TMS320C6000 Assembly Language Tools
v 7.0

User's Guide

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About This Manual

The TMS320C6000 Assembly Language Tools User's Guide explains how to use these assembly language tools:

- Assembler
- Archiver
- Linker
- Library information archiver
- Absolute lister
- Cross-reference lister
- Disassembler
- Object file display utility
- Name utility
- Strip utility
- Hex conversion utility

How to Use This Manual

This book helps you learn how to use the Texas Instruments assembly language tools designed specifically for the TMS320C6000 ™ 32-bit devices. This book consists of four parts:

- **Introductory information**, consisting of Chapter 1 and Chapter 2, gives you an overview of the assembly language development tools. It also discusses object modules, which helps you to use the TMS320C6000 tools more efficiently. Read Chapter 2 before using the assembler and linker.

- **Assembler description**, consisting of Chapter 3 through Chapter 5, contains detailed information about using the assembler. This portion explains how to invoke the assembler and discusses source statement format, valid constants and expressions, assembler output, and assembler directives. It also describes the macro language.

- **Additional assembly language tools description**, consisting of Chapter 6 through Chapter 11, describes in detail each of the tools provided with the assembler to help you create executable object files. For example, Chapter 7 explains how to invoke the linker, how the linker operates, and how to use linker directives; Chapter 11 explains how to use the hex conversion utility.

- **Reference material**, consisting of through , provides supplementary information including symbolic debugging directives that the TMS320C6000 C/C++ compiler uses. It also provides a description of the XML link information file and a glossary.
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:
```c
#include <stdio.h>
main()
{
    printf("hello, cruel world\n");
}
```

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

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

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

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

```
cl6x --run_linker {--rom_model | --ram_model} filenames [--output_file= name.out]
    --library= libraryname
```

- In assembler syntax statements, column 1 is reserved for the first character of a label or symbol. If the label or symbol is optional, it is usually not shown. If it is a required parameter, it is shown starting against the left margin of the box, as in the example below. No instruction, command, directive, or parameter, other than a symbol or label, can begin in column 1.

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

- Some directives can have a varying number of parameters. For example, the .byte directive can have up to 100 parameters. This syntax is shown as [, ..., parameter],

- The TMS320C6200 core is referred to as C6200. The TMS320C6400 core is referred to as C6400. The TMS320C6700 core is referred to as C6700. TMS320C6000 and C6000 can refer to either C6200, C6400, C6400+, C6700, C6700+, or C6740.

- Following are other symbols and abbreviations used throughout this document:

<table>
<thead>
<tr>
<th>Symbol</th>
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<tr>
<td>B, b</td>
<td>Suffix — binary integer</td>
</tr>
<tr>
<td>H, h</td>
<td>Suffix — hexadecimal integer</td>
</tr>
<tr>
<td>LSB</td>
<td>Least significant bit</td>
</tr>
<tr>
<td>MSB</td>
<td>Most significant bit</td>
</tr>
<tr>
<td>0x</td>
<td>Prefix — hexadecimal integer</td>
</tr>
<tr>
<td>Q, q</td>
<td>Suffix — octal integer</td>
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You can use the following books to supplement this user's guide:

**SPRAAO8 — Common Object File Format Application Report.** Provides supplementary information on the internal format of COFF object files. Much of this information pertains to the symbolic debugging information that is produced by the C compiler.

**SPRU187 — TMS320C6000 Optimizing Compiler v 7.0 User's Guide.** Describes the TMS320C6000 C compiler and the assembly optimizer. This C compiler accepts ANSI standard C source code and produces assembly language source code for the TMS320C6000 platform of devices (including the C64x+ and C67x+ generations). The assembly optimizer helps you optimize your assembly code.

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

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

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

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

**SPRU733 — TMS320C67x/C67x+ DSP CPU and Instruction Set Reference Guide.** Describes the CPU architecture, pipeline, instruction set, and interrupts for the TMS320C67x and TMS320C67x+ digital signal processors (DSPs) of the TMS320C6000 DSP platform. The C67x/C67x+ DSP generation comprises floating-point devices in the C6000 DSP platform. The C67x+ DSP is an enhancement of the C67x DSP with added functionality and an expanded instruction set.
Chapter 1

Introduction to the Software Development Tools

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

The TMS320C6000 is supported by the following assembly language development tools:

- Assembler
- Archiver
- Linker
- Library information archiver
- Absolute lister
- Cross-reference lister
- Object file display utility
- Disassembler
- Name utility
- Strip utility
- Hex conversion utility

This chapter shows how these tools fit into the general software tools development flow and gives a brief description of each tool. For convenience, it also summarizes the C/C++ compiler and debugging tools. For detailed information on the compiler and debugger, and for complete descriptions of the TMS320C6000, refer to the books listed in Related Documentation From Texas Instruments.

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Software Development Tools Overview
Tools Descriptions
1.1 Software Development Tools Overview

Figure 1-1 shows the TMS320C6000 software development flow. The shaded portion highlights the most common development path; the other portions are optional. The other portions are peripheral functions that enhance the development process.

Figure 1-1. TMS320C6000 Software Development Flow
1.2 Tools Descriptions

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

- The **C/C++ compiler** accepts C/C++ source code and produces TMS320C6000 assembly language source code. A **shell program**, an **optimizer**, and an **interlist utility** are included in the compiler package:
  - The shell program enables you to compile, assemble, and link source modules in one step.
  - The optimizer modifies code to improve the efficiency of C/C++ programs.
  - The interlist utility interlists C/C++ source statements with assembly language output to correlate code produced by the compiler with your source code.

See the **TMS320C6000 Optimizing Compiler User’s Guide** for more information.

- The **assembler** translates assembly language source files into machine language object modules. Source files can contain instructions, assembler directives, and macro directives. You can use assembler directives to control various aspects of the assembly process, such as the source listing format, data alignment, and section content. See Chapter 3 through Chapter 5. See the **TMS320C6000 DSP CPU and Instruction Set Reference Guide** for detailed information on the assembly language instruction set.

- 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 modules (created by the assembler) as input. It also accepts archiver library members and output modules created by a previous linker run. Link directives allow you to combine object file sections, bind sections or symbols to addresses or within memory ranges, and define or redefine global symbols. See Chapter 7.

- The **archiver** allows you to collect a group of files into a single archive file, called a library. For example, you can collect several macros into a macro library. The archiver searches the library and uses the members that are called as macros by the source file. You can also use the archiver to collect a group of object files into an object library. The archiver allows you to modify a library by deleting, replacing, extracting, or adding members. See Section 6.1.

- The **library information archiver** allows you to create an index library of several object file library versions, which is useful when several versions of a single library are available. This index library is the used in the link step in place of a particular version of your object file library. See Section 6.5.

- You can use the **library-build process** to build your own customized run-time-support library. See the **TMS320C6000 Optimizing Compiler User’s Guide** for more information.

- The **hex conversion utility** converts an object file into TI-Tagged, ASCII-Hex, Intel, Motorola-S, or Tektronix object format. The converted file can be downloaded to an EPROM programmer. See Chapter 11.

- The **absolute lister** uses linked object files to create .abs files. These files can be assembled to produce a listing of the absolute addresses of object code. See Chapter 8.

- The **cross-reference lister** uses object files to produce a cross-reference listing showing symbols, their definition, and their references in the linked source files. See Chapter 9.

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

In addition, the following utilities are provided:

- The **object file display utility** prints the contents of object files, executable files, and/or archive libraries in both human readable and XML formats. See Section 10.1.

- The **disassembler** writes the disassembled object code from object or executable files. See Section 10.2.

- The **name utility** prints a list of names defined and referenced in a object or an executable file. See Section 10.3.

- The **strip utility** removes symbol table and debugging information from object and executable files. See Section 10.4.
The assembler and linker create object modules that can be executed by a TMS320C6000™ device.

Object modules make modular programming easier because they encourage you to think in terms of blocks of code and data when you write an assembly language program. These blocks are known as sections. Both the assembler and the linker provide directives that allow you to create and manipulate sections.

This chapter focuses on the concept and use of sections in assembly language programs.

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2.1 Sections

The smallest unit of an object file is called a section. A section is a block of code or data that occupies contiguous space in the memory map with other sections. Each section of an object file is separate and distinct. Object files usually contain three default sections:

- **.text section** usually contains executable code
- **.data section** usually contains initialized data
- **.bss section** usually reserves space for uninitialized variables

In addition, the assembler and linker allow you to create, name, and link named sections that are used like the .data, .text, and .bss sections.

There are two basic types of sections:

- **Initialized sections** contain data or code. The .text and .data sections are initialized; named sections created with the .sect assembler directive are also initialized.
- **Uninitialized sections** reserve space in the memory map for uninitialized data. The .bss section is uninitialized; named sections created with the .usect assembler directive are also uninitialized.

Several assembler directives allow you to associate various portions of code and data with the appropriate sections. The assembler builds these sections during the assembly process, creating an object file organized as shown in Figure 2-1.

One of the linker's functions is to relocate sections into the target system's memory map; this function is called allocation. Because most systems contain several types of memory, using sections can help you use target memory more efficiently. All sections are independently relocatable; you can place any section into any allocated block of target memory. For example, you can define a section that contains an initialization routine and then allocate the routine into a portion of the memory map that contains ROM.

Figure 2-1 shows the relationship between sections in an object file and a hypothetical target memory.

---

**Figure 2-1. Partitioning Memory Into Logical Blocks**

```
<table>
<thead>
<tr>
<th>Object file</th>
<th>Target memory</th>
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</thead>
<tbody>
<tr>
<td>.bss</td>
<td>RAM</td>
</tr>
<tr>
<td>.data</td>
<td>EEPROM</td>
</tr>
<tr>
<td>.text</td>
<td>ROM</td>
</tr>
</tbody>
</table>
```

---
2.2 How the Assembler Handles Sections

The assembler identifies the portions of an assembly language program that belong in a given section. The assembler has five directives that support this function:

- .bss
- .usect
- .text
- .data
- .sect

The .bss and .usect directives create **uninitialized sections**; the .text, .data, and .sect directives create **initialized sections**.

You can create subsections of any section to give you tighter control of the memory map. Subsections are created using the .sect and .usect directives. Subsections are identified with the base section name and a subsection name separated by a colon; see Section 2.2.4.

### Default Sections Directive

**NOTE:** If you do not use any of the sections directives, the assembler assembles everything into the .text section.

#### 2.2.1 Uninitialized Sections

Uninitialized sections reserve space in TMS320C6000 memory; they are usually allocated into RAM. These sections have no actual contents in the object file; they simply reserve memory. A program can use this space at run time for creating and storing variables.

Uninitialized data areas are built by using the .bss and .usect assembler directives.

- The .bss directive reserves space in the .bss section.
- The .usect directive reserves space in a specific uninitialized named section.

Each time you invoke the .bss or .usect directive, the assembler reserves additional space in the .bss or the named section. The syntaxes for these directives are:

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

- **symbol** points to the first byte reserved by this invocation of the .bss or .usect directive. The symbol corresponds to the name of the variable that you are reserving space for. It can be referenced by any other section and can also be declared as a global symbol (with the .global directive).

- **size in bytes** is an absolute expression. The .bss directive reserves size in bytes bytes in the .bss section. The .usect directive reserves size in bytes bytes in section name. For both directives, you must specify a size; there is no default value.

- **alignment** is an optional parameter. It specifies the minimum alignment in bytes required by the space allocated. The default value is byte aligned. The value must be a power of 2.

- **bank offset** is an optional parameter. It ensures that the space allocated to the symbol occurs on a specific memory bank boundary. The bank offset measures the number of bytes to offset from the alignment specified before assigning the symbol to that location.

- **section name** tells the assembler which named section to reserve space in. See Section 2.2.3.

The initialized section directives (.text, .data, and .sect) tell the assembler to stop assembling into the current section and begin assembling into the indicated section. The .bss and .usect directives, however, do not end the current section and begin a new one; they simply escape from the current section temporarily. The .bss and .usect directives can appear anywhere in an initialized section without affecting its contents. For an example, see Section 2.2.6.
The assembler treats uninitialized subsections (created with the .usect directive) in the same manner as uninitialized sections. See Section 2.2.4, for more information on creating subsections.

2.2.2 Initialized Sections

Initialized sections contain executable code or initialized data. The contents of these sections are stored in the object file and placed in TMS320C6000 memory when the program is loaded. Each initialized section is independently relocatable and may reference symbols that are defined in other sections. The linker automatically resolves these section-relative references.

Three directives tell the assembler to place code or data into a section. The syntaxes for these directives are:

```
.text
.data
.sect "section name"
```

When the assembler encounters one of these directives, it stops assembling into the current section (acting as an implied end of current section command). It then assembles subsequent code into the designated section until it encounters another .text, .data, or .sect directive.

Sections are built through an iterative process. For example, when the assembler first encounters a .data directive, the .data section is empty. The statements following this first .data directive are assembled into the .data section (until the assembler encounters a .text or .sect directive). If the assembler encounters subsequent .data directives, it adds the statements following these .data directives to the statements already in the .data section. This creates a single .data section that can be allocated continuously into memory.

Initialized subsections are created with the .sect directive. The assembler treats initialized subsections in the same manner as initialized sections. See Section 2.2.4, for more information on creating subsections.
2.2.3 Named Sections

Named sections are sections that you create. You can use them like the default .text, .data, and .bss sections, but they are assembled separately.

For example, repeated use of the .text directive builds up a single .text section in the object file. When linked, this .text section is allocated into memory as a single unit. Suppose there is a portion of executable code (perhaps an initialization routine) that you do not want allocated with .text. If you assemble this segment of code into a named section, it is assembled separately from .text, and you can allocate it into memory separately. You can also assemble initialized data that is separate from the .data section, and you can reserve space for uninitialized variables that is separate from the .bss section.

Two directives let you create named sections:

- The .usect directive creates uninitialized sections that are used like the .bss section. These sections reserve space in RAM for variables.
- The .sect directive creates initialized sections, like the default .text and .data sections, that can contain code or data. The .sect directive creates named sections with relocatable addresses.

The syntaxes for these directives are:

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

The `section name` parameter is the name of the section. For COFF, you can create up to 32 767 separate named sections. For ELF, the max number of sections is $2^{32} - 1$ (4294967295). For the .usect and .sect directives, a section name can refer to a subsection; see Section 2.2.4 for details.

