CODE_SECTION Pragma

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_SECTION Pragma C Source File

```
char bufferA[80];
char bufferB[80];

#pragma CODE_SECTION(funcA, "codeA")

char funcA(int i);
char funcB(int i);

void main()
{
   char c;
   c = funcA(1);
   c = funcB(2);
}

char funcA (int i)
{
   return bufferA[i];
}

char funcB (int j)
{
   return bufferB[j];
}
```

Example 6-6. Generated Assembly Code From Example 6-5

```
        .sect   ".text"
        .global _main;

;*************************************************************
;* FNAME: _main                          FR SIZE:   2          *
;*                                                             *
;* FUNCTION ENVIRONMENT                                        *
;*                                                             *
;* FUNCTION PROPERTIES                                         *
;*                            0 Parameter,  1 Auto,  0 SOE     *
;*************************************************************

:_main:
        ADDB      SP,#2
        MOVB      AL,#1                 ; |12|
        LCR       #_funcA               ; |12|
                   ; call occurs [#_funcA] ; |12|
        MOV       *-SP[1],AL            ; |12|
        MOVB      AL,#1                 ; |13|
        LCR       #_funcB               ; |13|
                ; call occurs [#_funcB] ; |13|
        MOV       *-SP[1],AL            ; |13|
        SUBB      SP,#2
        LRETR
        ; return occurs

        .sect   "codeA"
        .global _funcA
;*************************************************************
;* FNAME: _funcA                         FR SIZE:   1          *
;*                                                             *
;* FUNCTION ENVIRONMENT                                        *
;*                                                             *
;* FUNCTION PROPERTIES                                         *
;*                            0 Parameter,  1 Auto,  0 SOE     *
;*************************************************************

_funcA:
        ADDB      SP,#1
        MOV       *-SP[1],AL            ; |17|
        MOVZ      AR6,*-SP[1]           ; |18|
```

Example 6-6. Generated Assembly Code From Example 6-5 (continued)

```
        ADD       AR6,#_bufferA         ; |18|
        SUBB      SP,#1                 ; |18|
        MOV       AL,*+XAR6[0]          ; |18|
        LRETR
        ;return occurs

         .sect   ".text"
         .global _funcB;

;****************************************************************
;* FNAME: _funcB                        FR SIZE:   1            *
;*                                                              *
;* FUNCTION ENVIRONMENT                                         *
;*                                                              *
;* FUNCTION PROPERTIES                                          *
;*                            0 Parameter,  1 Auto,  0 SOE      *
;****************************************************************

_funcB:
        ADDB      SP,#1
        MOV       *-SP[1],AL            ; |22|
        MOVZ      AR6,*-SP[1]           ; |23|
        ADD       AR6,#_bufferB         ; |23|
        SUBB      SP,#1                 ; |23|
        MOV       AL,*+XAR6[0]          ; |23|
        LRETR
        ;return occurs
```

6.10.5 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* **);**

6.10.6 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:

#pragma DATA_SECTION (*symbol* **, "** *section name* **");**

The syntax of the pragma in C++ is:

#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 6-7 through Example 6-9 demonstrate the use of the DATA_SECTION pragma.

Example 6-7. Using the DATA_SECTION Pragma C Source File

```
#pragma DATA_SECTION(bufferB, "my_sect")
char bufferA[512];
char bufferB[512];
```

Example 6-8. Using the DATA_SECTION Pragma C++ Source File

```
char bufferA[512];
#pragma DATA_SECTION("my_sect")
char bufferB[512];
```

Example 6-9. Using the DATA_SECTION Pragma Assembly Source File

```
           .global _bufferA
           .bss    _bufferA,512,4
           .global _bufferB
_bufferB:  .usect  "my_sect",512,4
```

6.10.7 The Diagnostic Message Pragmas

The following pragmas can be used to control diagnostic messages in the same ways as the corresponding command line options:

Pragma	Option	Description
DIAG_SUPPRESS *num*	-pds=*num*[, num_2, num_3...]	Suppress diagnostic *num*
DIAG_REMARK *num*	-pdsr=*num*[, num_2, num_3...]	Treat diagnostic *num* as a remark
DIAG_WARNING *num*	-pdsw=*num*[, num_2, num_3...]	Treat diagnostic *num* as a warning
DIAG_ERROR *num*	-pdse=*num*[, num_2, num_3...]	Treat diagnostic *num* as an error
DIAG_DEFAULT *num*	n/a	Use default severity of the diagnostic

The syntax of the pragmas in C is:

***#pragma DIAG**_XXX* [=]*num*[, num_2, num_3...]

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.

6.10.8 The FAST_FUNC_CALL Pragma

The FAST_FUNC_CALL pragma, when applied to a function, generates a TMS320C28x FFC instruction to call the function instead of the CALL instruction. Refer to the *TMS320C28x DSP CPU and Instruction Set User's Guide* for more details on the FFC instruction.

The syntax of the pragma in C is:

#pragma FAST_FUNC_CALL (*func* **);**

The syntax of the pragma in C++ is:

#pragma FAST_FUNC_CALL (*func* **);**

The FAST_FUNC_CALL pragma should be applied only to a call to an assembly function that returns with the LB *XAR7 instruction. See Section 7.4.1 for information on combining C/C++ and assembly code.

Since this pragma should be applied only to assembly functions, if the compiler finds a definition for *func* in the file scope, it issues a warning and ignores the pragma.

The following example demonstrates the use of the FAST_FUNC_CALL pragma.

Example 6-10. Using the FAST_FUNC_CALL Pragma Assembly Function

```
_add_long:
        ADD ACC, *-SP[2]
        LB *XAR7
```

Example 6-11. Using the FAST_FUNC_CALL Pragma C Source File

```
#pragma FAST_FUNC_CALL (add_long);

long add_long(long, long);

void foo()
{
   long x, y;
   x = 0xffff;
   y = 0xff;
   y = add_long(x, y);
}
```

Example 6-12. Generated Assembly File

```
;***************************************************************
;* FNAME: _foo                          FR SIZE:   6           *
;*                                                             *
;* FUNCTION ENVIRONMENT                                        *
;*                                                             *
;* FUNCTION PROPERTIES                                         *
;*                            2 Parameter,  4 Auto,  0 SOE     *
;***************************************************************

_foo:
        ADDB      SP,#6
        MOVB      ACC,#255
        MOVL      XAR6,#65535           ; |8|
        MOVL      *-SP[6],ACC
        MOVL      *-SP[2],ACC           ; |10|
        MOVL      *-SP[4],XAR6          ; |8|
        MOVL      ACC,*-SP[4]           ; |10|
        FFC       XAR7,#_add_long       ; |10|
        ; call occurs [#_add_long]      ; |10|
        MOVL      *-SP[6],ACC           ; |10|
        SUBB      SP,#6
        LRETR
        ; return occurs
```

6.10.9 The FUNC_EXT_CALLED Pragma

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 3.3.2.

6.10.10 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" );
```

6.10.11 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.

On the FPU, there are two kinds of interrupts - High Priority Interrupt (HPI) and Low Priority Interrupt (LPI). High priority interrupts use a fast context save and cannot be nested. Low priority interrupts behave like normal C28x interrupts and can be nested.

The kind of interrupt can be specified by way of the interrupt pragma using an optional second argument. The C syntax of the pragma is:

```
#pragma INTERRUPT ( func , {HPI|LPI} );
```

The syntax of the pragma in C++ is:

```
#pragma INTERRUPT ( {HPI|LPI} );
```

To specify an HPI interrupt use HPI. To specify an LPI interrupt use LPI. On FPU, if no interrupt priority is specified LPI is assumed. Interrupts specified with the interrupt keyword also default to LPI.

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.

6.10.12 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.

6.10.12.1 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.

6.10.12.2 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:

```
#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:

```
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:

```
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:

```
#pragma MUST_ITERATE(8, 8);

for(i2 = ipos[2]; i2 < 40; i2 += 5)  { ...
```

6.10.13 The NO_HOOKS Pragma

The NO_HOOKS pragma prevents entry and exit hook calls from being generated for a function.

The syntax of the pragma in C is:

#pragma NO_HOOKS (*func* **);**

The syntax of the pragma in C++ is:

#pragma NO_HOOKS;

See Section 2.13 for details on entry and exit hooks.

6.10.14 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 6.10.1) 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:

#pragma RESET_MISRA (" {all|required|advisory|*rulespec*} **")**

The *rulespec* parameter is a comma-separated list of specifiers. See Section 6.3 for details.

6.10.15 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:

#pragma RETAIN (*symbol* **)**

The CLINK pragma has the opposite effect of the RETAIN pragma. See Section 6.10.2 for more details.

6.11 The _Pragma Operator

The C28x 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.

6.12 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.

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.

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.

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:

```
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.

6.13 Initializing Static and Global Variables

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, 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.

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:

```
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 *TMS320C28x 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:

```
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:

```
const int zero = 0   /*  guaranteed to be 0  */
```

This corresponds to an entry in the .const section:

```
   .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:

```
#pragma DATA_SECTION (var, ".mysect");
   const int zero=0;
```

is compiled into this assembly code:

```
   .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:

  ```
  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:

  ```
  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 */
```

6.14.2 Enabling Strict ANSI/ISO Mode and Relaxed ANSI/ISO Mode (--strict_ansi and --relaxed_ansi Options)

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 C28x 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 TMS320C28x compiler defines the _embedded_cplusplus macro for embedded C++ compile.

The run-time-support libraries supplied with the compiler can be used to link with a module compiled for embedded C++.

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.

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 6-3, which is based on the list of extensions found at the GNU web site. The shaded rows describe extensions that are not supported.