Each time you invoke one of these directives with a new name, you create a new named section. Each time you invoke one of these directives with a name that was already used, the assembler assembles code or data (or reserves space) into the section with that name. You cannot use the same names with different directives. That is, you cannot create a section with the .usect directive and then try to use the same section with .sect.

2.2.4 Subsections

Subsections are smaller sections within larger sections. Like sections, subsections can be manipulated by the linker. Placing each function and object in a uniquely-named subsection allows finer-grained memory placement, and also allows the linker finer-grained unused-function elimination. You can create subsections by using the .sect or .usect directive. The syntaxes for a subsection name are:

```
symbol .usect "section name:subsection name", size in bytes[, alignment[, bank offset]]
.sect "section name:subsection name"
```

A subsection is identified by the base section name followed by a colon and the name of the subsection. A subsection can be allocated separately or grouped with other sections using the same base name. For example, you create a subsection called _func within the .text section:

```
.sect ".text:_func"
```

Using the linker's SECTIONS directive, you can allocate .text:_func separately, or with all the .text sections. See Section 7.5.4.1 for an example using subsections.

You can create two types of subsections:

- Initialized subsections are created using the .sect directive. See Section 2.2.2.
- Uninitialized subsections are created using the .usect directive. See Section 2.2.1.

Subsections are allocated in the same manner as sections. See Section 7.5.4 for information on the SECTIONS directive.
2.2.5 Section Program Counters

The assembler maintains a separate program counter for each section. These program counters are known as section program counters, or SPCs.

An SPC represents the current address within a section of code or data. Initially, the assembler sets each SPC to 0. As the assembler fills a section with code or data, it increments the appropriate SPC. If you resume assembling into a section, the assembler remembers the appropriate SPC's previous value and continues incrementing the SPC from that value.

The assembler treats each section as if it began at address 0; the linker relocates each section according to its final location in the memory map. See Section 2.4 for information on relocation.

2.2.6 Using Sections Directives

Figure 2-2 shows how you can build sections incrementally, using the sections directives to swap back and forth between the different sections. You can use sections directives to begin assembling into a section for the first time, or to continue assembling into a section that already contains code. In the latter case, the assembler simply appends the new code to the code that is already in the section.

The format in Figure 2-2 is a listing file. Figure 2-2 shows how the SPCs are modified during assembly. A line in a listing file has four fields:

Field 1 contains the source code line counter.
Field 2 contains the section program counter.
Field 3 contains the object code.
Field 4 contains the original source statement.

See Section 3.11 for more information on interpreting the fields in a source listing.
**Figure 2-2. Using Sections Directives Example**

```
1  *******************************************************
2  ** Assemble an initialized table into .data. **
3  *******************************************************
4  00000000 .data
5  00000000 00000011 coeff .word 011h,022h
6  00000004 00000022
7  *******************************************************
8  ** Reserve space in .bss for a variable. **
9  *******************************************************
10  00000000 .bss var1,4
11  00000004 .bss buffer,40
12  *******************************************************
13  ** Still in .data section **
14  00000008 00001234 ptr .word 01234h
15  *******************************************************
16  ** Assemble code into .text section **
17  *******************************************************
18  00000000 .text
19  00000000 00800528 sum: MVK 10,A1
20  00000004 021085E0 ZERO A4
21  22  00000008 01003664 aloop: LDW *A0++,A2
23  0000000c 00040000 NOP 3
24  24  00000010 0087E1A0 SUB A1,1,A1
25  25  00000014 021041E0 ADD A2,A4,A4
26  26  00000018 00000112 [A1] B aloop
27  27  0000001c 00008000 NOP 5
28  28  29  00000020 0200007C- STW A4, *+B14(var1)
30  *******************************************************
31  ** Assemble another initialized table in .data **
32  *******************************************************
33  00000000 .data
34  0000000c 00000AA ivals .word 0aah,0bbh,0cch
35  0000010 00000BB
36  00000014 000000CC
37  *******************************************************
38  ** Define another section for more variables. **
39  *******************************************************
40  00000000 var2 .usect "newvars",4
41  00000004 inbuf .usect "newvars",4
42  *******************************************************
43  ** Assemble more code into the .text section. **
44  *******************************************************
45  00000000 .text
46  00000004 01003664 xmult: LDW *A0++,A2
47  0000000c 00060000 NOP 4
48  00000010 020C4480 MPYHL A2,A3,A4
49  00000014 02800028- MVKL var2,A5
50  00000018 02800068- MVKH var2,A5
51  0000001c 02140274 STW A4,*A5
52  *******************************************************
53  ** Define a named section for interrupt vectors **
54  *******************************************************
55  00000000 .sect "vectors"
56  00000000 00000012 B sum
57  00000004 00080000 NOP 5
58
Field 1 Field 2 Field 3 Field 4
```

As Figure 2-3 shows, the file in Figure 2-2 creates five sections:

- **.text** contains 15 32-bit words of object code.
- **.data** contains six words of initialized data.
- **vectors** is a named section created with the `.sect` directive; it contains two words of object code.
- **.bss** reserves 44 bytes in memory.
- **newvars** is a named section created with the `.usect` directive; it contains eight bytes in memory.

The second column shows the object code that is assembled into these sections; the first column shows the source statements that generated the object code.

**Figure 2-3. Object Code Generated by the File in Figure 2-2**

<table>
<thead>
<tr>
<th>Line numbers</th>
<th>Object code</th>
<th>Section</th>
</tr>
</thead>
<tbody>
<tr>
<td>19</td>
<td>00800028</td>
<td>.text</td>
</tr>
<tr>
<td>20</td>
<td>021085E0</td>
<td></td>
</tr>
<tr>
<td>22</td>
<td>01003664</td>
<td></td>
</tr>
<tr>
<td>23</td>
<td>00004000</td>
<td></td>
</tr>
<tr>
<td>24</td>
<td>0087E1A0</td>
<td></td>
</tr>
<tr>
<td>25</td>
<td>021041E0</td>
<td></td>
</tr>
<tr>
<td>26</td>
<td>80000112</td>
<td></td>
</tr>
<tr>
<td>27</td>
<td>00008000</td>
<td></td>
</tr>
<tr>
<td>29</td>
<td>0200007C-</td>
<td></td>
</tr>
<tr>
<td>44</td>
<td>01003664</td>
<td></td>
</tr>
<tr>
<td>45</td>
<td>00008000</td>
<td></td>
</tr>
<tr>
<td>46</td>
<td>020C4480</td>
<td></td>
</tr>
<tr>
<td>47</td>
<td>02800028-</td>
<td></td>
</tr>
<tr>
<td>48</td>
<td>02800068-</td>
<td></td>
</tr>
<tr>
<td>49</td>
<td>02140274</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>00000011</td>
<td>.data</td>
</tr>
<tr>
<td>5</td>
<td>00000022</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>00001234</td>
<td></td>
</tr>
<tr>
<td>34</td>
<td>000000AA</td>
<td></td>
</tr>
<tr>
<td>34</td>
<td>000000BB</td>
<td></td>
</tr>
<tr>
<td>34</td>
<td>000000CC</td>
<td></td>
</tr>
<tr>
<td>54</td>
<td>00000000*</td>
<td>vectors</td>
</tr>
<tr>
<td>54</td>
<td>00000024*</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>No data—</td>
<td>.bss</td>
</tr>
<tr>
<td>10</td>
<td>44 bytes</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>reserved</td>
<td></td>
</tr>
<tr>
<td>38</td>
<td>No data—</td>
<td>newvars</td>
</tr>
<tr>
<td>39</td>
<td>8 bytes</td>
<td></td>
</tr>
<tr>
<td>39</td>
<td>reserved</td>
<td></td>
</tr>
</tbody>
</table>
2.3 How the Linker Handles Sections

The linker has two main functions related to sections. First, the linker uses the sections in object files as building blocks; it combines input sections (when more than one file is being linked) to create output sections in an executable output module. Second, the linker chooses memory addresses for the output sections.

Two linker directives support these functions:

- The **MEMORY** directive allows you to define the memory map of a target system. You can name portions of memory and specify their starting addresses and their lengths.
- The **SECTIONS** directive tells the linker how to combine input sections into output sections and where to place these output sections in memory.

Subsections allow you to manipulate sections with greater precision. You can specify subsections with the linker's SECTIONS directive. If you do not specify a subsection explicitly, then the subsection is combined with the other sections with the same base section name.

It is not always necessary to use linker directives. If you do not use them, the linker uses the target processor's default allocation algorithm described in Section 7.7. When you do use linker directives, you must specify them in a linker command file.

Refer to the following sections for more information about linker command files and linker directives:

- Section 7.5, Linker Command Files
- Section 7.5.3, The MEMORY Directive
- Section 7.5.4, The SECTIONS Directive
- Section 7.7, Default Allocation Algorithm

2.3.1 Default Memory Allocation

Figure 2-4 illustrates the process of linking two files together.

**Figure 2-4. Combining Input Sections to Form an Executable Object Module**

In Figure 2-4, file1.obj and file2.obj have been assembled to be used as linker input. Each contains the...
.text, .data, and .bss default sections; in addition, each contains a named section. The executable object module shows the combined sections. The linker combines the .text section from file1.obj and the .text section from file2.obj to form one .text section, then combines the two .data sections and the two .bss sections, and finally places the named sections at the end. The memory map shows how the sections are put into memory.

By default, the linker begins at 0h and places the sections one after the other in the following order: .text, .const, .data, .bss, .cinit, and then any named sections in the order they are encountered in the input files.

The C/C++ compiler uses the .const section to store string constants, and variables or arrays that are declared as far const. The C/C++ compiler produces tables of data for autounitializing global variables; these variables are stored in a named section called .cinit (see Example 7-7). For more information on the .const and .cinit sections, see the TMS320C6000 COFF and EABI guides. *Names to be corrected when ready*.

### 2.3.2 Placing Sections in the Memory Map

Figure 2-4 illustrates the linker's default method for combining sections. Sometimes you may not want to use the default setup. For example, you may not want all of the .text sections to be combined into a single .text section. Or you may want a named section placed where the .data section would normally be allocated. Most memory maps contain various types of memory (RAM, ROM, EPROM, etc.) in varying amounts; you may want to place a section in a specific type of memory.

For further explanation of section placement within the memory map, see the discussions in Section 7.5.3 and Section 7.5.4.

### 2.4 Relocation

The assembler treats each section as if it began at address 0. All relocatable symbols (labels) are relative to address 0 in their sections. Of course, all sections cannot actually begin at address 0 in memory, so the linker relocates sections by:

- Allocating them into the memory map so that they begin at the appropriate address as defined with the linker's MEMORY directive
- Adjusting symbol values to correspond to the new section addresses
- Adjusting references to relocated symbols to reflect the adjusted symbol values

The linker uses relocation entries to adjust references to symbol values. The assembler creates a relocation entry each time a relocatable symbol is referenced. The linker then uses these entries to patch the references after the symbols are relocated. Example 2-1 contains a code segment for a TMS320C6000 device that generates relocation entries.

#### Example 2-1. Code That Generates Relocation Entries

<p>| | | | | | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>.global X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>00000000 00000012! Z: B X ; Uses an external relocation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>00000004 0180082A' MVKL Y,B3 ; Uses an internal relocation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>00000008 0180006A' MVKH Y,B3 ; Uses an internal relocation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>0000000C 00004000 NOP 3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>00000010 001E000 Y: IDLE</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>00000014 0000212 B Y</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>00000018 0008000 NOP 5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

In Example 2-1, both symbols X and Y are relocatable. Y is defined in the .text section of this module; X is defined in another module. When the code is assembled, X has a value of 0 (the assembler assumes all undefined external symbols have values of 0), and Y has a value of 16 (relative to address 0 in the .text section). The assembler generates two relocation entries: one for X and one for Y. The reference to X is an external reference (indicated by the ! character in the listing). The reference to Y is to an internally defined relocatable symbol (indicated by the ' character in the listing).
Relocation

After the code is linked, suppose that X is relocated to address 0x7100. Suppose also that the .text section is relocated to begin at address 0x7200; Y now has a relocated value of 0x7210. The linker uses the two relocation entries to patch the two references in the object code:

00000012 B X
0180082A MVKL Y
0180006A MVKH Y

becomes
0ffe012
01B9082A
1860006A

Sometimes an expression contains more than one relocatable symbol, or cannot be evaluated at assembly time. In this case, the assembler encodes the entire expression in the object file. After determining the addresses of the symbols, the linker computes the value of the expression as shown in Example 2-2.

Example 2-2. Simple Assembler Listing

```assembly
1 .global sym1, sym2
2
3 00000000 00800028% MVKL sym2 - sym1, A1
```

The symbols sym1 and sym2 are both externally defined. Therefore, the assembler cannot evaluate the expression sym2 - sym1, so it encodes the expression in the object file. The '%' listing character indicates a relocation expression. Suppose the linker relocates sym2 to 300h and sym1 to 200h. Then the linker computes the value of the expression to be 300h - 200h = 100h. Thus the MVKL instruction is patched to:

00800828 MVKL 100h, A1

NOTE: If the value of an expression is larger, in bits, than the space reserved for it, you will receive an error message from the linker.

Each section in an object module has a table of relocation entries. The table contains one relocation entry for each relocatable reference in the section. The linker usually removes relocation entries after it uses them. This prevents the output file from being relocated again (if it is relinked or when it is loaded). A file that contains no relocation entries is an absolute file (all its addresses are absolute addresses). If you want the linker to retain relocation entries, invoke the linker with the --relocatable option (see Section 7.4.2.2).
2.5 Run-Time Relocation

At times you may want to load code into one area of memory and run it in another. For example, you may have performance-critical code in an external-memory-based system. The code must be loaded into external memory, but it would run faster in internal memory.

The linker provides a simple way to handle this. Using the SECTIONS directive, you can optionally direct the linker to allocate a section twice: first to set its load address and again to set its run address. Use the load keyword for the load address and the run keyword for the run address.

The load address determines where a loader places the raw data for the section. Any references to the section (such as references to labels in it) refer to its run address. The application must copy the section from its load address to its run address before the first reference of the symbol is encountered at run time; this does not happen automatically simply because you specify a separate run address. For an example that illustrates how to move a block of code at run time, see Example 7-9.

If you provide only one allocation (either load or run) for a section, the section is allocated only once and loads and runs at the same address. If you provide both allocations, the section is actually allocated as if it were two separate sections of the same size.

Uninitialized sections (such as .bss) are not loaded, so the only significant address is the run address. The linker allocates uninitialized sections only once; if you specify both run and load addresses, the linker warns you and ignores the load address.

For a complete description of run-time relocation, see Section 7.5.5.

2.6 Loading a Program

The linker produces executable object modules. An executable object module has the same format as object files that are used as linker input; the sections in an executable object module, however, are combined and relocated into target memory.

To run a program, the data in the executable object module must be transferred, or loaded, into target system memory. Several methods can be used for loading a program, depending on the execution environment. Common situations are described below:

- Code Composer Studio can load an executable object module onto hardware. The Code Composer Studio loader reads the executable file and copies the program into target memory.
- You can use the hex conversion utility (hex6x, which is shipped as part of the assembly language package) to convert the executable object module into one of several object file formats. You can then use the converted file with an EPROM programmer to burn the program into an EPROM.
- A standalone simulator can be invoked by the load6x command and the name of the executable object module. The standalone simulator reads the executable file, copies the program into the simulator and executes it, displaying any C I/O.
2.7 Symbols in an Object File

An object file contains a symbol table that stores information about symbols in the program. The linker uses this table when it performs relocation.

2.7.1 External Symbols

External symbols are symbols that are defined in one file and referenced in another file. You can use the .def, .ref, or .global directive to identify symbols as external:

- **.def** The symbol is defined in the current file and used in another file.
- **.ref** The symbol is referenced in the current file, but defined in another file.
- **.global** The symbol can be either of the above.

The following code segment illustrates these definitions.

```
.def x
.ref y
.global z
.global q
```

```
q:  B B3
    NOP 4
    MVK 1, B1
x:  MV A0, A1
    MVKL y, B3
    MVKH y, B3
    B  z
    NOP 5
```

In this example, the .def definition of x says that it is an external symbol defined in this file and that other files can reference x. The .ref definition of y says that it is an undefined symbol that is defined in another file. The .global definition of z says that it is defined in some file and available in this file. The .global definition of q says that it is defined in this file and that other files can reference q.

The assembler places x, y, z, and q in the object file's symbol table. When the file is linked with other object files, the entries for x and q resolve references to x and q in other files. The entries for y and z cause the linker to look through the symbol tables of other files for y's and z's definitions.

The linker must match all references with corresponding definitions. If the linker cannot find a symbol's definition, it prints an error message about the unresolved reference. This type of error prevents the linker from creating an executable object module.
2.8 Object File Format Specifications

The object files created by the assembler and linker conform to either the ELF (Executable and Linking Format) or COFF (Common Object File Format) binary formats, depending on the ABI selected when building your program. When using the EABI mode, the ELF format is used. For the older COFF ABI mode, the legacy COFF format is used.

Some features of the assembler may apply only to the ELF or COFF object file format. In these cases, the proper object file format is stated in the feature description.

See the TMS320C6000 Optimizing Compiler User's Guide for information on the different ABIs available.

See the Common Object File Format Application Note for information about the COFF object file format.

The ELF object files generated by the assembler and linker conform to the December 17, 2003 snapshot of the System V generic ABI (or gABI).
The TMS320C6000™ assembler translates assembly language source files into machine language object files. These files are in object modules, which are discussed in Chapter 2. Source files can contain the following assembly language elements:

- Assembler directives: described in Chapter 4
- Macro directives: described in Chapter 5
- Assembly language instructions: described in the TMS320C6000 DSP CPU and Instruction Set Reference Guide

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<td>3.13 Cross-Reference Listings</td>
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</tr>
</tbody>
</table>
3.1 Assembler Overview

The 2-pass assembler does the following:

- Processes the source statements in a text file to produce a relocatable object file
- Produces a source listing (if requested) and provides you with control over this listing
- Allows you to segment your code into sections and maintain a section program counter (SPC) for each section of object code
- Defines and references global symbols and appends a cross-reference listing to the source listing (if requested)
- Allows conditional assembly
- Supports macros, allowing you to define macros inline or in a library
3.2 The Assembler's Role in the Software Development Flow

Figure 3-1 illustrates the assembler's role in the software development flow. The shaded portion highlights the most common assembler development path. The assembler accepts assembly language source files as input, both those you create and those created by the TMS320C6000 C/C++ compiler.

Figure 3-1. The Assembler in the TMS320C6000 Software Development Flow
3.3 Invoking the Assembler

To invoke the assembler, enter the following:

```
cl6x input file [options]
```

`cl6x` is the command that invokes the assembler through the compiler. The compiler considers any file with an .asm extension to be an assembly file and calls the assembler.

`input file` names the assembly language source file.

`options` identify the assembler options that you want to use. Options are not case sensitive and can appear anywhere on the command line following the command. Precede each option with one or two hyphens as shown.

The valid assembler options are listed in Table 3-1:

<table>
<thead>
<tr>
<th>Option</th>
<th>Alias</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>--absolute_listing</td>
<td>-aa</td>
<td>creates an absolute listing. When you use --absolute_listing, the assembler does not produce an object file. The --absolute_listings option is used in conjunction with the absolute lister.</td>
</tr>
<tr>
<td>-ar=num</td>
<td></td>
<td>suppresses the assembler remark identified by num. A remark is an informational assembler message that is less severe than a warning. If you do not specify a value for #, all remarks are suppressed.</td>
</tr>
<tr>
<td>--asm_define=name[=def]</td>
<td>-ad</td>
<td>sets the name symbol. This is equivalent to defining name with a .set directive in the case of a numeric value or with an .asg directive otherwise. If value is omitted, the symbol is set to 1. See Section 3.9.4.</td>
</tr>
<tr>
<td>--asm_dependency</td>
<td>-apd</td>
<td>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.</td>
</tr>
<tr>
<td>--asm_includes</td>
<td>-api</td>
<td>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.</td>
</tr>
<tr>
<td>--asm_listing</td>
<td>-al</td>
<td>produces a listing file with the same name as the input file with a .lst extension.</td>
</tr>
<tr>
<td>--asm_undefine=name</td>
<td>-au</td>
<td>undefines the predefined constant name, which overrides any --asm_define options for the specified constant.</td>
</tr>
<tr>
<td>--cmd_file=filename</td>
<td>-@</td>
<td>appends the contents of a file to the command line. You can use this option to avoid limitations on command line length imposed by the host operating system. Use an asterisk or a semicolon (* or ;) at the beginning of a line in the command file to include comments. Comments that begin in any other column must begin with a semicolon. Within the command file, filenames or option parameters containing embedded spaces or hyphens must be surrounded with quotation marks. For example: &quot;this-file.asm&quot;</td>
</tr>
<tr>
<td>--copy_file=filename</td>
<td>-ahc</td>
<td>copies the specified file for the assembly module. The file is inserted before source file statements. The copied file appears in the assembly listing files.</td>
</tr>
<tr>
<td>--cross_reference</td>
<td>-ax</td>
<td>produces a cross-reference table and appends it to the end of the listing file; it also adds cross-reference information to the object file for use by the cross-reference utility. If you do not request a listing file but use the --cross_reference option, the assembler creates a listing file automatically, naming it with the same name as the input file with a .lst extension.</td>
</tr>
<tr>
<td>--include_file=filename</td>
<td>-ahi</td>
<td>includes the specified file for the assembly module. The file is included before source file statements. The included file does not appear in the assembly listing files.</td>
</tr>
<tr>
<td>--include_path=pathname</td>
<td>-I</td>
<td>specifies a directory where the assembler can find files named by the .copy, .include, or .mlib directives. There is no limit to the number of directories you can specify in this manner; each pathname must be preceded by the --include_path option. See Section 3.5.1.</td>
</tr>
<tr>
<td>--output_all_syms</td>
<td>-as</td>
<td>puts all defined symbols in the object file's symbol table. The assembler usually puts only global symbols into the symbol table. When you use --output_all_syms, symbols defined as labels or as assembly-time constants are also placed in the table.</td>
</tr>
<tr>
<td>--quiet</td>
<td>-q</td>
<td>suppresses the banner and progress information (assembler runs in quiet mode).</td>
</tr>
<tr>
<td>--symdebug:dwarf</td>
<td>-g</td>
<td>enables assembler source debugging in the C source debugger. Line information is output to the object module for every line of source in the assembly language source file. You cannot use the --symdebug:dwarf option on assembly code that contains .line directives. See Section 3.12.</td>
</tr>
</tbody>
</table>
### 3.4 Controlling Application Binary Interface

An Application Binary Interface (ABI) defines the low level interface between object files, and between an executable and its execution environment. An ABI allows ABI-compliant object code to link together, regardless of its source, and allows the resulting executable to run on any system that supports that ABI. Object modules conforming to different ABIs cannot be linked together. The linker detects this situation and generates an error.

The C6x compiler supports two ABIs. The ABI is chosen through the --abi option as follows:

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

- **C6x EABI** (--abi=eabi)
  Use this option to select the C6x Embedded Application Binary Interface (EABI).
  Using version 7.0 to build for EABI is not a practical reality today for most users. All code in an EABI application must be built for EABI, and EABI versions of C6000 libraries are not generally available. The principal purpose of supplying EABI in 7.0 is so C6000 library suppliers can begin creating EABI products. Please see [http://tiexpressdsp.com/index.php/EABI_Support_in_C6000_Compiler](http://tiexpressdsp.com/index.php/EABI_Support_in_C6000_Compiler) for full details.

### 3.5 Naming Alternate Directories for Assembler Input

The .copy, .include, and .mlib directives tell the assembler to use code from external files. The .copy and .include directives tell the assembler to read source statements from another file, and the .mlib directive names a library that contains macro functions. Chapter 4 contains examples of the .copy, .include, and .mlib directives. The syntax for these directives is:

```
.copy "filename"
.include "filename"
.mlib "filename"
```

The `filename` names a copy/include file that the assembler reads statements from or a macro library that contains macro definitions. If `filename` begins with a number the double quotes are required. The filename may be a complete pathname, a partial pathname, or a filename with no path information. The assembler searches for the file in the following locations in the order given:

1. The directory that contains the current source file. The current source file is the file being assembled when the .copy, .include, or .mlib directive is encountered.
2. Any directories named with the --include_path option
3. Any directories named with the C6X_A_DIR environment variable
4. Any directories named with the C6X_C_DIR environment variable

Because of this search hierarchy, you can augment the assembler's directory search algorithm by using the --include_path option (described in Section 3.5.1) or the C6X_A_DIR environment variable (described in Section 3.5.2). C6X_C_DIR is discussed in the TMS320C6000 Optimizing Compiler User's Guide.

---

**Table 3-1. TMS320C6000 Assembler Options (continued)**

<table>
<thead>
<tr>
<th>Option</th>
<th>Alias</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>--syms_ignore_case</td>
<td>-ac</td>
<td>makes case insignificant in the assembly language files. For example, --syms_ignore_case makes the symbols ABC and abc equivalent. If you do not use this option, case is significant (default). Case significance is enforced primarily with symbol names, not with mnemonics and register names.</td>
</tr>
</tbody>
</table>
3.5.1 Using the --include_path Assembler Option

The --include_path assembler option names an alternate directory that contains copy/include files or macro libraries. The format of the --include_path option is as follows:

```
cl6x --include_path= pathname source filename [other options]
```

There is no limit to the number of --include_path options per invocation; each --include_path option names one pathname. In assembly source, you can use the .copy, .include, or .mlib directive without specifying path information. If the assembler does not find the file in the directory that contains the current source file, it searches the paths designated by the --include_path options.

For example, assume that a file called source.asm is in the current directory; source.asm contains the following directive statement:

```
.copy "copy.asm"
```

Assume the following paths for the copy.asm file:

- UNIX: `/tools/files/copy.asm`
- Windows: `c:\tools\files\copy.asm`

You could set up the search path with the commands shown below:

<table>
<thead>
<tr>
<th>Operating System</th>
<th>Enter</th>
</tr>
</thead>
<tbody>
<tr>
<td>UNIX (Bourne shell)</td>
<td><code>cl6x --include_path=/tools/files source.asm</code></td>
</tr>
<tr>
<td>Windows</td>
<td><code>cl6x --include_path=c:\tools\files source.asm</code></td>
</tr>
</tbody>
</table>

The assembler first searches for copy.asm in the current directory because source.asm is in the current directory. Then the assembler searches in the directory named with the --include_path option.

3.5.2 Using the C6X_A_DIR Environment Variable

An environment variable is a system symbol that you define and assign a string to. The assembler uses the C6X_A_DIR environment variable to name alternate directories that contain copy/include files or macro libraries.

The assembler looks for the C6X_A_DIR environment variable and then reads and processes it. If the assembler does not find the C6X_A_DIR variable, it then searches for C6X_C_DIR. The processor-specific variables are useful when you are using Texas Instruments tools for different processors at the same time.

See the TMS320C6000 Optimizing Compiler User’s Guide for details on C6X_C_DIR.

The command syntax for assigning the environment variable is as follows:

<table>
<thead>
<tr>
<th>Operating System</th>
<th>Enter</th>
</tr>
</thead>
<tbody>
<tr>
<td>UNIX (Bourne Shell)</td>
<td><code>C6X_A_DIR= &quot; pathname1 ; pathname2 ; . . .&quot; ; export C6X_A_DIR</code></td>
</tr>
<tr>
<td>Windows</td>
<td><code>set C6X_A_DIR= pathname1 ; pathname2 ; . . .</code></td>
</tr>
</tbody>
</table>

The pathnames are directories that contain copy/include files or macro libraries. The pathnames must follow these constraints:

- Pathnames must be separated with a semicolon.
- Spaces or tabs at the beginning or end of a path are ignored. For example the space before and after the semicolon in the following is ignored:
  `set C6X_A_DIR= c:\path\one\to\tools ; c:\path\two\to\tools`
- Spaces and tabs are allowed within paths to accommodate Windows directories that contain spaces. For example, the pathnames in the following are valid:
  `set C6X_A_DIR= c:\first path\to\tools; d:\second path\to\tools`
In assembly source, you can use the .copy, .include, or .mlib directive without specifying path information. If the assembler does not find the file in the directory that contains the current source file or in directories named by the --include_path option, it searches the paths named by the environment variable.