Table 6-3. GCC Language Extensions

Extensions	Descriptions
Statement expressions	Putting statements and declarations inside expressions (useful for creating smart 'safe' macros)
Local labels	Labels local to a statement expression
Labels as values	Pointers to labels and computed gotos
Nested functions	As in Algol and Pascal, lexical scoping of functions
Constructing calls	Dispatching a call to another function
Naming types(1)	Giving a name to the type of an expression
typeof operator	typeof referring to the type of an expression
Generalized lvalues	Using question mark (?) and comma (,) and casts in lvalues
Conditionals	Omitting the middle operand of a ?: expression
long long	Double long word integers and long long int type
Hex floats	Hexadecimal floating-point constants
Complex	Data types for complex numbers
Zero length	Zero-length arrays
Variadic macros	Macros with a variable number of arguments
Variable length	Arrays whose length is computed at run time
Empty structures	Structures with no members
Subscripting	Any array can be subscripted, even if it is not an lvalue.
Escaped newlines	Slightly looser rules for escaped newlines
Multi-line strings(1)	String literals with embedded newlines
Pointer arithmetic	Arithmetic on void pointers and function pointers
Initializers	Non-constant initializers
Compound literals	Compound literals give structures, unions, or arrays as values
Designated initializers	Labeling elements of initializers
Cast to union	Casting to union type from any member of the union
Case ranges	'Case 1 ... 9' and such
Mixed declarations	Mixing declarations and code
Function attributes	Declaring that functions have no side effects, or that they can never return
Attribute syntax	Formal syntax for attributes
Function prototypes	Prototype declarations and old-style definitions
C++ comments	C++ comments are recognized.
Dollar signs	A dollar sign is allowed in identifiers.
Character escapes	The character ESC is represented as \e
Variable attributes	Specifying the attributes of variables
Type attributes	Specifying the attributes of types
Alignment	Inquiring about the alignment of a type or variable

(1) Feature defined for GCC 3.0; definition and examples at http://gcc.gnu.org/onlinedocs/gcc-3.0.4/gcc/C-Extensions.html

Table 6-3. GCC Language Extensions (continued)

Extensions	Descriptions
Inline	Defining inline functions (as fast as macros)
Assembly labels	Specifying the assembler name to use for a C symbol
Extended asm	Assembler instructions with C operands
Constraints	Constraints for asm operands
Alternate keywords	Header files can use __const__, __asm__, etc
Explicit reg vars	Defining variables residing in specified registers
Incomplete enum types	Define an enum tag without specifying its possible values
Function names	Printable strings which are the name of the current function
Return address	Getting the return or frame address of a function (limited support)
Other built-ins	Other built-in functions (see Section 6.15.5)
Vector extensions	Using vector instructions through built-in functions
Target built-ins	Built-in functions specific to particular targets
Pragmas	Pragmas accepted by GCC
Unnamed fields	Unnamed struct/union fields within structs/unions
Thread-local	Per-thread variables

6.15.2 Function Attributes

The following function attributes are supported: always_inline, const, constructor, deprecated, format, format_arg, malloc, noinline, noreturn, pure, section, unused, used and warn_unused_result.

The format attribute is applied to the declarations of printf, fprintf, sprintf, snprintf, vprintf, vfprintf, vsprintf, vsnprintf, scanf, fscanf and sscan 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).

6.15.4 Type Attributes

The following type attributes are supported: aligned, deprecated, packed, transparent_union, and unused.

The packed attribute on struct and union types is available only for target architectures that have hardware support for unaligned access .

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.

6.16 Compiler Limits

Due to the variety of host systems supported by the C/C++ compiler and the limitations of some of these systems, the compiler may not be able to successfully compile source files that are excessively large or complex. In general, exceeding such a system limit prevents continued compilation, so the compiler aborts immediately after printing the error message. Simplify the program to avoid exceeding a system limit.

Some systems do not allow filenames longer than 500 characters. Make sure your filenames are shorter than 500.

The compiler has no arbitrary limits but is limited by the amount of memory available on the host system. On smaller host systems such as PCs, the optimizer may run out of memory. If this occurs, the optimizer terminates and the shell continues compiling the file with the code generator. This results in a file compiled with no optimization. The optimizer compiles one function at a time, so the most likely cause of this is a large or extremely complex function in your source module. To correct the problem, your options are:

- Don't optimize the module in question.
- Identify the function that caused the problem and break it down into smaller functions.
- Extract the function from the module and place it in a separate module that can be compiled without optimization so that the remaining functions can be optimized.

Run-Time Environment

This chapter describes the TMS320C28x 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.

Topic **Page**

7.1 Memory Model

The C28x compiler treats memory as two linear blocks of program and data memory:

- Program memory contains executable code, initialization records, and switch tables.
- Data memory contains external variables, static variables, and the system stack.

Blocks of code or data generated by a C/C++ program are placed into contiguous blocks in the appropriate memory space.

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 module information in the *TMS320C28x 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 **.cinit section** and the **.pinit section** contain tables for initializing variables and constants. The C28x .cinit record is limited to 16 bits. This limits initialized objects to 64K.
  - The **.const section** contains string constants, switch tables, and data defined with the C/C++ qualifier *const* (provided the constant is not also defined as *volatile*).
  - The **.econst** section contains string constants, and the declaration and initialization of global and static variables (qualified by *far const* or the use of the large memory model) that are explicitly initialized and placed in far memory.
  - The **.switch** section contains tables for switch statements.
  - The **.text section** contains all the executable code as well as string literals and compiler-generated constants.
- **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:
  - The **.bss section** reserves space for global and static variables. At boot or load time, the C/C++ boot routine copies data out of the .cinit section (which can be in ROM) and stores it in the .bss section.
  - The **.ebss section** reserves space for global and static variables defined as far (C only) or when the large memory model is used. At program startup time, the C/C++ boot routine copies data out of the .cinit section (which can be in ROM) and uses it for initializing variables in the .ebss section.
  - The **.stack section** reserves memory for the C/C++ software stack. This memory is used to pass arguments to functions and to allocate space for local variables.
  - 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.
  - The **.esysmem section** reserves space for dynamic memory allocation. The reserved space is used by far malloc functions. If a C/C++ program does not use far malloc, the compiler does not

create the .esysmem section.

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 6.10.4 and Section 6.10.6).

The linker takes the individual sections from different modules and combines sections that have the same name. The resulting output sections and the appropriate placement in memory for each section are listed in Table 7-1. You can place these output sections anywhere in the address space as needed to meet system requirements.

Table 7-1. Summary of Sections and Memory Placement

Section	Type of Memory	Page	Section	Type of Memory	Page
.bss	RAM	1	.esysmem	RAM	1
.cinit	ROM or RAM	0	.pinit	ROM or RAM	0
.const	ROM or RAM	1	.stack	RAM	1
.data	ROM or RAM		.switch	ROM or RAM	0, 1
.ebss	RAM		.sysmem	RAM	1
.econst	ROM or RAM	1	.text	ROM or RAM	0

You can use the SECTIONS directive in the linker command file to customize the section-allocation process. For more information about allocating sections into memory, see the linker description chapter in the *TMS320C28x Assembly Language Tools User's Guide*.

7.1.2 C/C++ System Stack

The C/C++ compiler uses a stack to:

- Allocate local variables
- Pass arguments to functions
- Save the processor status
- Save function return addresses
- Save temporary results

The run-time stack grows up from low addresses to higher addresses. By default, the stack is allocated in the .stack section. (See the run-time-support boot.asm file.) The compiler uses the hardware stack pointer (SP) to manage this stack.

Linking the .stack Section

NOTE: The .stack section has to be linked into the low 64K of data memory. The SP is a 16-bit register and cannot access addresses beyond 64K.

For frames that exceed 63 words in size (the maximum reach of the SP offset addressing mode), the compiler uses XAR2 as a frame pointer (FP). Each function invocation creates a new frame at the top of the stack, from which local and temporary variables are allocated. The FP points at the beginning of this frame to access memory locations that can not be referenced directly using the SP.

The stack size is set by the linker. The linker also creates a global symbol, __STACK_SIZE_, and assigns it a value equal to the size of the stack in bytes. The default stack size is 1K words. You can change the size of the stack at link time by using the --stack_size linker option.

Stack Overflow

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 2.13.

7.1.3 Allocating .const/.econst to Program Memory

If your system configuration does not support allocating an initialized section such as .const/.econst to data memory, then you have to allocate the .const/.econst section to load in program memory and run in data memory. At boot time, copy the .const/.econst section from program to data memory. The following sequence shows how you can perform this task.

Modify the boot routine:

1. Extract boot.asm from the source library:
   ```
   ar2000 -x rts.src boot.asm
   ```
2. Edit boot.asm and change the CONST_COPY flag to 1:
   ```
   CONST_COPY  .set 1
   ```
3. Assemble boot.asm:
   ```
   cl2000 -v28 boot.asm
   ```
4. Archive the boot routine into the object library:
   ```
   ar2000 -r rts2800.lib boot.obj
   ```

For a .const section, link with a linker command file that contains the following entries:

```
MEMORY
{
   PAGE 0 : PROG : ...
   PAGE 1 : DATA : ...
}
SECTIONS
{
   ...
   .const  : load = PROG PAGE 1, run = DATA PAGE 1
             {
                /* GET RUN ADDRESS */
                __const_run = .;
                /* MARK LOAD ADDRESS */
                *(.c_mark)
                /* ALLOCATE .const */
                *(.const)
                /* COMPUTE LENGTH */
                __const_length = .- __const_run;
             }
   ...
}
```

For an .econst section, link with a linker command file that contains the following entries:

```
SECTIONS
{
   ...
   .econst : load = PROG PAGE 1, run = DATA PAGE 1
             {
                /* GET RUN ADDRESS */
                __econst_run = .;
                /* MARK LOAD ADDRESS */
                *(.ec_mark)
                /* ALLOCATE .econst */
                *(.econst)
                /* COMPUTE LENGTH */
                __econst_length = - .__econst_run;
             }
   ...
}
```

In your linker command file, you can substitute the name PROG with the name of a memory area on page 0 and DATA with the name of a memory area on page 1. The rest of the command file must use the names as above. The code in boot.asm that is enabled when you change CONST_COPY to 1 depends on the linker command file using these names in this manner. To change any of the names, you must edit boot.asm and change the names in the same way.

7.1.4 Dynamic Memory Allocation

The run-time-support library supplied with the C28x 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, __SYSMEM_SIZE, and assigns it a value equal to the size of the heap in words. The default size is 1K words. For more information on the --heap_size option, see the linker description chapter in the *TMS320C28x 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:

```
struct big table[100];
```

use a pointer and call the malloc function:

```
struct big *table
table = (struct big *)malloc(100*sizeof(struct big));
```

A far memory pool or far heap, is also available through several far run-time-support library functions (such as far_malloc, far_calloc, and far_realloc). The far heap is created by the linker. The linker also creates a global symbol, __FAR_SYSMEM_SIZE, and assigns it a value equal to the size of the far heap in words. The default size is 1k words. You can change the size of the far memory pool, at link time, with the −farheap option. Specify the size of the memory pool as a constant after the −farheap option on the link command line.

Heap Size Restriction

NOTE: The near heap implementation restricts the size of the heap to 32k words. This constraint does not apply to the far heap.

7.1.5 Initialization of Variables

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.

7.1.6 Allocating Memory for Static and Global Variables

A unique, contiguous space is allocated for all static variables declared in a C/C++ program. The linker determines the address of the space. The compiler ensures that space for these variables is allocated in multiples of words so that each variable is aligned on a word boundary.

The C/C++ compiler expects global variables to be allocated into data memory. (It reserves space for them in .bss.) Variables declared in the same module are allocated into a single, contiguous block of memory.

7.1.7 Field/Structure Alignment

When the compiler allocates space for a structure, it allocates as many words as are needed to hold all of the structure's members and to comply with alignment constraints for each member.