For example, assume that a file called source.asm contains these statements:

```asm
.copy "copy1.asm"
.copy "copy2.asm"
```

Assume the following paths for the files:

- **UNIX**: `/tools/files/copy1.asm` and `/dsys/copy2.asm`
- **Windows**: `c:\tools\files\copy1.asm` and `c:\dsys\copy2.asm`

You could set up the search path with the commands shown below:

### Operating System

<table>
<thead>
<tr>
<th>Operating System</th>
<th>Enter</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>UNIX (Bourne shell)</strong></td>
<td><code>C6X_A_DIR=&quot;/dsys&quot;; export C6X_A_DIR</code>&lt;br&gt;<code>cl6x --include_path=/tools/files source.asm</code></td>
</tr>
<tr>
<td><strong>Windows</strong></td>
<td><code>set C6X_A_DIR=c:\dsys</code>&lt;br&gt;<code>cl6x --include_path=c:\tools\files source.asm</code></td>
</tr>
</tbody>
</table>

The assembler first searches for `copy1.asm` and `copy2.asm` in the current directory because `source.asm` is in the current directory. Then the assembler searches in the directory named with the --include_path option and finds `copy1.asm`. Finally, the assembler searches the directory named with C6X_A_DIR and finds `copy2.asm`.

The environment variable remains set until you reboot the system or reset the variable by entering one of these commands:

### Operating System

<table>
<thead>
<tr>
<th>Operating System</th>
<th>Enter</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>UNIX (Bourne shell)</strong></td>
<td><code>unset C6X_A_DIR</code></td>
</tr>
<tr>
<td><strong>Windows</strong></td>
<td><code>set C6X_A_DIR=</code></td>
</tr>
</tbody>
</table>
3.6 Source Statement Format

TMS320C6000 assembly language source programs consist of source statements that can contain assembler directives, assembly language instructions, macro directives, and comments. A source statement can contain five ordered fields (label, mnemonic, unit specifier, operand list, and comment). The general syntax for source statements is as follows:

\[ \text{[label:]} \text{ || [register] } \text{ mnemonic [unit specifier] [operand list][;comment]} \]

Labels cannot be placed on instructions that have parallel bars.

Following are examples of source statements:

two .set 2 ; Symbol Two = 2
Label: MVK two,A2 ; Move 2 into register A2
.word 016h ; Initialize a word with 016h

The C6000 assembler reads up to 200 characters per line. Any characters beyond 200 are truncated. Keep the operational part of your source statements (that is, everything other than comments) less than 200 characters in length for correct assembly. Your comments can extend beyond the 200-character limit, but the truncated portion is not included in the listing file.

Follow these guidelines:

- All statements must begin with a label, a blank, an asterisk, or a semicolon.
- Labels are optional; if used, they must begin in column 1.
- One or more blanks must separate each field. Tab and space characters are blanks. You must separate the operand list from the preceding field with a blank.
- Comments are optional. Comments that begin in column 1 can begin with an asterisk or a semicolon (* or ;), but comments that begin in any other column must begin with a semicolon.
- In a conditional instruction, the condition register must be surrounded by square brackets.
- The functional unit specifier is optional. If you do not specify the functional unit, the assembler assigns a legal functional unit based on the mnemonic field.
- A mnemonic cannot begin in column 1 or it will be interpreted as a label.

The following sections describe each of the fields.
3.6.1 Label Field

Labels are optional for all assembly language instructions and for most (but not all) assembler directives. When used, a label must begin in column 1 of a source statement. A label can contain up to 128 alphanumeric characters (A-Z, a-z, 0-9, _, and $). Labels are case sensitive (except when the --symbs_ignore_case option is used), and the first character cannot be a number. A label can be followed by a colon (:). The colon is not treated as part of the label name. If you do not use a label, the first character position must contain a blank, a semicolon, or an asterisk. You cannot use a label with an instruction that is in parallel with a previous instruction.

When you use a label, its value is the current value of the SPC. The label points to the statement it is associated with. For example, if you use the .word directive to initialize several words, a label points to the first word. In the following example, the label Start has the value 40h.

```
9 * Assume some code was assembled
10 00000040 0000000A Start: .word 0Ah,3,7
     00000044 00000003
     00000048 00000007
```

A label on a line by itself is a valid statement. The label assigns the current value of the section program counter to the label; this is equivalent to the following directive statement:

```
label .equ $ ; $ provides the current value of the SPC
```

When a label appears on a line by itself, it points to the instruction on the next line (the SPC is not incremented):

```
1 00000000 Here:
2 00000000 00000003 .word 3
```

If you do not use a label, the character in column 1 must be a blank, an asterisk, or a semicolon.

3.6.2 Mnemonic Field

The mnemonic field follows the label field. The mnemonic field cannot start in column 1; if it does, it is interpreted as a label. There is one exception: the parallel bars (||) of the mnemonic field can start in column 1. The mnemonic field can begin with one of the following items:

- Pipe symbols (||) indicate instructions that are in parallel with a previous instruction. You can have up to eight instructions running in parallel. The following example demonstrates six instructions running in parallel:

```
\[\begin{array}{c|c|c|c|c|c|c|c}
| Inst1 | \| | Inst2 | \| | Inst3 | \| | Inst4 | \| | Inst5 | \| | Inst6 | \| | Inst7 |
\end{array}\]
These five instructions run in parallel with the first instruction.
```

- Square brackets ([ ]) indicate conditional instructions. The machine-instruction mnemonic is executed based on the value of the register within the brackets; valid register names are A0 for C64xx only, A1, A2, B0, B1, and B2. The instruction is executed if the value of the register is nonzero. If the register name is preceded by an exclamation point (!), then the instruction is executed if the value of the register is 0. For example:

```
[A1] ZERO A2 ; If A1 is not equal to zero, A2 = 0
```

Next, the mnemonic field contains one of the following items:

- Machine-instruction mnemonic (such as ADDK, MVKH, B)
- Assembler directive (such as .data, .list, .equ)
- Macro directive (such as .macro, .var, .mexit)
- Macro call
3.6.3 **Unit Specifier Field**

The unit specifier field is an optional field that follows the mnemonic field for machine-instruction mnemonics. The unit specifier field begins with a period (.) followed by a functional unit specifier. In general, one instruction can be assigned to each functional unit in a single instruction cycle. There are eight functional units, two of each functional type:

- **.D1 and .D2** Data/addition/subtraction
- **.L1 and .L2** ALU/compares/long data arithmetic
- **.M1 and .M2** Multiply
- **.S1 and .S2** Shift/ALU/branch/bit field

ALU refers to an arithmetic logic unit.

There are several ways to use the unit specifier field:

- You can specify the particular functional unit (for example, .D1).
- You can specify only the functional type (for example, .M), and the assembler assigns the specific unit (for example, .M2).
- If you do not specify the functional unit, the assembler assigns the functional unit based on the mnemonic field and operand field.

For more information on functional units, including which assembly instructions require which functional type, see the *TMS320C62x DSP CPU and Instruction Set Reference Guide*, *TMS320C64x/C64x+ DSP CPU and Instruction Set Reference Guide*, or *TMS320C67x/C67x+ DSP CPU and Instruction Set Reference Guide*.

3.6.4 **Operand Field**

The operand field follows the mnemonic field and contains one or more operands. The operand field is not required for all instructions or directives. An operand consists of the following items:

- Symbols (see Section 3.9)
- Constants (see Section 3.7)
- Expressions (combination of constants and symbols; see Section 3.10)

You must separate operands with commas.

3.6.5 **Comment Field**

A comment can begin in any column and extends to the end of the source line. A comment can contain any ASCII character, including blanks. Comments are printed in the assembly source listing, but they do not affect the assembly.

A source statement that contains only a comment is valid. If it begins in column 1, it can start with a semicolon (;) or an asterisk (*). Comments that begin anywhere else on the line must begin with a semicolon. The asterisk identifies a comment only if it appears in column 1.
3.7 Constants

The assembler supports several types of constants:

- Binary integer
- Octal integer
- Decimal integer
- Hexadecimal integer
- Character
- Assembly time

The assembler maintains each constant internally as a 32-bit quantity. Constants are not sign extended. For example, the constant 00FFh is equal to 00FF (base 16) or 255 (base 10); it does not equal -1. However, when used with the .byte directive, -1 is equivalent to 00FFh.

3.7.1 Binary Integers

A binary integer constant is a string of up to 32 binary digits (0s and 1s) followed by the suffix B (or b). If fewer than 32 digits are specified, the assembler right justifies the value and fills the unspecified bits with zeros. These are examples of valid binary constants:

- 00000000B  Constant equal to 0₁₀ or 0₁₆
- 0100000b   Constant equal to 32₁₀ or 2₀₁₆
- 01b        Constant equal to 1₁₀ or 1₁₆
- 11111000B  Constant equal to 248₁₀ or 0F8₁₆

3.7.2 Octal Integers

An octal integer constant is a string of up to 11 octal digits (0 through 7) followed by the suffix Q (or q). These are examples of valid octal constants:

- 10Q        Constant equal to 8₁₀ or 8₁₆
- 010        Constant equal to 8₁₀ or 8₁₆ (© format)
- 100000Q    Constant equal to 32 768₁₀ or 8000₁₆
- 226q       Constant equal to 150₁₀ or 96₁₆

3.7.3 Decimal Integers

A decimal integer constant is a string of decimal digits ranging from -2147 483 648 to 4 294 967 295. These are examples of valid decimal constants:

- 1000       Constant equal to 1000₁₀ or 3E8₁₆
- -32768     Constant equal to -32 768₁₀ or 8000₁₆
- 25         Constant equal to 25₁₀ or 19₁₆
3.7.4 Hexadecimal Integers

A hexadecimal integer constant is a string of up to eight hexadecimal digits followed by the suffix H (or h) or preceded by 0x. Hexadecimal digits include the decimal values 0-9 and the letters A-F or a-f. A hexadecimal constant must begin with a decimal value (0-9). If fewer than eight hexadecimal digits are specified, the assembler rightjustifies the bits. These are examples of valid hexadecimal constants:

- 78h: Constant equal to 120₁₀ or 0078₁₆
- 0x78: Constant equal to 120₁₀ or 0078₁₆ (© format)
- 0Fh: Constant equal to 15₁₀ or 000F₁₆
- 37ACh: Constant equal to 14 252₁₀ or 37AC₁₆

3.7.5 Character Constants

A character constant is a single character enclosed in single quotes. The characters are represented internally as 8-bit ASCII characters. Two consecutive single quotes are required to represent each single quote that is part of a character constant. A character constant consisting only of two single quotes is valid and is assigned the value 0. These are examples of valid character constants:

- 'a': Defines the character constant a and is represented internally as 61₁₆
- 'C': Defines the character constant C and is represented internally as 43₁₆
- '''': Defines the character constant ’ and is represented internally as 27₁₆
- "": Defines a null character and is represented internally as 00₁₆

Notice the difference between character constants and character strings (Section 3.8 discusses character strings). A character constant represents a single integer value; a string is a sequence of characters.

3.7.6 Assembly-Time Constants

If you use the .set directive to assign a value to a symbol (see Define Assembly-Time Constant), the symbol becomes a constant. To use this constant in expressions, the value that is assigned to it must be absolute. For example:

```
sym .set 3
MVK sym,B1
```

You can also use the .set directive to assign symbolic constants for register names. In this case, the symbol becomes a synonym for the register:

```
sym .set B1
MVK 10,sym
```
3.8 Character Strings

A character string is a string of characters enclosed in double quotes. Double quotes that are part of character strings are represented by two consecutive double quotes. The maximum length of a string varies and is defined for each directive that requires a character string. Characters are represented internally as 8-bit ASCII characters.

These are examples of valid character strings:

"sample program" defines the 14-character string sample program.
"PLAN "C"" defines the 8-character string PLAN "C".

Character strings are used for the following:

• Filenames, as in .copy "filename"
• Section names, as in .sect "section name"
• Data initialization directives, as in .byte "charstring"
• Operands of .string directives

3.9 Symbols

Symbols are used as labels, constants, and substitution symbols. A symbol name is a string of alphanumeric characters, the dollar sign, and underscores (A-Z, a-z, 0-9, $, and _). The first character in a symbol cannot be a number, and symbols cannot contain embedded blanks. The symbols you define are case sensitive; for example, the assembler recognizes ABC, Abc, and abc as three unique symbols. You can override case sensitivity with the --syms_ignore_case assembler option (see Section 3.3). A symbol is valid only during the assembly in which it is defined, unless you use the .global directive or the .def directive to declare it as an external symbol (see Identify Global Symbols).

3.9.1 Labels

Symbols used as labels become symbolic addresses that are associated with locations in the program. Labels used locally within a file must be unique. Mnemonic opcodes and assembler directive names without the . prefix are valid label names.

Labels can also be used as the operands of .global, .ref, .def, or .bss directives; for example:

```
.global label1
```

```
label2: MVKL label2, B3
MVKH label2, B3
B label1
NOP 5
```

3.9.2 Local Labels

Local labels are special labels whose scope and effect are temporary. A local label can be defined in two ways:

• $n, where n is a decimal digit in the range 0-9. For example, $4 and $1 are valid local labels. See Example 3-1.
• name?, where name is any legal symbol name as described above. The assembler replaces the question mark with a period followed by a unique number. When the source code is expanded, you will not see the unique number in the listing file. Your label appears with the question mark as it did in the source definition. You cannot declare this label as global. See Example 3-2.

Normal labels must be unique (they can be declared only once), and they can be used as constants in the operand field. Local labels, however, can be undefined and defined again. Local labels cannot be defined by directives.
A local label can be undefined or reset in one of these ways:

- By using the .newblock directive
- By changing sections (using a .sect, .text, or .data directive)
- By entering an include file (specified by the .include or .copy directive)
- By leaving an include file (specified by the .include or .copy directive)

**Example 3-1. Local Labels of the Form $n**

This is an example of code that declares and uses a local label legally:

```assembly
$1:
SUB A1,1,A1
[A1] B $1
SUBC A3,A0,A3
NOP 4

.newblock ; undefine $1 to use it again

$1 SUB A2,1,A2
[A2] B $1
MPY A3,A3,A3
NOP 4
```

The following code uses a local label illegally:

```assembly
$1:
SUB A1,1,A1
[A1] B $1
SUBC A3,A0,A3
NOP 4
$1 SUB A2,1,A2 ; WRONG - $1 is multiply defined
[A2] B $1
MPY A3,A3,A3
NOP 4
```

The $1 label is not undefined before being reused by the second branch instruction. Therefore, $1 is redefined, which is illegal.

Local labels are especially useful in macros. If a macro contains a normal label and is called more than once, the assembler issues a multiple-definition error. If you use a local label and .newblock within a macro, however, the local label is used and reset each time the macro is expanded.

Up to ten local labels of the $n form can be in effect at one time. Local labels of the form name? are not limited. After you undefine a local label, you can define it and use it again. Local labels do not appear in the object code symbol table.

Because local labels are intended to be used only locally, branches to local labels are not expanded in case the branch’s offset is out of range.
Example 3-2. Local Labels of the Form name?

**************************************************************************
** First definition of local label mylab                          **
**************************************************************************
nop
mylab?  nop
  B mylab?
  nop 5
**************************************************************************
** Include file has second definition of mylab                   **
**************************************************************************
.copy  "a.inc"
**************************************************************************
** Third definition of mylab, reset upon exit from .include     **
**************************************************************************
mylab?  nop
  B mylab?
  nop 5
**************************************************************************
** Fourth definition of mylab in macro, macros use different    **
** namespace to avoid conflicts                                 **
**************************************************************************
mymac  .macro
mylab?  nop
  B mylab?
  nop 5
  .ends
**************************************************************************
** Macro invocation                                            **
**************************************************************************
mymac
**************************************************************************
** Reference to third definition of mylab. Definition is not     **
** reset by macro invocation.                                  **
**************************************************************************
mylab?
  B mylab?
  nop 5
**************************************************************************
** Changing section, allowing fifth definition of mylab         **
**************************************************************************
.sect  "Sect_One"
nop
mylab?  .word 0
  nop
  B mylab?
  nop 5
**************************************************************************
** The .newblock directive allows sixth definition of mylab     **
**************************************************************************
.mynewblock
mylab?  .word 0
  nop
  B mylab?
  nop 5
**************************************************************************
3.9.3 Symbolic Constants

Symbols can be set to constant values. By using constants, you can equate meaningful names with constant values. The .set and .struct/.tag/.endstruct directives enable you to set constants to symbolic names. Symbolic constants cannot be redefined. The following example shows how these directives can be used:

```
K .set 1024 ; constant definitions
maxbuf .set 2*K

item .struct ; item structure definition
data .int ; value offset = 0
delta .int ; delta offset = 4
i_len .endstruct ; item size = 8

array .tag item
    .bss array, i_len*K ; declare an array of K "items"
    .text
    LDW *+B14(array.delta + 2*i_len),A1
    ; access array [2].delta
```

The assembler also has several predefined symbolic constants; these are discussed in Section 3.9.5.

3.9.4 Defining Symbolic Constants (--asm_define Option)

The --asm_define option equates a constant value or a string with a symbol. The symbol can then be used in place of a value in assembly source. The format of the --asm_define option is as follows:

```
c66x --asm_define= name [= value]
```

The name is the name of the symbol you want to define. The value is the constant or string value you want to assign to the symbol. If the value is omitted, the symbol 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 "value"`. For example, `--asm_define=car ="sedan"`
- For UNIX, use `--asm_define= name ="value"`. For example, `--asm_define=car ="sedan"
- For Code Composer, enter the definition in a file and include that file with the --cmd_file (or -@) option.

Once you have defined the name with the --asm_define option, the symbol can be used in place of a constant value, a well-defined expression, or an otherwise undefined symbol used with assembly directives and instructions. For example, on the command line you enter:

```
c66x --asm_define=SYM1=1 --asm_define=SYM2=2 --asm_define=SYM3=3 --asm_define=SYM4=4 value.asm
```

Since you have assigned values to SYM1, SYM2, SYM3, and SYM4, you can use them in source code. Example 3-3 shows how the value.asm file uses these symbols without defining them explicitly.

Within assembler source, you can test the symbol defined with the --asm_define option with the following directives:

```
Type of Test                Directive Usage
Existence                   .if $isdefined(" name ")
Nonexistence                .if $isdefined(" name ") = 0
Equal to value              .if name = value
Not equal to value          .if name ! = value
```

The argument to the $isdefined built-in function must be enclosed in quotes. The quotes cause the argument to be interpreted literally rather than as a substitution symbol.
Example 3-3. Using Symbolic Constants Defined on Command Line

```assembly
IF_4: if SYM4 = SYM2 * SYM2
    .byte SYM4        ; Equal values
    .else
    .byte SYM2 * SYM2 ; Unequal values
    .endif
IF_5: .if SYM1 <= 10
    .byte 10          ; Less than / equal
    .else
    .byte SYM1        ; Greater than
    .endif
IF_6: .if SYM3 * SYM2 != SYM4 + SYM2
    .byte SYM3 * SYM2 ; Unequal value
    .else
    .byte SYM4 + SYM4 ; Equal values
    .endif
IF_7: .if SYM1 = SYM2
    .byte SYM1
    .elseif SYM2 + SYM3 = 5
    .byte SYM2 + SYM3
    .endif
```

3.9.5 Predefined Symbolic Constants

The assembler has several predefined symbols, including the following types:

- $, the dollar-sign character, represents the current value of the section program counter (SPC). $ is a relocatable symbol.
- **Register symbols**, including A0-A15 and B0-B15; and A16-31 and B16-31 for C6400 and C6400+.
- **CPU control registers**, including those listed in Table 3-2. Control registers can be entered as all upper-case or all lower-case characters; for example, CSR can also be entered as csr.
- **Processor symbols**, including those listed in Table 3-3.

### Table 3-2. CPU Control Registers

<table>
<thead>
<tr>
<th>Register</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>AMR</td>
<td>Addressing mode register</td>
</tr>
<tr>
<td>CSR</td>
<td>Control status register</td>
</tr>
<tr>
<td>DESR</td>
<td>(C6700+ only) dMAX event status register</td>
</tr>
<tr>
<td>DETR</td>
<td>(C6700+ only) dMAX event trigger register</td>
</tr>
<tr>
<td>DNUM</td>
<td>(C6400+ only) DSP core number register</td>
</tr>
<tr>
<td>ECR</td>
<td>(C6400+ only) Exception clear register</td>
</tr>
<tr>
<td>EFR</td>
<td>(C6400+ only) Exception flag register</td>
</tr>
<tr>
<td>FADCR</td>
<td>(C6700 only) Floating-point adder configuration register</td>
</tr>
<tr>
<td>FAUCR</td>
<td>(C6700 only) Floating-point auxiliary configuration register</td>
</tr>
<tr>
<td>FMCR</td>
<td>(C6700 only) Floating-point multiplier configuration register</td>
</tr>
<tr>
<td>GFPGFR</td>
<td>(C6400 only) Galois field polynomial generator function register</td>
</tr>
<tr>
<td>GPLYA</td>
<td>(C6400+ only) GMPY A-side polynomial register</td>
</tr>
<tr>
<td>GPLYB</td>
<td>(C6400+ only) GMPY B-side polynomial register</td>
</tr>
<tr>
<td>ICR</td>
<td>Interrupt clear register</td>
</tr>
<tr>
<td>IER</td>
<td>Interrupt enable register</td>
</tr>
<tr>
<td>IERR</td>
<td>(C6400+ only) Interrupt exception report register</td>
</tr>
<tr>
<td>IFR</td>
<td>Interrupt flag register</td>
</tr>
<tr>
<td>ILC</td>
<td>(C6400+ only) Inner loop count register</td>
</tr>
</tbody>
</table>
Table 3-2. CPU Control Registers  (continued)

<table>
<thead>
<tr>
<th>Register</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>NRP</td>
<td>Nonmaskable interrupt return pointer</td>
</tr>
<tr>
<td>IRP</td>
<td>Interrupt return pointer</td>
</tr>
<tr>
<td>ISR</td>
<td>Interrupt set register</td>
</tr>
<tr>
<td>TSR</td>
<td>(C6400+ only) Task status register</td>
</tr>
<tr>
<td>TSCH</td>
<td>(C6400+ only) Time-stamp counter (high 32) register</td>
</tr>
<tr>
<td>TSCL</td>
<td>(C6400+ only) Time-stamp counter (low 32) register</td>
</tr>
<tr>
<td>TPR</td>
<td>(C6400+ only) Task priority register</td>
</tr>
</tbody>
</table>

Table 3-3. Processor Symbols

<table>
<thead>
<tr>
<th>Symbol name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>TI_EABI</em></td>
<td>Set to 1 if EABI is enabled (see Section 3.4); otherwise, it is set to 0</td>
</tr>
<tr>
<td>.TMS320C6X</td>
<td>Always set to 1</td>
</tr>
<tr>
<td>.TMS320C6200</td>
<td>Set to 1 for C6200, otherwise 0</td>
</tr>
<tr>
<td>.TMS320C6400</td>
<td>Set to 1 for C6400 and C6400+, otherwise 0</td>
</tr>
<tr>
<td>.TMS320C6400_PLUS</td>
<td>Set to 1 for C6400+, otherwise 0</td>
</tr>
<tr>
<td>.TMS320C6700</td>
<td>Set to 1 for C6700 and C6700+, otherwise 0</td>
</tr>
<tr>
<td>.TMS320C6700_PLUS</td>
<td>Set to 1 for C6700+, otherwise 0</td>
</tr>
<tr>
<td>.LITTLE_ENDIAN</td>
<td>Set to 1 if little-endian mode is selected (the -me assembler option is not used); otherwise 0</td>
</tr>
<tr>
<td>.BIG_ENDIAN</td>
<td>Set to 1 if big-endian mode is selected (the -me assembler option is used); otherwise 0</td>
</tr>
<tr>
<td>.SMALL_MODEL</td>
<td>Set to 1 if --memory_model:code=near and --memory_model:data=near, otherwise 0.</td>
</tr>
<tr>
<td>.LARGE_MODEL</td>
<td>Set to 1 if .SMALL_MODEL is 0, otherwise 0.</td>
</tr>
</tbody>
</table>

3.9.6 Substitution Symbols

Symbols can be assigned a string value (variable). This enables you to alias character strings by equating them to symbolic names. Symbols that represent character strings are called substitution symbols. When the assembler encounters a substitution symbol, its string value is substituted for the symbol name. Unlike symbolic constants, substitution symbols can be redefined.

A string can be assigned to a substitution symbol anywhere within a program; for example:

```
.globl _table
.asg "B14", PAGEPTR
.asg "**B15(4)" , LOCAL1
.asg "**B15(8)" , LOCAL2

LDW  "+PAGEPTR(_table), A0
NOP  4
STW  A0, LOCAL1
```
When you are using macros, substitution symbols are important because macro parameters are actually substitution symbols that are assigned a macro argument. The following code shows how substitution symbols are used in macros:

```
MAC .macro src1, src2, dst ; Multiply/Accumulate macro
  MPY src1, src2, src2
  NOP
  ADD src2, dst, dst
.endm

* MAC macro invocation
MAC A0,A1,A2
```

See Chapter 5 for more information about macros.

### 3.10 Expressions

An expression is a constant, a symbol, or a series of constants and symbols separated by arithmetic operators. The 32-bit ranges of valid expression values are -2147 483 648 to 2147 483 647 for signed values, and 0 to 4 294 967 295 for unsigned values. Three main factors influence the order of expression evaluation:

#### Parentheses
Expressions enclosed in parentheses are always evaluated first.

```
8 / (4 / 2) = 4, but 8 / 4 / 2 = 1
```

You **cannot** substitute braces ( `{ }` ) or brackets ( `[ ]` ) for parentheses.

#### Precedence groups
Operators, listed in Table 3-4, are divided into nine precedence groups. When parentheses do not determine the order of expression evaluation, the highest precedence operation is evaluated first.

```
8 + 4 / 2 = 10 (4 / 2 is evaluated first)
```

#### Left-to-right evaluation
When parentheses and precedence groups do not determine the order of expression evaluation, the expressions are evaluated from left to right, except for Group 1, which is evaluated from right to left.

```
8 / 4*2 = 4, but 8 / (4*2) = 1
```

### 3.10.1 Operators

Table 3-4 lists the operators that can be used in expressions, according to precedence group.

<table>
<thead>
<tr>
<th>Group</th>
<th>Operator</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>+</td>
<td>Unary plus</td>
</tr>
<tr>
<td></td>
<td>-</td>
<td>Unary minus</td>
</tr>
<tr>
<td></td>
<td>~</td>
<td>1s complement</td>
</tr>
<tr>
<td></td>
<td>!</td>
<td>Logical NOT</td>
</tr>
<tr>
<td>2</td>
<td>*</td>
<td>Multiplication</td>
</tr>
<tr>
<td></td>
<td>/</td>
<td>Division</td>
</tr>
<tr>
<td></td>
<td>%</td>
<td>Modulo</td>
</tr>
<tr>
<td>3</td>
<td>+</td>
<td>Addition</td>
</tr>
<tr>
<td></td>
<td>-</td>
<td>Subtraction</td>
</tr>
<tr>
<td>4</td>
<td>&lt;&lt;</td>
<td>Shift left</td>
</tr>
<tr>
<td></td>
<td>&gt;&gt;</td>
<td>Shift right</td>
</tr>
<tr>
<td>5</td>
<td>&lt;</td>
<td>Less than</td>
</tr>
<tr>
<td></td>
<td>&lt;=</td>
<td>Less than or equal to</td>
</tr>
<tr>
<td></td>
<td>&gt;</td>
<td>Greater than</td>
</tr>
<tr>
<td></td>
<td>&gt;=</td>
<td>Greater than or equal to</td>
</tr>
<tr>
<td>6</td>
<td>=</td>
<td>Equal to</td>
</tr>
<tr>
<td></td>
<td>!=</td>
<td>Not equal to</td>
</tr>
<tr>
<td>7</td>
<td>&amp;</td>
<td>Bitwise AND</td>
</tr>
</tbody>
</table>

(1) Group 1 operators are evaluated right to left. All other operators are evaluated left to right.
(2) Unary + and - have higher precedence than the binary forms.
### Table 3-4. Operators Used in Expressions (Precedence) (continued)

<table>
<thead>
<tr>
<th>Group</th>
<th>Operator</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
<td>^</td>
<td>Bitwise exclusive OR (XOR)</td>
</tr>
<tr>
<td>9</td>
<td></td>
<td>Bitwise OR</td>
</tr>
</tbody>
</table>

### 3.10.2 Expression Overflow and Underflow

The assembler checks for overflow and underflow conditions when arithmetic operations are performed at assembly time. It issues a warning (the message *Value Truncated*) whenever an overflow or underflow occurs. The assembler does not check for overflow or underflow in multiplication.