All non-field types are aligned on word boundaries. Fields are allocated as many bits as requested. Adjacent fields are packed into adjacent bits of a word, but they do not overlap words. If a field would overlap into the next word, the entire field is placed into the next word.

Fields are packed as they are encountered; the least significant bits of the structure word are filled first.

7.1.8 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:

  ```
  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:

  ```
  strcpy (s, "abc");
  ```

  When a string is used in an expression, the string itself is defined in the .const section with the .string assembler directive, along with a unique label that points to the string; the terminating 0 byte is included. For example, the following lines define the string abc, and the terminating 0 byte (the label SL5 points to the string):

  ```
       .sect   ".const"
  SL5: .string "abc",0
  ```

  String labels have the form SL*n*, where *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 SL*n* 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:

  ```
  const char   *a = "abc"
  a[1] = 'x';             /* Incorrect! */
  ```

7.1.9 far Character String Constants

In C, a character string constant can be placed in the .econst section. When initializing a character pointer or using a character in an expression, use the far keyword. For example:

far string constants are placed in the .econst section is the same manner as described in Section 7.1.8. The far string labels have the form FSLn. This method is also used with the large memory model.

7.2 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. There are two types of register variable registers, save on entry and save on call. The distinction between these two types of registers is the method by which they are preserved across function calls. It is the called function's responsibility to preserve save-on-entry registers, and the calling function's responsibility to preserve save-on-call registers if you need to preserve that register's value.

7.2.1 TMS320C28x Register Use and Preservation

Table 7-2 summarizes how the compiler uses the TMS320C28x registers and shows which registers are defined to be preserved across function calls.

The FPU uses all the C28x registers as well as the registers described in Table 7-3.

Table 7-2. Register Use and Preservation Conventions

Register	Usage	Save on Entry	Save on Call
AL	Expressions, argument passing, and returns 16-bit results from functions	No	Yes
AH	Expressions and argument passing	No	Yes
DP	Data page pointer (used to access global variables)	No	No
PH	Multiply expressions and Temp variables	No	Yes
PL	Multiply expressions and Temp variables	No	Yes
SP	Stack pointer		(1)(1)
T	Multiply and shift expressions	No	Yes
TL	Multiply and shift expressions	No	Yes
XAR0	Pointers and expressions	No	Yes
XAR1	Pointers and expressions	Yes	No
XAR2	Pointers, expressions, and frame pointing (when needed)	Yes	No
XAR3	Pointers and expressions	Yes	No
XAR4	Pointers, expressions, argument passing, and returns 16- and 22-bit pointer values from functions	No	Yes
XAR5	Pointers, expressions, and arguments	No	Yes
XAR6	Pointers and expressions	No	Yes
XAR7	Pointers, expressions, indirect calls and branches (used to implement pointers to functions and switch statements)	No	Yes

(1) The SP is preserved by the convention that everything pushed on the stack is popped off before returning.

Table 7-3. FPU Register Use and Preservation Conventions

Register	Usage	Save on Entry	Save on Call
R0H	Expressions, argument passing, and returns 32-bit float from functions	No	Yes
R1H	Expressions and argument passing	No	Yes
R2H	Expressions and argument passing	No	Yes
R3H	Expressions and argument passing	No	Yes
R4H	Expressions	Yes	No
R5H	Expressions	Yes	No
R6H	Expressions	Yes	No
R7H	Expressions	Yes	No

7.2.2 Status Registers

Table 7-4 shows all of the status fields used by the compiler. Presumed value is the value the compiler expects in that field upon entry to, or return from, a function; a dash in this column indicates the compiler does not expect a particular value. The modified column indicates whether code generated by the compiler ever modifies this field.

Table 7-4. Status Register Fields

Field	Name	Presumed Value	Modified
ARP	Auxiliary Register Pointer	-	Yes
C	Carry	-	Yes
N	Negative flag	-	Yes
OVM	Overflow mode	0(1)	Yes
PAGE0	Direct/stack address mode	0(1)	No
PM	Product shift mode	0(1)	Yes
SPA	Stack pointer align bit	-	Yes (in interrupts)
SXM	Sign extension mode	-	Yes
TC	Test/control flag	-	Yes
V	Overflow flag	-	Yes
Z	Zero flag	-	Yes

(1) The initialization routine that sets up the C run-time environment sets these fields to the presumed value.

Table 7-5 shows the additional status fields used by the compiler for FPU Targets.

Table 7-5. Floating-Point Status Register (STF(1)) Fields For FPU Targets Only

Field	Name	Presumed Value	Modified
LVF(2) (3)	Latched overflow float flag	-	Yes
LUF(2) (3)	Latched underflow float flag	-	Yes
NF(2)	Negative float flag	-	Yes
ZF(2)	Zero float flag	-	Yes
NI(2)	Negative integer flag	-	Yes
ZI(2)	Zero integer flag bit	-	Yes
TF(2)	Test flag bit	-	Yes
RNDF32	Round F32 mode(4)	-	Yes
RNDF64	Round F64 mode(4)	-	Yes
SHDWS	Shadow mode status	-	Yes

(1) Unused STF register bits read 0 and writes are ignored.
(2) Specified flags in the STF register can be exported to the ST0 register by way of the MOVST0 instruction.
(3) The LVF and LUF flag signals can be connected to the PIE to generate an overflow-and-underflow interrupt. This can be a useful debug tool.
(4) If RNDF32 or RNDF64 is 0, mode is round to zero (truncate), otherwise mode is round to nearest (even).

All other status register fields are not used and do not affect code generated by the compiler.

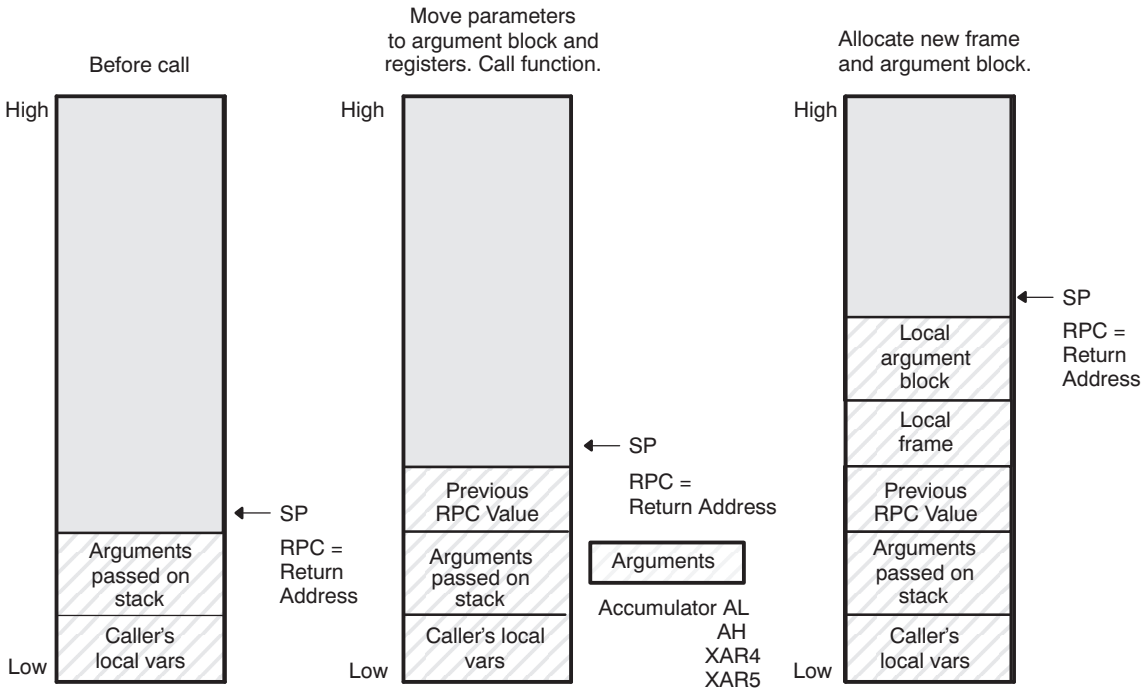
7.3 Function Structure and Calling Conventions

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.

Figure 7-1 illustrates a typical function call. In this example, parameters that cannot be placed in registers are passed to the function on the stack. The function then allocates local variables and calls another function. This example shows the allocated local frame and argument block for the called function. Functions that have no local variables and do not require an argument block do not allocate a local frame.

The term *argument block* refers to the part of the local frame used to pass arguments to other functions. Parameters are passed to a function by moving them into the argument block rather than pushing them on the stack. The local frame and argument block are allocated at the same time.

Figure 7-1. Use of the Stack During a Function Call



7.3.1 How a Function Makes a Call

A function (parent function) performs the following tasks when it calls another function (child function).

1. Any registers whose values are not necessarily preserved by the function being called (registers that are not save-on-entry (SOE) registers), but will be needed after the function returns are saved on the stack.
2. If the called function returns a structure, the calling function allocates the space for the structure and pass the address of that space to the called function as the first argument.
3. Arguments passed to the called function are placed in registers and, when necessary, placed on the stack.

   Arguments are placed in registers using the following scheme:

   (a) If the target is FPU and there are any 32-bit float arguments, the first four float arguments are placed in registers R0H-R3H.
   (b) If there are any 64-bit integer arguments (long long), the first is placed in ACC and P (ACC holds the upper 32 bits and P holds the lower 32 bits). All other 64-bit arguments are placed on the stack in reverse order.

   If the P register is used for argument passing, then prolog/epilog abstraction is disabled for that function. See Section 3.10 for more information on abstraction.

(c) If there are any 32-bit arguments (longs or floats) the first is placed in the 32-bit ACC (AH/AL). All other 32-bit arguments are placed on the stack in reverse order.