### 3.10.3 Well-Defined Expressions

Some assembler directives require well-defined expressions as operands. Well-defined expressions contain only symbols or assembly-time constants that are defined before they are encountered in the expression. The evaluation of a well-defined expression must be absolute.

This is an example of a well-defined expression:

```
1000h+X
```

where X was previously defined as an absolute symbol.

### 3.10.4 Conditional Expressions

The assembler supports relational operators that can be used in any expression; they are especially useful for conditional assembly. Relational operators include the following:

- `=` Equal to
- `!=` Not equal to
- `<` Less than
- `<=` Less than or equal to
- `>` Greater than
- `>=` Greater than or equal to

Conditional expressions evaluate to 1 if true and 0 if false and can be used only on operands of equivalent types; for example, absolute value compared to absolute value, but not absolute value compared to relocatable value.

### 3.10.5 Legal Expressions

With the exception of the following expression contexts, there is no restriction on combinations of operations, constants, internally defined symbols, and externally defined symbols.

When an expression contains more than one relocatable symbol or cannot be evaluated at assembly time, the assembler encodes a relocation expression in the object file that is later evaluated by the linker. If the final value of the expression is larger in bits than the space reserved for it, you receive an error message from the linker. See Section 2.4 for more information on relocation expressions.

- When using the register relative addressing mode, the expression in brackets or parenthesis must be a well-defined expression, as described in Section 3.10.3. For example:
  ```
  *+A4[15]
  ```
- Expressions used to describe the offset in register relative addressing mode for the registers B14 and B15, or expressions used as the operand to the branch instruction, are subject to the same limitations. For these two cases, all legal expressions can be reduced to one of two forms:
  ```
  *XA4[7]
  ```
  ```
  relocatable symbol ± absolute symbol
  ```
  or
  ```
  a well-defined expression
  ```
  ```
  B (extern_1=10)
  ```
  ```
  *+B14/B15[14]
  ```

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Expressions

3.10.6 Expression Examples

Following are examples of expressions that use relocatable and absolute symbols. These examples use four symbols that are defined in the same section:

- **.global extern_1** ; Defined in an external module
- **intern_1**: .word "D" ; Relocatable, defined in current module
- **intern_2** ; Relocatable, defined in current module
- **intern_3** ; Relocatable, defined in current module

- **Example 1**
  In these contexts, there are no limitations on how expressions can be formed.
  ```
  .word extern_1 * intern_2 - 13 ; Legal
  MVKL (intern_1 - extern_1),A1 ; Legal
  ```

- **Example 2**
  The first statement in the following example is valid; the statements that follow it are invalid.
  ```
  B (extern_1 - 10) ; Legal
  B (10-extern_1) ; Can't negate reloc. symbol
  LDW *+B14 -(intern_1), A1 ; Can't negate reloc. symbol
  LDW *+B14 (extern_1/10), A1 ; / not an additive operator
  B (intern_1 + extern_1) ; Multiple relocatables
  ```

- **Example 3**
  The first statement below is legal; although intern_1 and intern_2 are relocatable, their difference is absolute because they are in the same section. Subtracting one relocatable symbol from another reduces the expression to **relocatable symbol + absolute value**. The second statement is illegal because the sum of two relocatable symbols is not an absolute value.
  ```
  B (intern_1 - intern_2 + extern_3) ; Legal
  B (intern_1 + intern_2 + extern_3) ; Illegal
  ```

- **Example 4**
  A relocatable symbol's placement in the expression is important to expression evaluation. Although the statement below is similar to the first statement in the previous example, it is illegal because of left-to-right operator precedence; the assembler attempts to add intern_1 to extern_3.
  ```
  B (intern_1 + extern_3 - intern_2) ; Illegal
  ```
3.11 Source Listings

A source listing shows source statements and the object code they produce. To obtain a listing file, invoke the assembler with the --asm_listing option (see Section 3.3).

Two banner lines, a blank line, and a title line are at the top of each source listing page. Any title supplied by the .title directive is printed on the title line. A page number is printed to the right of the title. If you do not use the .title directive, the name of the source file is printed. The assembler inserts a blank line below the title line.

Each line in the source file produces at least one line in the listing file. This line shows a source statement number, an SPC value, the object code assembled, and the source statement. Show these in actual listing files.

Each line in the source file produces at least one line in the listing file. This line shows a source statement number, an SPC value, the object code assembled, and the source statement. Figure 3-2 shows these in an actual listing file.

Field 1: Source Statement Number
- Line number
  The source statement number is a decimal number. The assembler numbers source lines as it encounters them in the source file; some statements increment the line counter but are not listed. (For example, .title statements and statements following a .nolist are not listed.) The difference between two consecutive source line numbers indicates the number of intervening statements in the source file that are not listed.
- Include file letter
  A letter preceding the line number indicates the line is assembled from the include file designated by the letter.
- Nesting level number
  A number preceding the line number indicates the nesting level of macro expansions or loop blocks.

Field 2: Section Program Counter
- This field contains the SPC value, which is hexadecimal. All sections (.text, .data, .bss, and named sections) maintain separate SPCs. Some directives do not affect the SPC and leave this field blank.

Field 3: Object Code
- This field contains the hexadecimal representation of the object code. All machine instructions and directives use this field to list object code. This field also indicates the relocation type associated with an operand for this line of source code. If more than one operand is relocatable, this column indicates the relocation type for the first operand. The characters that can appear in this column and their associated relocation types are listed below:

! undefined external reference
' .text relocatable
+ .sect relocatable
" .data relocatable
- .bss, .usect relocatable
% relocation expression

Field 4: Source Statement Field
- This field contains the characters of the source statement as they were scanned by the assembler. The assembler accepts a maximum line length of 200 characters. Spacing in this field is determined by the spacing in the source statement.

Figure 3-2 shows an assembler listing with each of the four fields identified.
3.12 Debugging Assembly Source

When you invoke cl6x with --symdebug:dwarf (or -g) when compiling an assembly file, the assembler provides symbolic debugging information that allows you to step through your assembly code in a debugger rather than using the Disassembly window in Code Composer Studio. This enables you to view source comments and other source-code annotations while debugging.

The .asmfunc and .endasmfunc (see Mark Function Boundaries) directives enable you to use C characteristics in assembly code that makes the process of debugging an assembly file more closely resemble debugging a C/C++ source file.

The .asmfunc and .endasmfunc directives allow you to name certain areas of your code, and make these areas appear in the debugger as C functions. Contiguous sections of assembly code that are not enclosed by the .asmfunc and .endasmfunc directives are automatically placed in assembler-defined functions named with this syntax:

\[ \$ \text{filename} : \text{starting source line} : \text{ending source line} \$ \]

If you want to view your variables as a user-defined type in C code, the types must be declared and the variables must be defined in a C file. This C file can then be referenced in assembly code using the .ref directive (see Identify Global Symbols).

Example 3-4 shows the cvar.c C program that defines a variable, svar, as the structure type X. The svar variable is then referenced in the addfive.asm assembly program in Example 3-5 and 5 is added to svar's second data member.

Compile both source files with the --symdebug:dwarf option (-g) and link them as follows:

\[ \text{cl6x --symdebug:dwarf cvars.c addfive.asm --run_linker --library=lnk.cmd --library=rts6200.lib} \]
\[ \text{--output_file=addfive.out} \]

When you load this program into a symbolic debugger, addfive appears as a C function. You can monitor the values in svar while stepping through main just as you would any regular C variable.

Example 3-4. Viewing Assembly Variables as C Types C Program

```c
typedef struct
{
    int m1;
    int m2;
} X;

X svar = { 1, 2 };
```

Example 3-5. Assembly Program for Example 3-4

```assembly
; Tell the assembler we're referencing variable "_svar", which is defined in
; another file (cvars.c).
;---------------------------------------------------------------
;ref _svar
;---------------------------------------------------------------
:addfive() - Add five to the second data member of _svar
;---------------------------------------------------------------
.text
.global addfive
addfive: .asmfunc
    LDW .D2T2 *+B14(_svar+4),B4 ; load svar.m2 into B4
    RET .S2 B3 ; return from function
    NOP 3 ; delay slots 1-3
    ADD .D2 5,B4,B4 ; add 5 to B4 (delay slot 4)
    STW .D2T2 B4,**+B14(_svar+4) ; store B4 back into svar.m2
            ; (delay slot 5)
.endasmfunc
```
3.13 Cross-Reference Listings

A cross-reference listing shows symbols and their definitions. To obtain a cross-reference listing, invoke the assembler with the --cross_reference option (see Section 3.3) or use the .option directive with the X operand (see Select Listing Options). The assembler appends the cross-reference to the end of the source listing. Example 3-6 shows the four fields contained in the cross-reference listing.

Example 3-6. An Assembler Cross-Reference Listing

<table>
<thead>
<tr>
<th>LABEL</th>
<th>VALUE</th>
<th>DEFN</th>
<th>REF</th>
</tr>
</thead>
<tbody>
<tr>
<td>.BIG_ENDIAN</td>
<td>00000000</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>.LITTLE_ENDIAN</td>
<td>00000001</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>.TMS320C6200</td>
<td>00000001</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>.TMS320C6700</td>
<td>00000000</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>.TMS320C6X</td>
<td>00000001</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>_func</td>
<td>00000000'</td>
<td>18</td>
<td></td>
</tr>
<tr>
<td>var1</td>
<td>00000000-</td>
<td>4</td>
<td>17</td>
</tr>
<tr>
<td>var2</td>
<td>00000004-</td>
<td>5</td>
<td>18</td>
</tr>
</tbody>
</table>

Label column contains each symbol that was defined or referenced during the assembly. Value column contains an 8-digit hexadecimal number (which is the value assigned to the symbol) or a name that describes the symbol's attributes. A value may also be preceded by a character that describes the symbol's attributes. Table 3-5 lists these characters and names.

Definition (DEFN) column contains the statement number that defines the symbol. This column is blank for undefined symbols.

Reference (REF) column lists the line numbers of statements that reference the symbol. A blank in this column indicates that the symbol was never used.

Table 3-5. Symbol Attributes

<table>
<thead>
<tr>
<th>Character or Name</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>REF</td>
<td>External reference (global symbol)</td>
</tr>
<tr>
<td>UNDF</td>
<td>Undefined</td>
</tr>
<tr>
<td>'</td>
<td>Symbol defined in a .text section</td>
</tr>
<tr>
<td>*</td>
<td>Symbol defined in a .data section</td>
</tr>
<tr>
<td>+</td>
<td>Symbol defined in a .sect section</td>
</tr>
<tr>
<td>-</td>
<td>Symbol defined in a .bss or .usect section</td>
</tr>
</tbody>
</table>

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Assembler directives supply data to the program and control the assembly process. Assembler directives enable you to do the following:

- Assemble code and data into specified sections
- Reserve space in memory for uninitialized variables
- Control the appearance of listings
- Initialize memory
- Assemble conditional blocks
- Define global variables
- Specify libraries from which the assembler can obtain macros
- Examine symbolic debugging information

This chapter is divided into two parts: the first part (Section 4.1 through Section 4.11) describes the directives according to function, and the second part (Section 4.12) is an alphabetical reference.

<table>
<thead>
<tr>
<th>Topic</th>
<th>Page</th>
</tr>
</thead>
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</tr>
<tr>
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<td>64</td>
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<td>67</td>
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<td>70</td>
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<td>70</td>
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<tr>
<td>4.10 Directives That Define Symbols at Assembly Time</td>
<td>71</td>
</tr>
<tr>
<td>4.11 Miscellaneous Directives</td>
<td>72</td>
</tr>
<tr>
<td>4.12 Directives Reference</td>
<td>73</td>
</tr>
</tbody>
</table>
4.1 Directives Summary

Table 4-1 through Table 4-16 summarize the assembler directives.

Besides the assembler directives documented here, the TMS320C6000™ software tools support the following directives:

- The assembler uses several directives for macros. Macro directives are discussed in Chapter 5; they are not discussed in this chapter.
- The assembly optimizer uses several directives that supply data and control the optimization process. Assembly optimizer directives are discussed in the TMS320C6000 Optimizing Compiler User's Guide.
- The C compiler uses directives for symbolic debugging. Unlike other directives, symbolic debugging directives are not used in most assembly language programs. Discusses these directives; they are not discussed in this chapter.

Labels and Comments Are Not Shown in Syntaxes

NOTE: Any source statement that contains a directive can also contain a label and a comment. Labels begin in the first column (only labels and comments can appear in the first column), and comments must be preceded by a semicolon, or an asterisk if the comment is the only element in the line. To improve readability, labels and comments are not shown as part of the directive syntax.