```
func1(long a, long long b, int c, int* d);
      stack   ACC/P   XAR5,  XAR4
```

(d) Pointer arguments are placed in XAR4 and XAR5. All other pointers are placed on the stack.
(e) Remaining 16-bit arguments are placed in the order AL, AH, XAR4, XAR5 if they are available.

4. Any remaining arguments not placed in registers are pushed on the stack in reverse order. That is, the leftmost argument that is placed on the stack is pushed on the stack last. All 32-bit arguments are aligned to even addresses on the stack.

   A structure argument is passed as the address of the structure. The called function must 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.

5. The stack pointer (SP) must be even-aligned by the parent function prior to making a call to the child function. This is done by incrementing the stack pointer by 1, if necessary. If needed, the coder should increment the SP before making the call.

   Some examples of function calls that show where arguments are placed are listed below:

```
func1 (int a, int b. long c)
       XAR4   XAR5    AH/AL
func1 (long a, int b, long c) ;
       AH/AL   XAR4   stack
vararg (int a, int b, int c, ...)
        AL     AH     stack
```

6. The caller calls the function using the LCR instruction. The RPC register value is pushed on the stack. The return address is then stored in the RPC register.
7. The stack is aligned at function boundary.

7.3.2 How a Called Function Responds

A called function (child function) must perform the following tasks:

1. If the called function modifies XAR1, XAR2, or XAR3, it must save them, since the calling function assumes that the values of these registers are preserved upon return. If the target is FPU, then in addition to the C28x registers, the called function must save registers R4H, R5H, R6H or R7H, if it modifies any of them. Any other registers may be modified without preserving them.
2. The called function allocates enough space on the stack for any local variables, temporary storage area, and arguments to functions that this function might call. This allocation occurs once at the beginning of the function by adding a constant to the SP register.
3. The stack is aligned at function boundary.
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 passes 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 properly declare functions 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. The called function returns a value. It is placed in a register using the following convention:

16-bit integer value	AL
32-bit integer value	ACC
64-bit integer value	ACC/P
16- or 22-bit pointer	XAR4

If the target is FPU and a 32-bit float value is returned, the called function places this value in R0H.

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 XAR4. To return a structure, the called function copies the structure to the memory block pointed 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 properly declare functions 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). Returning 64-bit floating-point values (long double) are returned similarly to structures.

7. The called function deallocates the frame by subtracting the value that was added to the SP earlier.
8. The called function restores the values of all registers saved in .
9. The called function returns using the LRETR instruction. The PC is set to the value in the RPC register. The previous RPC value is popped from the stack and stored in the RPC register.

7.3.3 Special Case for a Called Function (Large Frames)

If the space that needs to be allocated on the stack (step 2 in the previous section) is larger than 63 words, additional steps and resources are required to ensure that all local nonregister variables can be accessed. Large frames require using a frame pointer register (XAR2) to reference local non-register variables within the frame. Prior to allocating space on the frame, the frame pointer is set up to point at the first argument on the stack that was passed on to the called function. If no incoming arguments are passed on to the stack, the frame pointer points to the return address of the calling function, which is at the top of the stack upon entry to the called function.

Avoid allocating large amounts of local data when possible. For example, do not declare large arrays within functions.

7.3.4 Accessing Arguments and Local Variables

A function accesses its local nonregister variables and its stack arguments indirectly through either the SP or the FP (frame pointer, designated to be XAR2). All local and argument data that can be accessed with the SP use the *−SP [offset] addressing mode since the SP always points one past the top of the stack and the stack grows toward larger addresses.

The PAGE0 Mode Bit Must Be Reset

NOTE: Since the compiler uses the *-SP [offset] addressing mode, the PAGE0 mode bit must be reset (set to 0).

The largest offset available using *-SP [offset] is 63. If an object is too far away from the SP to use this mode of access, the compiler uses the FP (XAR2). Since FP points at the bottom of the frame, accesses made with the FP use either *+FP [offset] or *+FP [AR0/AR1] addressing modes. Since large frames require utilizing XAR2 and possibly an index register, extra code and resources are required to make local accesses.

7.3.5 Allocating the Frame and Accessing 32-Bit Values in Memory

Some TMS320C28x instructions read and write 32 bits of memory at once (MOVL, ADDL, etc.). These instructions require that 32-bit objects be allocated on an even boundary. To ensure that this occurs, the compiler takes these steps:

1. It initializes the SP to an even boundary.
2. Because a call instruction adds 2 to the SP, it assumes that the SP is pointing at an even address.
3. It makes sure that the space allocated on the frame totals an even number, so that the SP points to an even address.
4. It makes sure that 32-bit objects are allocated to even addresses, relative to the known even address in the SP.
5. Because interrupts cannot assume that the SP is odd or even, it aligns the SP to an even address.

For more information on how these instructions access memory, see the *TMS320C28x Assembly Language Tools User's Guide*.

7.4 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 7.4.1).
- Use assembly language variables and constants in C/C++ source (see Section 7.4.2).
- Use inline assembly language embedded directly in the C/C++ source (see Section 7.4.4).
- Use intrinsics in C/C++ source to directly call an assembly language statement (see Section 7.4.5).

7.4.1 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 7.3, and the register conventions defined in Section 7.2. 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 7.2.
- Dedicated registers modified by a function must be preserved. Dedicated registers include:

XAR1	R4H (FPU only)
XAR2	R5H (FPU only)
XAR3	R6H (FPU only)
SP	R7H (FPU only)

  If the SP is used normally, it does not need to be preserved explicitly. The assembly function is free to use the stack as long as anything that is pushed on the stack is popped back off before the function returns (thus preserving the SP).

  Any register that is not dedicated can be used freely without being preserved.
- The stack pointer (SP) must be even-aligned by the parent function prior to making a call to the child function. This is done by incrementing the stack pointer by 1, if necessary. If needed, the coder should increment the SP before making the call.
- The stack is aligned at function boundary.
- Interrupt routines must save *all* the registers they use. For more information, see Section 7.5.
- 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 7.3.1.

  When accessing arguments passed in from a C/C++ function, these same conventions apply.
- Longs and floats are stored in memory with the least significant word at the lower address.
- Structures are returned as described in in Section 7.3.2.

- 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 prepends an underscore (_) to the beginning of all identifiers. In assembly language modules, you must use the prefix _ for all objects that are to be accessible from C/C++. For example, a C/C++ object named x is called _x in assembly language. For identifiers that are to be used only in an assembly language module or modules, any name that does not begin with an underscore can be safely used without conflicting with a C/C++ identifier.
- 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.
- Because compiled code runs with the PAGE0 mode bit reset, if you set the PAGE0 bit to 1 in your assembly language function, you must set it back to 0 before returning to compiled code.
- If you define a structure in assembly and access it in C using extern struct, the structure should be blocked. The compiler assumes that structure definitions are blocked to optimize the DP load. So the definition should honor this assumption. You can block the structure by specifying the blocking flag in the .usect or .bss directive. See the *TMS320C28x Assembly Language Tools User's Guide* for more information on these directives.

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

```
extern "C"{
extern int asmfunc(int a); /* declare external asm function */
int gvar = 0;              /* define global variable        */
}

void main()
{

   int i = 5;
   i = asmfunc(i);        /* call function normally         */
}
```

Example 7-2. Assembly Language Program Called by Example 7-1

```
        .global _gvar
        .global _asmfunc

_asmfunc:
        MOVZ    DP,#_gvar
        ADDB    AL,#5
        MOV     @_gvar,AL
        LRETR
```

In the C++ program in Example 7-1, the extern "C" declaration tells the compiler to use C naming conventions (i.e., no name mangling). When the linker resolves the .global _asmfunc reference, the corresponding definition in the assembly file will match.

The parameter i is passed in register AL.

7.4.2 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.

7.4.2.1 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. Use the .def or .global directive to make the definition external.
3. Use the appropriate linkname in assembly language.
4. 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

```
* Note the use of underscores in the following lines

       .bss     _var,1   ; Define the variable
       .global  _var     ; Declare it as external
```

Example 7-4. C Program to Access Assembly Language From Example 7-3

```
extern int var;       /* External variable */
var = 1;              /* Use the variable  */
```

7.4.2.2 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

```
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

```
_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.

7.4.3 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 *TMS320C28x Assembly Language Tools User's Guide*.

7.4.4 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 6.9.

The asm statement is useful for inserting comments in the compiler output. Simply start the assembly code string with a semicolon (;) as shown below:

```
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.

7.4.5 Using Intrinsics to Access Assembly Language Statements

The C28x 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:

```
int x1, x2, y;
y = _sadd(x1, x2);

long lvar;

int  ivar;

unsigned int uivar;

lvar = __mpyxu(ivar, uivar);
```

The intrinsics listed in Table 7-6 are included. They correspond to the indicated TMS320C28x assembly language instruction(s). See the *TMS320C28x CPU and Instruction Set Reference Guide* for more information.

Table 7-6. TMS320C28x C/C++ Compiler Intrinsics

Intrinsic	Assembly Instruction(s)	Description
int **__abs16_sat(** int *src* **);**	**SETC OVM** **MOV AH,** *src* **ABS ACC** **MOV** *dst* **, AH** **CLRC OVM**	Clear the OVM status bit. Load *src* into AH. Take absolute value of ACC. Store AH into *dst*. Clear the OVM status bit.
void **__add(** int ***m*,** int *b* **);**	**ADD *** *m* **,** *b*	Add the contents of memory location *m* to *b* and store the result in *m*, in an atomic way.
long **__addcu(** long *src1*, unsigned int *src2* **);**	**ADDCU ACC,** {*mem* | *reg*}	The contents of *src2* and the value of the carry bit are added to ACC. The result is in ACC.
void **__addl(** long ***m*,** long *b* **);**	**ADDL *** *m*, *b*	Add the contents of memory location *m* to *b* and store the result in *m*, in an atomic way.
void **__and(** int ***m*,** int *b* **);**	**AND *** *m*, *b*	AND the contents of memory location *m* to *b* and store the result in m, in an atomic way.
int &**__byte(** int ***array*,** unsigned int *byte_index* **);**	**MOVB** *array* **[***byte_index***].LSB,** *src* or **MOVB** *dst*, *array* **[***byte_index* **].LSB**	The lowest addressable unit in C28x is 16 bits. Therefore, normally you cannot access 8-bit entities off a memory location. This intrinsic helps access an 8-bit quantity off a memory location, and can be invoked as follows: `__byte(array,5) = 10;` `b = __byte(array,20);`
void **__dec(** int ***m*);**	**DEC *** *m*	Decrement the contents of memory location *m* in an atomic way.
unsigned int **__disable_interrupts( );**	**PUSH ST1** **SETC INTM, DBGM** **POP** *reg16*	Disable interrupts and return the old value of the interrupt vector.
long long **_dtoll(** double **);**		Reinterpret double as long (when long is 40 bits).
long long **_dtoll(** double **);**		Reinterpret double as long long.
unsigned int **__enable_interrupts( );**	**PUSH ST1** **CLRC INTM, DBGM** **POP** *reg16*	Enable interrupts and return the old value of the interrupt vector.
void **__inc(** int ***m*);**	**INC *** *m*	Increment the contents of memory location *m* in an atomic way.

Table 7-6. TMS320C28x C/C++ Compiler Intrinsics (continued)

Intrinsic	Assembly Instruction(s)	Description
long= __**IQ(** long double *A* **,** int *N* **);**		Convert the long double *A* into the correct IQN value returned as a long type. If both arguments are constants the compiler converts the arguments to the IQ value during compile time. Otherwise a call to the RTS routine, __IQ, is made. This intrinsic cannot be used to initialize global variables to the .cinit section.
long *dst* **=** __**IQmpy(** long *A***,** long *B* **,** int *N* **);**		The *dst* becomes ACC or P, *A* becomes XT:
If *N* == 0:	**IMPYL** {**ACC**|**P**}**, XT, B**	The dst is ACC or P. If *dst* is ACC, the instruction takes 2 cycles. If dst is P, the instruction takes 1 cycle.
If 0 < *N* < 16:	**IMPYL P, XT, B** **QMPYL ACC, XT, B** **LSR64 ACC:P,** # *N*	
If 15 < *N* < 32:	**IMPYL P, XT, B** **QMPYL ACC, XT, B** **LSL64 ACC:P, #(32-** *N* **)**	
If *N* == 32:	**QMPYL** {**ACC**|**P**}**, XT, B**	
If *N* is a variable:	**IMPYL P, XT, B** **QMPYL ACC, XT, B** **MOV T,** *N* **LSR64 ACC:P, T**	
long *dst* **=** __**IQsat(** long *A***,** long *max***,** long *min* **);**		The *dst* becomes ACC. Different code is generated based on the value of *max* and/or *min*.
If *max* and *min* are 22-bit unsigned constants:	**MOVL ACC, A** **MOVL XAR** *n***,** # *22bits* **MINL ACC, P** **MOVL XAR** *n***,** # *22bits* **MAXL ACC, P**	
If *max* and *min* are other constants:	**MOVL ACC, A** **MOV PL,** # *max lower 16 bits* **MOV PH,** # *max upper 16 bits* **MINL ACC, P** **MOV PL,** # *min lower 16 bits* **MOV PH,** # *min upper 16 bits* **MAXL ACC, P**	
If *max* and/or *min* are variables:	**MOVL ACC, A** **MINL ACC,** *max* **MAXL ACC,** *min*	
long *dst* **=** __**IQxmpy(**long *A* **,** long *B***,** int *N***);**		The *dst* becomes ACC or P; *A* becomes XT. Code is generated based on the value of *N*.
If *N* == 0:	**IMPYL ACC/P, XT, B**	The *dst* is in ACC or P.
If 0 < *N* < 17:	**IMPYL P, XT, B** **QMPYL ACC, XT, B** **LSL64 ACC:P,** # *N*	The *dst* is in ACC.
If 0 > *N* > -17:	**QMPYL ACC, XT, B** **SETC SXM** **SFR ACC, #abs(***N***)**	The *dst* is in ACC.
If 16 < *N* < 32:	**IMPYL P, XT, B** **QMPYL ACC, XT, B** **ASR64 ACC:P,** # *N*	The *dst* is in P.
If *N* == 32:	**IMPYL P, XT, B**	The *dst* is in P.
If -16 > *N* > -33	**QMPYL ACC, XT, B** **SETC SXM SRF ACC, #16** **SRF ACC, #abs(***N***)−16**	The *dst* is in ACC.
If 32 < *N* < 49:	**IMPYL ACC, XT, B** **LSL ACC,** # *N* **-32**	The *dst* is in ACC.
If -32 > *N* > -49:	**QMPYL ACC, XT, B** **SETC SXM SFR ACC, #16** **SFR ACC, #16**	The *dst* is in ACC.

Table 7-6. TMS320C28x C/C++ Compiler Intrinsics (continued)

Intrinsic	Assembly Instruction(s)	Description
If 48 < *N* < 65:	**IMPYL ACC, XT, B** **LSL64 ACC:P, #16** **LSL64 ACC:P, #** *N* **−48**	The *dst* is in ACC.
If -48 > *N* > -65:	**QMPYL ACC, XT, B** **SETC SXM SFR ACC, #16** **SFR ACC, #16**	The *dst* is in ACC.
double **_lltod(** long long **);**		Reinterpret long long as double.
double **_ltod(** long **);**		Reinterpret long as double (when long is 40 bits).
int **__mov_byte(** int **src*, unsigned int *n* **);**	**MOVB AX.LSB,*+XARx[** *n* **]** or **MOVZ AR0/AR1,** @ *n* **MOVB AX.LSB,*XARx[** {AR0|AR1} **]**	Return the 8-bit *n*th element of a byte table pointed to by *src*. This intrinsic is provided for backward compatibility. The intrinsic __byte is preferred as it returns a reference. Nothing can be done with __mov_byte() that cannot be done with __byte().
long **__mpy(** int *src1*, int *src2* **);**	**MPY ACC,** *src1* **,** # *src2*	Move *src1* to the T register. Multiply T by a 16-bit immediate (*src2*). The result is in ACC.
long **__mpyb(** int *src1*, uint *src2* **);**	**MPYB** {ACC | P}**, T,** # *src2*	Multiply *src1* (the T register) by an unsigned 8-bit immediate (*src2*). The result is in ACC or P.
long **__mpy_mov_t(** int *src1*, int *src2*, int ***** *dst2* **);**	**MPY ACC, T,** *src2* **MOV** *dst2*, **T**	Multiply *src1* (the T register) by *src2*. The result is in ACC. Move *src1* to *dst2*.
unsigned long **__mpyu(**unit *src2*, unit *srt2***);**	**MPYU** {ACC | P}**, T,***src2*	Multiply *src1* (the T register) by *src2*. Both operands are treated as unsigned 16-bit numbers. The result is in ACC or P.
long **__mpyxu(** int *src1*, uint *src2* **);**	**MPYXU ACC, T,** {*mem*|*reg*}	The T register is loaded with *src1*. The *src2* is referenced by memory or loaded into a register. The result is in ACC.
long *dst* **=** **__norm32(**long *src*, int ***** *shift* **);**	**CSB ACC** **LSLL ACC, T** **MOV** @ *shift*, **T**	Normalize *src* into *dst* and update *shift* with the number of bits shifted.
long long *dst* **=** **__norm64(**long long *src*, int ***** *shift* **);**	**CSB ACC** **LSL64 ACC:P, T** **MOV** *shift* **, T** **CSB ACC** **LSL64 ACC:P, T** **MOV TMP16, AH** **MOV AH, T** **ADD** *shift*, **AH** **MOV AH, TMP16**	Normalize 64-bit *src* into *dst* and update *shift* with the number of bits shifted.
void **__or(** int ***** *m* **,** int *b* **);**	**OR *** *m* **,** *b*	OR the contents of memory location *m* to *b* and store the result in m, in an atomic way.
long **__qmpy32(** long *src32a*, long *src32b*, int *q* **);**	**CLRC OVM SPM − 1** **MOV T,** *src32a* **+ 1** **MPYXU P, T,** *src32b* **+ 0** **MOVP T,** *src32b* **+ 1** **MPYXU P, T,** *src32a* **+ 0** **MPYA P, T,** *src32a* **+ 1**	Extended precision DSP Q math. Different code is generated based on the value of *q*.
If *q* = 31,30:	**SPM** *q* **− 30** **SFR ACC, #45 −** *q* **ADDL ACC, P**	
If *q* = 29:	**SFR ACC, #16** **ADDL ACC, P**	
If *q* = 28 through 24:	**SPM** *q* **- 30** **SFR ACC, #16** **SFR ACC, #29 -** *q* **ADDL ACC, P**	
If *q* = 23 through 13:	**SFR ACC, #16** **ADDL ACC, P** **SFR ACC, #29 −** *q*	

Table 7-6. TMS320C28x C/C++ Compiler Intrinsics (continued)

Intrinsic	Assembly Instruction(s)	Description
If *q* = 12 through 0:	**SFR ACC, #16** **ADDL ACC, P** **SFR ACC, #16** **SFR ACC, #13 −** *q*	
long **__qmpy32by16(**long *src32***,** int *src16***,** int *q***);**	**CLRC OVM** **MOV T,** *src16* **+ 0** **MPYXU P, T,** *src32* **+ 0** **MPY P, T,** *src32* **+ 1**	Extended precision DSP Q math. Different code is generated based on the value of *q*.
If *q* = 31, 30:	**SPM** *q* **− 30** **SFR ACC, #46 −** *q* **ADDL ACC, P**	
If *q* = 29 through 14:	**SPM 0** **SFR ACC, #16** **ADDL ACC, P** **SFR ACC, #30 −** *q*	
If *q* = 13 through 0:	**SPM 0** **SFR ACC, #16** **ADDL ACC, P** **SFR ACC, #16** **SFR ACC, #14 −** *q*	
void **__restore_interrupts(**unsigned int *val* **);**	**PUSH** *val* **POP ST1**	Restore interrupts and set the interrupt vector to value *val*.
long **__rol(** long *src* **);**	**ROL ACC**	Rotate ACC left.
long **__ror(** long *src* **);**	**ROR ACC**	Rotate ACC right.
void ***** *result* **= __rpt_mov_imm(**void ***** *dst* **,** int *src* **,** int *count* **);**	**MOV** *result* **,** *dst* **MOV ARx,** *dst* **RPT #** *count* **|| MOV *XARx++,** # *src*	Move the *dst* register to the *result* register. Move the *dst* register to a temp (ARx) register. Copy the immediate *src* to the temp register *count* + 1 times. The *src* must be a 16-bit immediate. The *count* can be an immediate from 0 to 255 or a variable.
far void *****result **= __rpt_mov_imm_far (** far void ***** *dst* **,** int *src***,** int *count* **);**	**MOVL** *result***,** *dst* **MOVL ARx,** *dst* **RPT #** *count* **|| MOVL *XARx++,** # *src*	Move the *dst* register to the *result* register. Move the *dst* register to a temp (XARx) register. Copy the immediate *src* to the temp register *count* + 1 times. The *src* must be a 16-bit immediate. The *count* can be an immediate from 0 to 255 or a variable.
int **__rpt_norm_inc(** long *src***,** int *dst***,** int *count* **);**	**MOV ARx,** *dst* **RPT #** *count* **|| NORM ACC, ARx++**	Repeat the normalize accumulator value *count* + 1 times. The *count* can be an immediate from 0 to 255 or a variable.
int **__rpt_norm_dec(**long *src***,** int *dst***,** int *count***);**	**MOV ARx,** *dst* **RPT #** *count* **|| NORM ACC, ARx--**	Repeat the normalize accumulator value *count* + 1 times. The *count* can be an immediate from 0 to 255 or a variable.
long **__rpt_rol(**long *src***,** int *count***);**	**RPT #** *count* **|| ROL ACC**	Repeat the rotate accumulator left *count* + 1 times. The result is in ACC. The *count* can be an immediate from 0 to 255 or a variable.
long **__rpt_ror(**long *src***,** int *count***);**	**RPT #** *count* **|| ROR ACC**	Repeat the rotate accumulator right *count* + 1 times. The result is in ACC. The *count* can be an immediate from 0 to 255 or a variable.
long **__rpt_subcu(**long *ds* **t,** int *src***,** int *count***);**	**RPT** *count* **|| SUBCU ACC,** *src*	The *src* operand is referenced from memory or loaded into a register and used as an operand to the SUBCU instruction. The result is in ACC. The *count* can be an immediate from 0 to 255 or a variable. The instruction repeats *count* + 1 times.