Table 4-1. Directives That Define Sections

<table>
<thead>
<tr>
<th>Mnemonic and Syntax</th>
<th>Description</th>
<th>See</th>
</tr>
</thead>
<tbody>
<tr>
<td>.bss symbol, size in bytes[ip alignment]</td>
<td>Reserves size bytes in the .bss (uninitialized data) section</td>
<td>.bss topic</td>
</tr>
<tr>
<td>.clink</td>
<td>Enables conditional linking for the current or specified section</td>
<td>.clink topic</td>
</tr>
<tr>
<td>.data</td>
<td>Assembles into the .data (initialized data) section</td>
<td>.data topic</td>
</tr>
<tr>
<td>.sect &quot;section name&quot;</td>
<td>Assembles into a named (initialized) section</td>
<td>.sect topic</td>
</tr>
<tr>
<td>.text</td>
<td>Assembles into the .text (executable code) section</td>
<td>.text topic</td>
</tr>
<tr>
<td>symbol .usect &quot;section name&quot;, size in bytes[ip alignment, bank offset]</td>
<td>Reserves size bytes in a named (uninitialized) section</td>
<td>.usect topic</td>
</tr>
</tbody>
</table>

Table 4-2. Directives That Initialize Values (Data and Memory)

<table>
<thead>
<tr>
<th>Mnemonic and Syntax</th>
<th>Description</th>
<th>See</th>
</tr>
</thead>
<tbody>
<tr>
<td>.byte value[, ..., value]</td>
<td>Initializes one or more successive bytes in the current section</td>
<td>.byte topic</td>
</tr>
<tr>
<td>.char value[, ..., value]</td>
<td>Initializes one or more successive bytes in the current section</td>
<td>.char topic</td>
</tr>
<tr>
<td>.cstring [expr,&quot;string&quot;,&quot;[... , {expr,&quot;string,&quot;}]&quot;]</td>
<td>Initializes one or more text strings</td>
<td>.cstring topic</td>
</tr>
<tr>
<td>.double value[, ..., value]</td>
<td>Initializes one or more 64-bit, IEEE double-precision, floating-point constants</td>
<td>.double topic</td>
</tr>
<tr>
<td>.field value[size]</td>
<td>Initializes a field of size bits (1-32) with value</td>
<td>.field topic</td>
</tr>
<tr>
<td>.float value[, ..., value]</td>
<td>Initializes one or more 32-bit, IEEE single-precision, floating-point constants</td>
<td>.float topic</td>
</tr>
<tr>
<td>.half value[, ..., value]</td>
<td>Initializes one or more 16-bit integers (halfword)</td>
<td>.half topic</td>
</tr>
<tr>
<td>.int value[, ..., value]</td>
<td>Initializes one or more 32-bit integers</td>
<td>.int topic</td>
</tr>
<tr>
<td>.long value[, ..., value]</td>
<td>Initializes one or more 32-bit integers</td>
<td>.long topic</td>
</tr>
<tr>
<td>.short value[, ..., value]</td>
<td>Initializes one or more 16-bit integers (halfword)</td>
<td>.short topic</td>
</tr>
<tr>
<td>.string [expr,&quot;string&quot;,&quot;[... , {expr,&quot;string,&quot;}]&quot;]</td>
<td>Initializes one or more text strings</td>
<td>.string topic</td>
</tr>
<tr>
<td>.ubyte value[, ..., value]</td>
<td>Initializes one or more successive unsigned bytes in the current section</td>
<td>.ubyte topic</td>
</tr>
<tr>
<td>.uhalf value[, ..., value]</td>
<td>Initializes one or more unsigned 16-bit integers (halfword)</td>
<td>.uhalf topic</td>
</tr>
<tr>
<td>.uint value[, ..., value]</td>
<td>Initializes one or more unsigned 32-bit integers</td>
<td>.uint topic</td>
</tr>
<tr>
<td>.ushort value[, ..., value]</td>
<td>Initializes one or more unsigned 16-bit integers (halfword)</td>
<td>.ushort topic</td>
</tr>
<tr>
<td>.uword value[, ..., value]</td>
<td>Initializes one or more unsigned 32-bit integers</td>
<td>.uword topic</td>
</tr>
</tbody>
</table>
Table 4-2. Directives That Initialize Values (Data and Memory) (continued)

<table>
<thead>
<tr>
<th>Mnemonic and Syntax</th>
<th>Description</th>
<th>See</th>
</tr>
</thead>
<tbody>
<tr>
<td>.word {value, ..., value}</td>
<td>Initializes one or more 32-bit integers</td>
<td>.word topic</td>
</tr>
</tbody>
</table>

Table 4-3. Directives That Perform Alignment and Reserve Space

<table>
<thead>
<tr>
<th>Mnemonic and Syntax</th>
<th>Description</th>
<th>See</th>
</tr>
</thead>
<tbody>
<tr>
<td>.align {size in bytes}</td>
<td>Aligns the SPC on a boundary specified by size in bytes, which must be a power of 2; defaults to byte boundary</td>
<td>.align topic</td>
</tr>
<tr>
<td>.bes size</td>
<td>Reserves size bytes in the current section; a label points to the end of the reserved space</td>
<td>.bes topic</td>
</tr>
<tr>
<td>.space size</td>
<td>Reserves size bytes in the current section; a label points to the beginning of the reserved space</td>
<td>.space topic</td>
</tr>
</tbody>
</table>

Table 4-4. Directives That Format the Output Listing

<table>
<thead>
<tr>
<th>Mnemonic and Syntax</th>
<th>Description</th>
<th>See</th>
</tr>
</thead>
<tbody>
<tr>
<td>.drlist</td>
<td>Enables listing of all directive lines (default)</td>
<td>.drlist topic</td>
</tr>
<tr>
<td>.drnolist</td>
<td>Suppresses listing of certain directive lines</td>
<td>.drnolist topic</td>
</tr>
<tr>
<td>.fclist</td>
<td>Allows false conditional code block listing (default)</td>
<td>.fclist topic</td>
</tr>
<tr>
<td>.fcnolist</td>
<td>Suppresses false conditional code block listing</td>
<td>.fcnolist topic</td>
</tr>
<tr>
<td>.length {page length}</td>
<td>Sets the page length of the source listing</td>
<td>.length topic</td>
</tr>
<tr>
<td>.list</td>
<td>Restarts the source listing</td>
<td>.list topic</td>
</tr>
<tr>
<td>.mlist</td>
<td>Allows macro listings and loop blocks (default)</td>
<td>.mlist topic</td>
</tr>
<tr>
<td>.mnolist</td>
<td>Suppresses macro listings and loop blocks</td>
<td>.mnolist topic</td>
</tr>
<tr>
<td>.nolist</td>
<td>Stops the source listing</td>
<td>.nolist topic</td>
</tr>
<tr>
<td>.option option1, ..., optionn</td>
<td>Selects output listing options; available options are A, B, D, H, L, M, N, O, R, T, W, and X</td>
<td>.option topic</td>
</tr>
<tr>
<td>.page</td>
<td>Ejects a page in the source listing</td>
<td>.page topic</td>
</tr>
<tr>
<td>.sslist</td>
<td>Allows expanded substitution symbol listing</td>
<td>.sslist topic</td>
</tr>
<tr>
<td>.ssnolist</td>
<td>Suppresses expanded substitution symbol listing (default)</td>
<td>.ssnolist topic</td>
</tr>
<tr>
<td>.tab size</td>
<td>Sets tab to size characters</td>
<td>.tab topic</td>
</tr>
<tr>
<td>.title &quot;string&quot;</td>
<td>Prints a title in the listing page heading</td>
<td>.title topic</td>
</tr>
<tr>
<td>.width page width</td>
<td>Sets the page width of the source listing</td>
<td>.width topic</td>
</tr>
</tbody>
</table>

Table 4-5. Directives That Reference Other Files

<table>
<thead>
<tr>
<th>Mnemonic and Syntax</th>
<th>Description</th>
<th>See</th>
</tr>
</thead>
<tbody>
<tr>
<td>.copy &quot;filename&quot;</td>
<td>Includes source statements from another file</td>
<td>.copy topic</td>
</tr>
<tr>
<td>.include &quot;filename&quot;</td>
<td>Includes source statements from another file</td>
<td>.include topic</td>
</tr>
<tr>
<td>.mlib &quot;filename&quot;</td>
<td>Specifies a macro library from which to retrieve macro definitions</td>
<td>.mlib topic</td>
</tr>
</tbody>
</table>
### Table 4-6. Directives That Effect Symbol Linkage and Visibility

<table>
<thead>
<tr>
<th>Mnemonic and Syntax</th>
<th>Description</th>
<th>See</th>
</tr>
</thead>
<tbody>
<tr>
<td>.def symbol[, ... , symbol]</td>
<td>Identifies one or more symbols that are defined in the current module and that can be used in other modules</td>
<td>.def topic</td>
</tr>
<tr>
<td>.global symbol[, ... , symbol]</td>
<td>Identifies one or more global (external) symbols</td>
<td>.global topic</td>
</tr>
<tr>
<td>.ref symbol[, ... , symbol]</td>
<td>Identifies one or more symbols used in the current module that are defined in another module</td>
<td>.ref topic</td>
</tr>
<tr>
<td>.symdepend dst symbol name[, src symbol name]</td>
<td>Creates an artificial reference from a section to a symbol</td>
<td>.symdepend topic</td>
</tr>
<tr>
<td>.weak symbol name</td>
<td>Identifies a symbol used in the current module that is defined in another module</td>
<td>.weak topic</td>
</tr>
</tbody>
</table>

### Table 4-7. Directives That Control Dynamic Symbol Visibility

<table>
<thead>
<tr>
<th>Mnemonic and Syntax</th>
<th>Description</th>
<th>See</th>
</tr>
</thead>
<tbody>
<tr>
<td>.export &quot;symbolname&quot;</td>
<td>Sets visibility of symbolname to STV_EXPORT</td>
<td>.export topic</td>
</tr>
<tr>
<td>.hidden &quot;symbolname&quot;</td>
<td>Sets visibility of symbolname to STV_HIDDEN</td>
<td>.hidden topic</td>
</tr>
<tr>
<td>.import &quot;symbolname&quot;</td>
<td>Sets visibility of symbolname to STV_IMPORT</td>
<td>.import topic</td>
</tr>
<tr>
<td>.protected &quot;symbolname&quot;</td>
<td>Sets visibility of symbolname to STV_PROTECTED</td>
<td>.protected topic</td>
</tr>
</tbody>
</table>

### Table 4-8. Directives That Enable Conditional Assembly

<table>
<thead>
<tr>
<th>Mnemonic and Syntax</th>
<th>Description</th>
<th>See</th>
</tr>
</thead>
<tbody>
<tr>
<td>.break [well-defined expression]</td>
<td>Ends .loop assembly if well-defined expression is true. When using the .loop construct, the .break construct is optional.</td>
<td>.break topic</td>
</tr>
<tr>
<td>.else</td>
<td>Assembles code block if the .if well-defined expression is false. When using the .if construct, the .else construct is optional.</td>
<td>.else topic</td>
</tr>
<tr>
<td>.elseif well-defined expression</td>
<td>Assembles code block if the .if well-defined expression is false and the .elseif condition is true. When using the .if construct, the .elseif construct is optional.</td>
<td>.elseif topic</td>
</tr>
<tr>
<td>.endif</td>
<td>Ends .if code block</td>
<td>.endif topic</td>
</tr>
<tr>
<td>.endloop</td>
<td>Ends .loop code block</td>
<td>.endloop topic</td>
</tr>
<tr>
<td>.if well-defined expression</td>
<td>Assembles code block if the well-defined expression is true</td>
<td>.if topic</td>
</tr>
<tr>
<td>.loop [well-defined expression]</td>
<td>Begins repeatable assembly of a code block; the loop count is determined by the well-defined expression.</td>
<td>.loop topic</td>
</tr>
</tbody>
</table>

### Table 4-9. Directives That Define Union or Structure Types

<table>
<thead>
<tr>
<th>Mnemonic and Syntax</th>
<th>Description</th>
<th>See</th>
</tr>
</thead>
<tbody>
<tr>
<td>.cstruct</td>
<td>Acts like .struct, but adds padding and alignment like that which is done to C structures</td>
<td>.cstruct topic</td>
</tr>
<tr>
<td>.cunion</td>
<td>Acts like .union, but adds padding and alignment like that which is done to C unions</td>
<td>.cstruct/.cunion</td>
</tr>
<tr>
<td>.emember</td>
<td>Sets up C-like enumerated types in assembly code</td>
<td>Section 4.9</td>
</tr>
<tr>
<td>.endenum</td>
<td>Sets up C-like enumerated types in assembly code</td>
<td>Section 4.9</td>
</tr>
<tr>
<td>.endstruct</td>
<td>Ends a structure definition</td>
<td>.cstruct/.cunion, .struct topic</td>
</tr>
<tr>
<td>.endunion</td>
<td>Ends a union definition</td>
<td>.cstruct/.cunion, .union topic</td>
</tr>
<tr>
<td>.enum</td>
<td>Sets up C-like enumerated types in assembly code</td>
<td>Section 4.9</td>
</tr>
<tr>
<td>.union</td>
<td>Begins a union definition</td>
<td>.union topic</td>
</tr>
<tr>
<td>.struct</td>
<td>Begins structure definition</td>
<td>.struct topic</td>
</tr>
<tr>
<td>.tag</td>
<td>Assigns structure attributes to a label</td>
<td>.cstruct/.cunion topic, .struct .union topic</td>
</tr>
</tbody>
</table>
### Table 4-10. Directives That Define Symbols at Assembly Time

<table>
<thead>
<tr>
<th>Mnemonic and Syntax</th>
<th>Description</th>
<th>See</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>.asg [&quot;character string&quot;], substitution symbol</code></td>
<td>Assigns a character string to substitution symbol</td>
<td><code>.asg topic</code></td>
</tr>
<tr>
<td><code>.clearmap</code></td>
<td>Cancels all .map assignments. Used by compiler for linear assembly source.</td>
<td><code>.clearmap topic</code></td>
</tr>
<tr>
<td><code>symbol .equ value</code></td>
<td>Equates value with symbol</td>
<td><code>.equ topic</code></td>
</tr>
<tr>
<td><code>.eval well-defined expression , substitution symbol</code></td>
<td>Performs arithmetic on a numeric substitution symbol</td>
<td><code>.eval topic</code></td>
</tr>
<tr>
<td><code>.label symbol</code></td>
<td>Defines a load-time relocatable label in a section</td>
<td><code>.label topic</code></td>
</tr>
<tr>
<td><code>.mapsymbol/register</code></td>
<td>Assigns symbol to register. Used by compiler for linear assembly source.</td>
<td><code>.map topic</code></td>
</tr>
<tr>
<td><code>.newblock</code></td>
<td>Undefines local labels</td>
<td><code>.newblock topic</code></td>
</tr>
<tr>
<td><code>symbol .set value</code></td>
<td>Equates value with symbol</td>
<td><code>.set topic</code></td>
</tr>
<tr>
<td><code>.unasg symbol</code></td>
<td>Turns off assignment of symbol as a substitution symbol</td>
<td><code>.unasg topic</code></td>
</tr>
<tr>
<td><code>.undefine symbol</code></td>
<td>Turns off assignment of symbol as a substitution symbol</td>
<td><code>.unasg topic</code></td>
</tr>
</tbody>
</table>