Table 7-6. TMS320C28x C/C++ Compiler Intrinsics (continued)

Intrinsic	Assembly Instruction(s)	Description
long __**sat(** long *src* **);**	**SAT ACC**	Load ACC with 32-bit *src*. The result is in ACC.
long __**sat32(** long *src*, long *limit* **);**	**SETC OVM** **ADDL ACC,** {*mem*|**P**} **SUBL ACC,** {*mem*|**P**} **SUBL ACC,** {*mem*|**P**} **ADDL ACC,** {*mem*|**P**} **CLRC OVM**	Saturate a 32-bit value to a 32-bit mask. Load ACC with *src*. Limit value is either referenced from memory or loaded into the P register. The result is in ACC.
long __**sathigh16(**long *src*, int *limit***);**	**SETC OVM** **ADDL ACC,** {*mem*|**P**}**<<16** **SUBL ACC,** {*mem*|**P**}**<<16** **SUBL ACC,** {*mem*|**P**}**<<16** **ADDL ACC,** {*mem*|**P**}**<<16** **CLRC OVM** **SFR ACC,** *rshift*	Saturate a 32-bit value to 16-bits high. Load ACC with *src*. The *limit* value is either referenced from memory or loaded into register. The result is in ACC. The result can be right shifted and stored into an int. For example: `ivar=__sathigh16(lvar, mask)>>6;`
long __**satlow16(** long *src* **);**	**SETC OVM** **MOV T, #0xFFFF** **CLR SXM** ; if necessary **ADD ACC, T <<15** **SUB ACC, T <<15** **SUB ACC, T <<15** **ADD ACC, T <<15** **CLRC OVM**	Saturate a 32-bit value to 16-bits low. Load ACC with *src*. Load T register with #0xFFFF. The result is in ACC.
long __**sbbu(** long *src1* **,** uint *src2* **);**	**SBBU ACC,** *src2*	Subtract *src2* + logical inverse of C from ACC (*src1*). The result is in ACC.
void __**sub(** int ***** *m*, int *b* **);**	**SUB *** *m* **,** *b*	Subtract *b* from the contents of memory location *m* and store the result in m, in an atomic way.
long __**subcu(** long *src1*, int *src2* **);**	**SUBCU ACC,** *src2*	Subtract *src2* shifted left 15 from ACC (*src1*). The result is in ACC.
void __**subl(** long ***** *m*, long *b* **);**	**SUBL *** *m* **,** *b*	Subtract *b* from the contents of memory location *m* and store the result in m, in an atomic way.
void __**subr(** int ***** *m* **,** int *b* **);**	**SUBR *** *m* **,** *b*	Subtract the contents of memory location *m* from *b* and store the result in m, in an atomic way.
void __**subrl(** long ***** *m* **,** long *b* **);**	**SUBRL *** *m* **,** *b*	Subtract the contents of memory location *m* from *b* and store the result in m, in an atomic way.
if (__tbit(int *src* **,** int *bit* **));**	**TBIT** *src* **,** # *bit*	SET TC status bit if specified *bit* of *src* is 1.
void __**xor(** int ***** *m*, int *b* **);**	**XOR *** *m*, *b*	XOR the contents of memory location *m* to *b* and store the result in m, in an atomic way.

Table 7-7. C/C++ Compiler Intrinsics for FPU

Intrinsic	Assembly Instruction(s)	Description
double __**einvf32(** double *x* **);**	**EINVF32** *x*	Compute and return 1/*x* to about 8 bits of precision.
double __**eisqrtf32(** double *x* **);**	**EISQRTF32** *x*	Find the square root of 1/*x* to about 8 bits of precision.
void __**f32_max_idx(** double *dst*, double *src*, double *idx_dst*, double *idx_src* **);**	**MAXF32** *dst* **,** *src* **|| MOV32** *idx_dst*, *idx_src*	If *src*>*dst*, copy src to dst, and copy *idx_src* to *idx_dst*.
void __**f32_min_idx(** double *dst*, double *src*, double *idx_dst*, double *idx_src* **);**	**MINF32** *dst* **,** *src* **|| MOV32** *idx_dst*, *idx_src*	If *src*<*dst*, copy src to dst, and copy *idx_src* to *idx_dst*.
float __**fmax(** float *x*, float *y* **);**	**MAXF32** *dst*, *src*	If *src*>*dst*, copy src to dst
float __**fmin(** float *x*, float *y* **);**	**MINF32** *dst*, *src*	If *src*<*dst*, copy src to dst
void __**swapf(** double *a*, double *b* **);**	**swapf** *a*, *b*	Swap the contents of *a* and *b*.

7.5 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.

7.5.1 General Points About Interrupts

An interrupt routine can perform any task performed by any other function, including accessing global variables, allocating local variables, and calling other functions.

When you write interrupt routines, keep the following points in mind:

- An interrupt handling routine cannot have arguments. If any are declared, they are ignored.
- An interrupt handling routine can be called by normal C/C++ code, but it is inefficient to do this because all the registers are saved.
- An interrupt handling routine can handle a single interrupt or multiple interrupts. The compiler does not generate code that is specific to a certain interrupt, except for c_int00, which is the system reset interrupt. When you enter this routine, you cannot assume that the run-time stack is set up; therefore, *you cannot allocate local variables, and you cannot save any information on the run-time stack*.
- To associate an interrupt routine with an interrupt, the address of the interrupt function must be placed in the appropriate interrupt vector. You can use the assembler and linker to do this by creating a simple table of interrupt addresses using the .sect assembler directive.
- In assembly language, remember to precede the symbol name with an underscore. For example, refer to c_int00 as _c_int00.

7.5.2 Using C/C++ Interrupt Routines

If a C/C++ interrupt routine does not call any other functions, only those registers that the interrupt handler uses 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 compiler saves all the save-on-call registers if any other functions are called.

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. Interrupt handling functions should not be called directly.

Interrupts can be handled directly with C/C++ functions by using the interrupt pragma or the interrupt keyword. For information about the interrupt pragma, see Section 6.10.11. For information about the interrupt keyword, see Section 6.5.4.

7.6 Integer Expression Analysis

This section describes some special considerations to keep in mind when evaluating integer expressions.

7.6.1 Operations Evaluated With Run-Time-Support Calls

The TMS320C28x does not directly support some C/C++ integer operations. Evaluating these operations is done with calls to run-time-support routines. These routines are hard-coded in assembly language. They are members of the object and source run-time-support libraries (rts2800.lib and rtssrc.zip) in the toolset.

The conventions for calling these routines are modeled on the standard C/C++ calling conventions.

Operation Type	Operations Evaluated With Run-Time-Support Calls
16-bit int	Divide (signed)
	Modulus
32-bit long	Divide (signed)
	Modulus
64-bit long long	Multiply[(1)]
	Divide
	Bitwise AND, OR, and XOR
	Compare

(1) 64-bit long long multiplies are inlined if -mf=5 is specified.

7.6.2 C/C++ Code Access to the Upper 16 Bits of 16-Bit Multiply

The following methods provide access to the upper 16 bits of a 16-bit multiply in C/C++ language:

- Signed-results method:

```
int m1, m2;
int result;

result = ((long) m1 * (long) m2) >> 16;
```

- Unsigned-results method:

```
unsigned m1, m2;
unsigned result;

result = ((unsigned long) m1 * (unsigned long) m2) >> 16;
```

Danger of Complicated Expressions

NOTE: The compiler must recognize the structure of the expression for it to return the expected results. Avoid complicated expressions such as the following example:

```
((long)((unsigned)((a*b)+c)<5)*(long)(z*sin(w)>6))>>16
```

7.7 Floating-Point Expression Analysis

The C28x C/C++ compiler represents float and double floating-point values as IEEE single-precision numbers. Long double floating-point values are represented as IEEE double-precision numbers. Single-precision floating-point numbers are represented as 32-bit values and double-precision floating-point numbers are represented as 64-bit values.

The run-time-support library, rts2800.lib, contains a set of floating-point math functions that support:

- Addition, subtraction, multiplication, and division
- Comparisons (>, <, >=, <=, ==, !=)
- Conversions from integer or long to floating-point and floating-point to integer or long, both signed and unsigned
- Standard error handling

The conventions for calling these routines are the same as the conventions used to call the integer operation routines. Conversions are unary operations.

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 called by reset hardware. You must link the c_int00 function with the other object modules. 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 module to the symbol c_int00.

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. 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 7.8.2.
3. Executes the global constructors found in the global constructors table. For more information, see Section 7.8.6.
4. 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 Run-Time Stack

The run-time stack is allocated in a single continuous block of memory and grows down from low addresses to higher addresses. The SP points to the top of the stack.

The code does not check to see if the run-time stack overflows. Stack overflow occurs when the stack grows beyond the limits of the memory space that was allocated for it. Be sure to allocate adequate memory for the stack.

The stack size can be changed at link time by using the --stack_size link option on the linker command line and specifying the stack size as a constant directly after the option.

7.8.2 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 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 C/C++ compiler does not perform any preinitialization of uninitialized variables. Explicitly initialize any variable that must have an initial value of 0.

The easiest method is to have a loader clear the .bss section before the program starts running. Another method is to set a fill value of 0 in the linker control map for the .bss section.

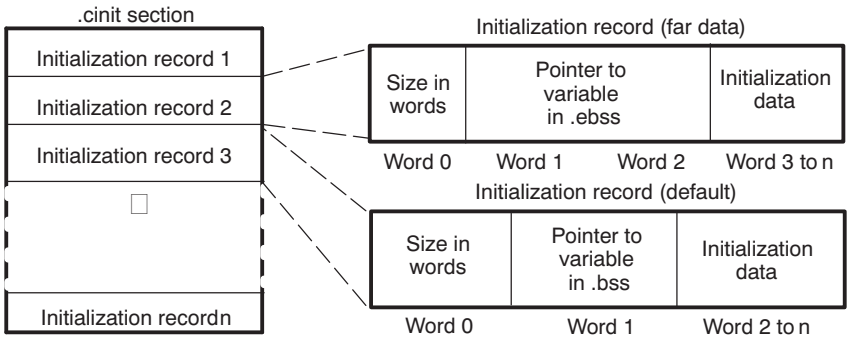
You cannot use these methods with code that is burned into ROM.

Global variables are either autoinitialized at run time or at load time; see Section 7.8.4 and Section 7.8.5. Also see Section 6.13.

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 7-2 shows the format of the .cinit section and the initialization records.

Figure 7-2. Format of Initialization Records in the .cinit Section (Default and far Data)



The fields of an initialization record contain the following information:

- The first field of an initialization record contains the size (in words) of the initialization data. A negative value for this field denotes that the variable's address is far.
- The second field contains the starting address of the area within the .bss section where the initialization data must be copied. If the variable is far, the field points to the variable's space in .ebss. For far data the second field requires two words to hold the address.
- The third field contains the data that is copied into the .bss section to initialize the variable. The width of this field is variable.

Size of Initialized Variables

NOTE: In the small memory model, the compiler only supports initializing variables that are 64K words or less. In the large memory model, multiple cinit records are generated for objects that are over 32K words in size.

Each variable that must be autoinitialized has an initialization record in the .cinit section.

Example 7-7 shows initialized global variables defined in C. Example 7-8 shows the corresponding initialization table.

Example 7-7. Initialized Variables Defined in C

```
int    i= 23;
far    int j[2] = { 1,2};
```

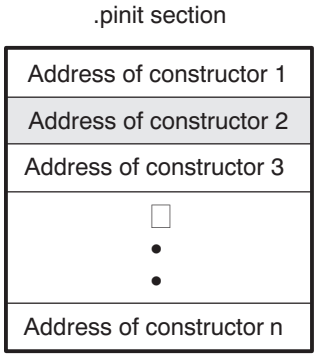
Example 7-8. Initialized Information for Variables Defined in Example 7-7

```
       .global   _i
       .bss      _i,1,1,0
       .global   _j
_j:    .usect    .ebss,2,1,0

       .sect     ".cinit"
       .align    1
       .field        1,16
       .field        _i+0,16
       .field        23,16        ; _i @ 0

       .sect     ".cinit"
       .align    1
       .field        -IR_1,16
       .field        _j+0,32
       .field        1,16         ; _j[0] @ 0
       .field        2,16         ; _j[1] @ 16
IR_1:  .set2
```

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 7-3). The constructors appear in the table after the .cinit initialization.

Figure 7-3. Format of Initialization Records in the .pinit Section



When you use the --rom_model or --ram_model option, the linker combines the .cinit sections from all the 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.

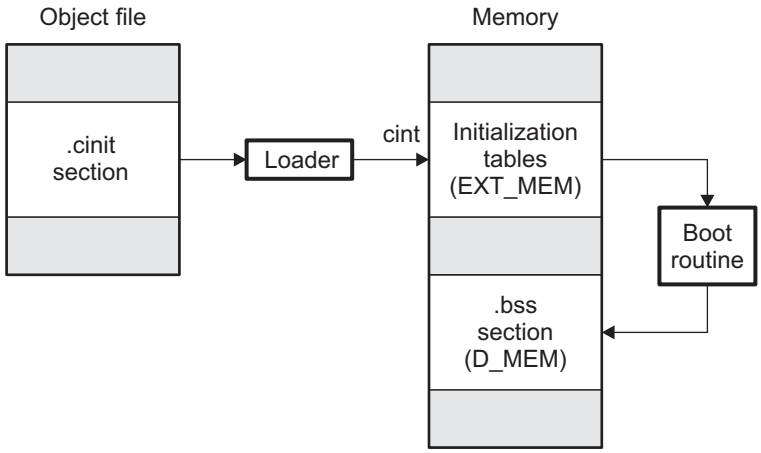
7.8.4 Autoinitialization of Variables at Run Time

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 7-4 illustrates autoinitialization at run time. Use this method in any system where your application runs from code burned into ROM.

Figure 7-4. Autoinitialization at Run Time



7.8.5 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.

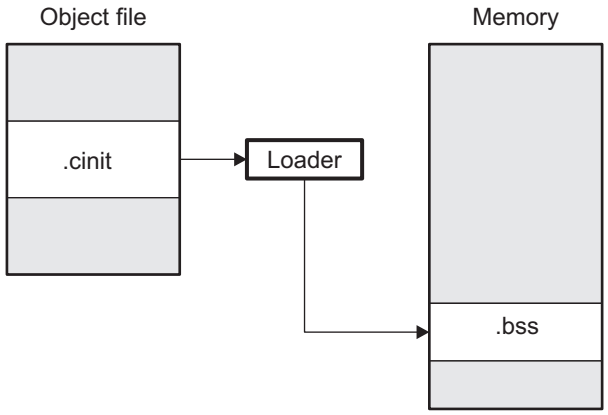
When you use the --ram_model link option, the linker sets the STYP_COPY bit in the .cinit section's header. This tells the loader not to load the .cinit section into memory. (The .cinit section occupies no space in the memory map.) The linker also sets the cinit symbol to -1 (normally, cinit points to 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 7-5 illustrates the initialization of variables at load time.

Figure 7-5. Initialization 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.

7.8.6 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 .pinit. The linker combines the .pinit section form each input file to form a single table in the .pinit section. The boot routine uses this table to execute the constructors.

Using Run-Time-Support Functions and Building Libraries

Some of the tasks that a C/C++ program performs (such as I/O, dynamic memory allocation, string operations, and trigonometric functions) are not part of the C/C++ language itself. However, the ANSI/ISO C standard defines a set of run-time-support functions that perform these tasks. The C/C++ compiler implements the complete ISO standard library except for those facilities that handle exception conditions 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 inSection 8.1 and Section 8.3.

A library-build process is provided with the code generation tools that lets you create customized run-time-support libraries. This process is described in Section 8.5 .

Topic **Page**

8.1 C and C++ Run-Time Support Libraries

TMS320C28x compiler releases include pre-built run-time libraries that provide all the standard capabilities. Separate libraries are provided for large-memory-model support 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
- Intrinsic 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, 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 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:

- *The Standard C++ Library: A Tutorial and Reference*,Nicolai M. Josuttis, Addison-Wesley, ISBN 0-201-37926-0
- *The C++ Programming Language* (Third or Special Editions), Bjarne Stroustrup, Addison-Wesley, ISBN 0-201-88954-4 or 0-201-70073-5
- Dinkumware's online reference at 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 4.3.1 for further information.

You should specify libraries *last* on the linker command line because the linker searches a library for unresolved references when it encounters the library on the command line. You can also use the --reread_libs linker option to force repeated searches of each library until the linker can resolve no more references.

When a library is linked, the linker includes only those library members required to resolve undefined references. For more information about linking, see the *TMS320C28x 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

To include the correct set of header files depending on which library you are using, you can set the C2000_C_DIR environment variable to the specific include directory: "include\lib". The source for the libraries is included in the rtssrc.zip file. See Section 8.5 for details on rebuilding.

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 will recreate the run-time source tree for the run-time library.

You can also build a new library this way, rather than rebuilding into rts2800.lib. See Section 8.5.

8.1.4 Changes to the Run-Time-Support Libraries

The following changes and additions apply to the run-time-support libraries in the /lib subdirectory of the release package.

8.1.4.1 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 hard-coded to the behavior of the C locale, and attempting to install a different locale via a call to setlocale() will return NULL.

8.1.4.2 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.

8.1.5 Library Naming Conventions

The run-time support libraries now have the following naming scheme:

rts2800[_ml][_fpu32][_eh].lib

rts2800	Indicates the library is built for C28x support
_ml	Indicates the large memory model.(Small memory model is used by default.)
_fpu32	Indicates support for FPU targets (Specifying -ml is not necessary as FPU target work only with the large memory model.)
_eh	Indicates the library has exception handling support

8.2 Far Memory Support

As described in Section 6.5.3, *The far Keyword*, the C/C++ compiler extends the C language (not C++) by providing the far keyword. The far keyword is used to access 22 bits of address space.

The run-time-support library is extended to include far versions of the ANSI/ISO routines and far dynamic memory management routines.

The large memory model C++ run-time-support library automatically supports far memory since all pointers are 22 bits.

8.2.1 Far Versions of Run-Time-Support Functions

To provide far support to the C run-time library, a far version is defined for most of the run-time-support functions that either have a pointer argument or returns a pointer. In the following example, the atoi() run-time-support function takes a string (pointer to char) argument and returns the integer value represented by the string.

```
#include <stdlib.h>
char * st = "1234";
.
.
.
.
int    ival = atoi(st);   /* ival is 1234 */
```

The far version of the atoi() function, far_atoi(), is defined to take a far string (pointer to far char) argument and return the integer value.

```
#include <stdlib.h>
far char * fst = "1234";
.
.
.
.
int    ival = far_atoi(fst); /* ival is 1234 */
```

The far version of the run-time-support function performs the same operations except that it accepts or returns pointer to far objects.

8.2.2 Global and Static Variables in Run-Time-Support Functions

The run-time-support library uses several global and static variables. Some of them are for internal use and others are for passing status and other information on to you, as in the case of global variable errno defined in stderr.h. By default, these variables are placed in the .bss section and considered near objects. For more information, see Section 7.1.1.

The C I/O functions do not have corresponding far versions. Also, the functions that use the C I/O functions do not have corresponding far versions.

You can place global and static variables in far memory (.ebss section) by defining _FAR_RTS (−d_FAR_RTS) when building the C run-time library (not C++). The library-build process is described in Section 8.5. To build a library with far mode support, use the gmake command with OPT_ALL=_d_FAR_RTS, along with other gmake options.

8.2.3 Far Dynamic Memory Allocation in C

You can allocate far memory dynamically at run time. The far memory is allocated from a global pool or far heap that is defined in the .esysmem section. For more information about dynamic memory allocation, see Section 7.1.4.

The run-time-support library includes the following functions that allow you to dynamically allocate far memory at run time:

far void *	far_malloc (unsigned long *size*);
far void *	far_calloc (unsigned long *num*, unsigned long *size*);
far void *	far_realloc (far void **ptr*, unsigned long *size*);
void	far_free (far void **ptr*);
long	far_free_memory (void);
long	far_max_free(void)

The following C code allocates memory for 100 far objects and deallocates the memory at the end.

```
#include <stdlib.h>

struct big {
    int a, b;
    char c[80];
};

int main()
{
    far struct big *table;
    table=(far struct big *)far_malloc(100*sizeof(struct
big));
.
.
/* use the memory here */
.
.
far_free(table);
/* exit code here */
}
```

8.2.4 Far Dynamic Memory Allocation in C++

In C++ mode the compiler does not support the far keyword. Far intrinsics are provided to access far memory if the large memory model is not used. For more information, see Section 6.6.2. You can dynamically define objects in far memory and access them using the far intrinsics. The data type long is used to hold the far pointer.

The C++ run-time-support library provides the same set of dynamic far memory allocation functions as C run-time-support library. The C++ functions use the data type long to accept as return the far pointers, so that the memory can be accessed using far intrinsics. The C++ dynamic far memory allocation functions are listed below:

long std::far_malloc	(unsigned long *size*);
long std::far_calloc	(unsigned long *num*, unsigned long *size*);
long std::far_realloc*	(far void **ptr*, unsigned long *size*);
void std::far_free	(far void **ptr*);
long std::far_free_memory	(void);
long std::far_max_free(void)	

The following C++ code allocates memory for 100 far objects and deallocates the memory at the end.

```
#include <cstdlib>

struct big {
    int a, b;
    char c[80];
};
int main()
{
    long table;//Note-use of long to hold address.
    table = std::far_malloc(100 * sizeof(struct big));
    .
    .
    /* use the memory here using intrinsic*/
    .
    .
    std::far_free(table);
    /* exit code here */
}
```

Using far Intrinsics

NOTE: The farmemory.cpp file in rtssrc.zip implements far dynamic memory allocation functions using far intrinsics. You can refer to this file as an example about how to use far intrinsics.

8.3 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.

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 printf() 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 (see).

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 todal). The macro _NDEVICE controls how many device drivers are installed at one time (the HOST device counts against this total).

8.3.1 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:

```
#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:

```
cl2000 -v28 main.c --run_linker --heap_size=400 --library=rts2800.lib --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.

8.3.2 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 may be treated as files, although some operations (such as lseek) may not be appropriate. See Section 8.3.3 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 are designed to be appropriate for all I/O methods, even those which are not actually disk files. Abstractly, all I/O channels may be treated as files, although some operations (such as lseek) may not be appropriate. See the device-driver section for more details.

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

#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 8.3.5).
- 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

#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

#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

#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

lseek *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 8.3.3.

The *path* is the filename of the file, including path information and optional device prefix. (See Section 8.3.5.)

Return Value

The function returns one of the following values:

0	if successful
-1	on failure

rename ***Rename File***

Syntax for C

#include {<stdio.h> | <file.h>}

int rename (const char * *old_name* **, const char *** *new_name* **);**

Syntax for C++

#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:

0	if successful
-1	on failure

NOTE: Although rename is a low-level function, it is defined by the C standard and can be used by portable applications.

8.3.3 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 (C$$IO$$), 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 chose any name except for HOST.

DEV_open

Open File for I/O

Syntax

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 8.3.5 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 *buf* 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 *** *buf* **, 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

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

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 8.3.3.

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

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.

8.3.4 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(). Example (see email). 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

```
#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"); }
```

NOTE: Use Unique Function Names

The function names open, read, write, close, lseek, rename, and unlink are used by the low-level routines. Use other names for the device-level functions that you write.

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.

8.3.5 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:

```
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

#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 8.3.2. The device driver for the HOST that the TMS320C28x 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

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

```
#include <file.h>
#include <stdio.h>
/*****************************************************************************/
/* Declarations of the user-defined device drivers                           */
/*****************************************************************************/
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);
}
```

8.4 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:

```
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:

```
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.

8.5 Library-Build Process

When using the C/C++ compiler, you can compile your code under a number of different configurations and options that are not necessarily compatible with one another. Because it would be cumbersome to include all possible combinations in individual run-time-support libraries, this package includes a basic run-time-support library, rts2800.lib. Also included are library versions that support various C28x devices and versions that support C++ exception handling.

You can also build your own run-time-support libraries using the self-contained run-time-support build process, which is found in rtssrc.zip. This process is described in this chapter and the archiver described in the *TMS320C28x Assembly Language Tools User's Guide*.

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 support items are required:

- Perl version 5.6 or later available as perl

  Perl is a high-level programming language designed for process, file, and text manipulation. It is:

  – Generally available from http://www.perl.org/get.htm
  – Available from ActiveState.com as ActivePerl for the PC
  – Available as part of the Cygwin package for the PC

  It must be installed and added to PATH so it is available at the command-line prompt as perl. To ensure perl is available, open a Command Prompt window and execute:

  ```
  perl -v
  ```

  No special or additional Perl modules are required beyond the standard perl module distribution.
- GNU-compatible command-line make tool, such as gmake

  More information is available from GNU at http://www.gnu.org/software/ make. This file requires a host C compiler to build. GNU make (gmake) is shipped as part of Code Composer Studio on Windows. 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 built for Windows32 when the following is executed from the Command Prompt window:

  ```
  gmake -h
  ```

8.5.2 Using the Library-Build Process

gmake [OPT_ALL=*compiler_options*][LIBINSTALL_TO=*path*][LIBLIST=*rts_libraries*]

OPT_ALL defines other options to build libraries with. For example, -d_FAR_RTS.

LIBINSTALL_TO moves the newly generated run-time-support libraries into the specified path.

LIBLIST builds a subset of run-time-support libraries. A full list of run-time-support libraries to build is listed when you enter:

```
gmake liblist
```

See the Makefile for additional information on how to customize a library build by modifying the LIBLIST and/or the OPT_XXX macros.

8.5.2.1 The Base Option Sets for Building the Libraries

For C28x these libraries can be built:

- rts2800.lib (C/C++ run-time object library)
- rts2800_ml.lib (C/C++ large memory model run-time object library)
- rts2800_eh.lib (C/C++ run-time object library with exception handling support)
- rts2800_ml_eh.lib (C/C++ large memory model run-time object library with exception handling support)
- rts2800_fpu32.lib (C/C++ run-time object library for FPU targets)
- rts2800_fpu32_eh.lib (C/C++ run-time object library for FPU targets with exception handling support)

8.5.3 Rebuild the Desired Library

Once the desired changes have been made, simply use the following syntax from the command-line while in the rtssrc.zip top level directory to rebuild the selected rtsname library.

gmake *rtsname*

To use custom options to rebuild a library, simply change the list of options for the appropriate base listed in Section 8.1.5 and then rebuild the library. See the tables in Section 2.3 for a summary of available generic and C28x-specific options.

To build an library with a completely different set of options, define a new OPT_XXX base, choose the type of library per Section 8.1.5, and then rebuild the library. Not all library types are supported by all targets. You may need to make changes to targets_rts_cfg.pm to ensure the proper files are included in your custom library.

C++ Name Demangler

The C++ compiler implements function overloading, operator overloading, and type-safe linking by encoding a function's signature in its link-level name. The process of encoding the signature into the linkname is often referred to as name mangling. When you inspect mangled names, such as in assembly files or linker output, 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.

Topic **Page**

9.1 Invoking the C++ Name Demangler

The syntax for invoking the C++ name demangler is:

dem2000 [*options*] [*filenames*]

dem2000	Command that invokes the C++ name demangler.
options	Options affect how the name demangler behaves. Options can appear anywhere on the command line. (Options are discussed in Section 9.2.)
filenames	Text input files, such as the assembly file output by the compiler, the assembler listing file, and the linker map file. If no filenames are specified on the command line, dem2000 uses standard in.

By default, the C++ name demangler outputs to standard out. 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:

-h	Prints a help screen that provides an online summary of the C++ name demangler options
-o *file*	Outputs to the given file rather than to standard out
-u	Specifies that external names do not have a C++ prefix
-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

```
int compute(int val, int *err);

int foo(int val, int *err)
{

   static int last_err = 0;
   int result = 0

   if (last_err == 0)
   result = compute(val, &last_err);

   *err = last_err;
   return result;
}
```

Example 9-2. Resulting Assembly for Example 9-1

```
;****************************************************************
;* FNAME: _foo_FiPi                     FR SIZE:   4           *
;*                                                              *
;* FUNCTION ENVIRONMENT                                         *
;*                                                              *
;* FUNCTION PROPERTIES                                          *
;*                            0 Parameter,  3 Auto,  0 SOE      *
;****************************************************************

_foo_FiPi:
       ADDB       SP,#4
       MOVZ       DP,#_last_err$1
       MOV        *-SP[1],AL            ; |4|
       MOV        AL,@_last_err$1       ; |8|
       MOV        *-SP[2],AR4           ; |4|
       MOV        *-SP[3],#0            ; |6|
       BF         L1,NEQ                ; |8|
       ; branch occurs                  ; |8|
       MOVL       XAR4,#_last_err$1     ; |9|
       MOV        AL,*-SP[1]            ; |9|
       LCR        #_compute__FiPi       ; |9|
       ; call occurs [#_compute__FiPi]  ; |9|
       MOV        *-SP[3],AL            ; |9|
L1:
       MOVZ       AR6,*-SP[2]           ; |11|
       MOV        *+XAR6[0],*(0:_last_err$1) ; |11|
       MOV        AL,*-SP[3]            ; |12|
       SUBB       SP,#4                 ; |12|
       LRETR
       ; return occurs
```

Executing the C++ name demangler demangles all names that it believes to be mangled. Enter:

```
dem2000 -v28 foo.asm
```

The result is shown in Example 9-3. The linknames in Example 9-2 foo( ) and compute( ) are demangled.

Example 9-3. Result After Running the C++ Name Demangler

```
;****************************************************************
;* FNAME: foo(int, int *)                FR SIZE: 4           *
```

Example 9-3. Result After Running the C++ Name Demangler (continued)

```
;*                                                              *
;* FUNCTION ENVIRONMENT                                         *
;*                                                              *
;* FUNCTION PROPERTIES                                          *
;*                            0 Parameter,  3 Auto,  0 SOE      *
;****************************************************************

foo(int, int *):
       ADDB       SP,#4
       MOVZ       DP,#_last_err$1
       MOV        *-SP[1],AL            ; |4|
       MOV        AL,@_last_err$1       ; |8|
       MOV        *-SP[2],AR4           ; |4|
       MOV        *-SP[3],#0            ; |6|
       BF         L1,NEQ                ; |8|
       ; branch occurs                  ; |8|
       MOVL       XAR4,#_last_err$1     ; |9|
       MOV        AL,*-SP[1]            ; |9|
       LCR        #compute(int, int *)     ; |9|
       ; call occurs [#compute(int, int *)] ; |9|
       MOV        *-SP[3],AL            ; |9|
L1:
       MOVZ       AR6,*-SP[2]           ; |11|
       MOV        *+XAR6[0],*(0:_last_err$1) ; |11|
       MOV        AL,*-SP[3]            ; |12|
       SUBB       SP,#4                 ; |12|
       LRETR
       ; return occurs
```

Glossary

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 linking format; a system of object files configured according to the System V Application Binary Interface specification.

emulator— A hardware development system that duplicates the TMS320C28x 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.

executable module— A linked object file that can be executed in 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 autoinitialization 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 module.

input section— A section from an object file that will be linked into an executable module.

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.

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 object module 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 module into system memory.

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.

object module— A linked, executable object file that can be downloaded and executed on a target system.

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.

options— Command-line parameters that allow you to request additional or specific functions when you invoke a software tool.

output module— A linked, executable object file that is downloaded and executed on a target system.

output section— A final, allocated section in a linked, executable module.

overlay page— A section of physical memory that is mapped into the same address range as another section of memory. A hardware switch determines which range is active.

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.

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.

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 TMS320C28x 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 ^.

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.

veneer— A sequence of instructions that serves as an alternate entry point into a routine if a state change is required.

word— A 16-bit addressable location in target memory

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