### Table 4-11. Directives That Define Common Data Sections

<table>
<thead>
<tr>
<th>Mnemonic and Syntax</th>
<th>Description</th>
<th>See</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>.endgroup</code></td>
<td>Ends the group declaration</td>
<td><code>.endgroup topic</code></td>
</tr>
<tr>
<td><code>.gmember section name</code></td>
<td>Designates section name as a member of the group</td>
<td><code>.gmember topic</code></td>
</tr>
<tr>
<td><code>.group group section name group type</code></td>
<td>Begins a group declaration</td>
<td><code>.group topic</code></td>
</tr>
</tbody>
</table>

### Table 4-12. Directives That Create or Effect Macros

<table>
<thead>
<tr>
<th>Mnemonic and Syntax</th>
<th>Description</th>
<th>Directive</th>
<th>See</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>.endm</code></td>
<td>End macro definition</td>
<td><code>.endm</code></td>
<td><code>.endm topic</code></td>
</tr>
<tr>
<td><code>.loop[well-defined expression]</code></td>
<td>Begins repeatable assembly of a code block; the loop count is determined by the well-defined expression.</td>
<td><code>.loop</code></td>
<td><code>.loop topic</code></td>
</tr>
<tr>
<td><code>macname .macro [parameter,][..., parameter_n]</code></td>
<td>Define macro by macname</td>
<td><code>.macro</code></td>
<td><code>.macro topic</code></td>
</tr>
<tr>
<td><code>.mexit</code></td>
<td>Go to .endm</td>
<td></td>
<td>Section 5.2</td>
</tr>
<tr>
<td><code>.mlib filename</code></td>
<td>Identify library containing macro definitions</td>
<td><code>.mlib</code></td>
<td><code>.mlib topic</code></td>
</tr>
<tr>
<td><code>.var</code></td>
<td>Adds a local substitution symbol to a macro's parameter list</td>
<td><code>.var</code></td>
<td><code>.var topic</code></td>
</tr>
</tbody>
</table>

### Table 4-13. Directives That Control Diagnostics

<table>
<thead>
<tr>
<th>Mnemonic and Syntax</th>
<th>Description</th>
<th>See</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>.emsg string</code></td>
<td>Sends user-defined error messages to the output device; produces no .obj file</td>
<td><code>.emsg topic</code></td>
</tr>
<tr>
<td><code>.mmsg string</code></td>
<td>Sends user-defined messages to the output device</td>
<td><code>.mmsg topic</code></td>
</tr>
<tr>
<td><code>.noremark[num]</code></td>
<td>Identifies the beginning of a block of code in which the assembler suppresses the remark(s)</td>
<td><code>.noremark topic</code></td>
</tr>
<tr>
<td><code>.remark [num]</code></td>
<td>Resumes the default behavior of generating the remark(s) previously suppressed by .noremark</td>
<td><code>.remark topic</code></td>
</tr>
<tr>
<td><code>.wmsg string</code></td>
<td>Sends user-defined warning messages to the output device</td>
<td><code>.wmsg topic</code></td>
</tr>
</tbody>
</table>

### Table 4-14. Directives That Perform Assembly Source Debug

<table>
<thead>
<tr>
<th>Mnemonic and Syntax</th>
<th>Description</th>
<th>See</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>.asmfunc</code></td>
<td>Identifies the beginning of a block of code that contains a function</td>
<td><code>.asmfunc topic</code></td>
</tr>
<tr>
<td><code>.endasmfunc</code></td>
<td>Identifies the end of a block of code that contains a function</td>
<td><code>.endasmfunc topic</code></td>
</tr>
</tbody>
</table>
Directives That Define Sections

Table 4-15. Directives That Are Used by the Absolute Lister

<table>
<thead>
<tr>
<th>Mnemonic and Syntax</th>
<th>Description</th>
<th>See</th>
</tr>
</thead>
<tbody>
<tr>
<td>.setsect</td>
<td>Produced by absolute lister; sets a section</td>
<td>Chapter 8</td>
</tr>
<tr>
<td>.setsym</td>
<td>Produced by the absolute lister; sets a symbol</td>
<td>Chapter 8</td>
</tr>
</tbody>
</table>

Table 4-16. Directives That Perform Miscellaneous Functions

<table>
<thead>
<tr>
<th>Mnemonic and Syntax</th>
<th>Description</th>
<th>See</th>
</tr>
</thead>
<tbody>
<tr>
<td>.cdecls [options ;&quot;filename&quot;, &quot;filename2&quot;, ...]</td>
<td>Share C headers between C and assembly code</td>
<td>.cdecls topic</td>
</tr>
<tr>
<td>.end</td>
<td>Ends program</td>
<td>.end topic</td>
</tr>
<tr>
<td>.nocmp</td>
<td>Instructs tools to not utilize 16-bit instructions for section</td>
<td>.nocmp topic</td>
</tr>
</tbody>
</table>

In addition to the assembly directives that you can use in your code, the compiler produces several directives when it creates assembly code. These directives are to be used only by the compiler; do not attempt to use these directives.

- DWARF directives listed in Section A.1
- COFF/STABS directives listed in Section A.2
- The .battr directive is used to encode build attributes for the object file.
- The .template directive is used for early template instantiation. It encodes information about a template that has yet to be instantiated. This is a COFF C++ directive.
- The .compiler_opts directive indicates that the assembly code was produced by the compiler, and which build model options were used for this file.

4.2 Directives That Define Sections

These directives associate portions of an assembly language program with the appropriate sections:

- The .bss directive reserves space in the .bss section for uninitialized variables.
- The .data directive identifies portions of code in the .data section. The .data section usually contains initialized data.
- The .sect directive defines an initialized named section and associates subsequent code or data with that section. A section defined with .sect can contain code or data.
- The .text directive identifies portions of code in the .text section. The .text section usually contains executable code.
- The .usect directive reserves space in an uninitialized named section. The .usect directive is similar to the .bss directive, but it allows you to reserve space separately from the .bss section.

Chapter 2 discusses these sections in detail.

Example 4-1 shows how you can use sections directives to associate code and data with the proper sections. This is an output listing; column 1 shows line numbers, and column 2 shows the SPC values. (Each section has its own program counter, or SPC.) When code is first placed in a section, its SPC equals 0. When you resume assembling into a section after other code is assembled, the section's SPC resumes counting as if there had been no intervening code.

The directives in Example 4-1 perform the following tasks:

- .text initializes words with the values 1, 2, 3, 4, 5, 6, 7, and 8.
- .data initializes words with the values 9, 10, 11, 12, 13, 14, 15, and 16.
- var_def initializes words with the values 17 and 18.
- .bss reserves 19 bytes.
- xy reserves 20 bytes.
The .bss and .usect directives do not end the current section or begin new sections; they reserve the specified amount of space, and then the assembler resumes assembling code or data into the current section.

**Example 4-1. Sections Directives**

```
00000004 00000002
  6 00000008 00000003 .word 3,4
  0000000c 00000004

7
8  **************************************************
9 * Start assembling into the .data section *
10  **************************************************
11 00000000 .data
12 00000000 00000009 .word 9, 10
  00000004 0000000A
13 00000008 0000000B .word 11, 12
  0000000c 0000000C
14
15  **************************************************
16 * Start assembling into a named, *
17 * initialized section, var_defs *
18  **************************************************
19 00000000 .sect "var_defs"
20 00000000 00000011 .word 17, 18
  00000004 00000012
21
22  **************************************************
23 * Resume assembling into the .data section *
24  **************************************************
25 00000010 .data
26 00000010 0000000D .word 13, 14
  00000014 0000000E
27 00000000 .bss sym, 19 ; Reserve space in .bss
28 00000018 0000000F .word 15, 16 ; Still in .data
  0000001c 00000010
29
30  **************************************************
31 * Resume assembling into the .text section *
32  **************************************************
33 00000010 .text
34 00000010 00000005 .word 5, 6
  00000014 00000006
35 00000000 usym .usect "xy", 20 ; Reserve space in xy
36 00000018 00000007 .word 7, 8 ; Still in .text
  0000001c 00000008
```
4.3 Directives That Initialize Constants

Several directives assemble values for the current section:

- The `.byte` and `.char` directives place one or more 8-bit values into consecutive bytes of the current section. These directives are similar to `.long` and `.word`, except that the width of each value is restricted to eight bits.

- The `.double` directive calculates the double-precision (64-bit) IEEE floating-point representation of one or more floating-point values and stores them in two consecutive words in the current section. The `.double` directive automatically aligns to the double-word boundary.

- The `.field` directive places a single value into a specified number of bits in the current word. With `.field`, you can pack multiple fields into a single word; the assembler does not increment the SPC until a word is filled.

Figure 4-1 shows how fields are packed into a word. Using the following assembled code, notice that the SPC does not change (the fields are packed into the same word):

```
1 00000000 00000003 .field 3,4
2 00000000 00000083 .field 8,5
3 00000000 00002083 .field 16,7
```

![Figure 4-1. The .field Directive](image)

- The `.float` directive calculates the single-precision (32-bit) IEEE floating-point representation of a single floating-point value and stores it in a word in the current section that is aligned to a word boundary.

- The `.half`, `.uhalf`, `.short`, and `.ushort` directives place one or more 16-bit values into consecutive 16-bit fields (halfwords) in the current section. The `.half` and `.short` directives automatically align to a short (2-byte) boundary.

- The `.int`, `.uint`, `.long`, `.word`, `.uword` directives place one or more 32-bit values into consecutive 32-bit fields (words) in the current section. The `.int`, `.long`, and `.word` directives automatically align to a word boundary.

- The `.string` and `.cstring` directives place 8-bit characters from one or more character strings into the current section. The `.string` and `.cstring` directives are similar to `.byte`, placing an 8-bit character in each consecutive byte of the current section. The `.cstring` directive adds a NUL character needed by C; the `.string` directive does not add a NUL character.

Directives That Initialize Constants When Used in a .struct/.endstruct Sequence

**NOTE:** The `.byte`, `.char`, `.int`, `.long`, `.word`, `.double`, `.half`, `.short`, `.string`, `.float`, and `.field` directives do not initialize memory when they are part of a `.struct/.endstruct` sequence; rather, they define a member's size. For more information, see the `.struct/.endstruct` directives.

Figure 4-2 compares the `.byte`, `.half`, `.word`, and `.string` directives. Using the following assembled code:

```
1 00000000 0000000A .byte 0ABh
2 .align 4
3 00000004 0000CDEF .half 0CDEFh
4 00000000 89ABCDEF .word 089ABCDEFh
5 00000000 00000068 .string "help"
 00000004 0000006C
 0000000f 00000070
```
4.4 Directives That Perform Alignment and Reserve Space

These directives align the section program counter (SPC) or reserve space in a section:

- The `.align` directive aligns the SPC at the next byte boundary. This directive is useful with the `.field` directive when you do not want to pack two adjacent fields in the same byte. Figure 4-3 demonstrates the `.align` directive. Using the following assembled code:

```assembly
1 2 00000000 00AABBCC .field 0AABBCCh,24
3 .align 2
4 00000000 0BAABBCC .field 0Bh,5
5 00000004 000000DE .field 0DEh,10
```

Figure 4-3. The `.align` Directive

- The `.bes` and `.space` directives reserve a specified number of bytes in the current section. The assembler fills these reserved bytes with 0s.
  - When you use a label with `.space`, it points to the first byte that contains reserved bits.
  - When you use a label with `.bes`, it points to the last byte that contains reserved bits.

Figure 4-4 shows how the `.space` and `.bes` directives work for the following assembled code:

```assembly
67
```
4.5 Directives That Format the Output Listings

These directives format the listing file:

- The `.drlist` directive causes printing of the directive lines to the listing; the `.drnolist` directive turns it off for certain directives. You can use the `.drnolist` directive to suppress the printing of the following directives. You can use the `.drlist` directive to turn the listing on again.

  `.asg`       `.eval`      `.length`    `.mnolist`  `.var`
  `.break`     `.fclist`    `.mlist`     `.sslist`   `.width`
  `.emsg`      `.fcnolist`  `.mmsg`      `.ssnolist` .wmsg

- The source code listing includes false conditional blocks that do not generate code. The `.fclist` and `.fcnolist` directives turn this listing on and off. You can use the `.fclist` directive to list false conditional blocks exactly as they appear in the source code. You can use the `.fcnolist` directive to list only the conditional blocks that are actually assembled.

- The `.length` directive controls the page length of the listing file. You can use this directive to adjust listings for various output devices.

- The `.list` and `.nolist` directives turn the output listing on and off. You can use the `.nolist` directive to prevent the assembler from printing selected source statements in the listing file. Use the `.list` directive to turn the listing on again.

- The source code listing includes macro expansions and loop blocks. The `.mlist` and `.mnolist` directives turn this listing on and off. You can use the `.mlist` directive to print all macro expansions and loop blocks to the listing, and the `.mnolist` directive to suppress this listing.

- The `.option` directive controls certain features in the listing file. This directive has the following operands:

  **A** turns on listing of all directives and data, and subsequent expansions, macros, and blocks.
  **B** limits the listing of `.byte` and `.char` directives to one line.
  **D** turns off the listing of certain directives (same effect as `.drnolist`).
  **H** limits the listing of `.half` and `.short` directives to one line.
  **L** limits the listing of `.long` directives to one line.
  **M** turns off macro expansions in the listing.
  **N** turns off listing (performs `.nolist`).

Res_1 points to the first byte in the space reserved by `.space`. Res_2 points to the last byte in the space reserved by `.bes`.

**Figure 4-4. The `.space` and `.bes` Directives**

![Diagram showing the space reserved by .space and the space reserved by .bes with Res_1 at 08h and Res_2 at 33h.]
O  turns on listing (performs .list).
T  limits the listing of .string directives to one line.
W  limits the listing of .word and .int directives to one line.
X  produces a cross-reference listing of symbols. You can also obtain a cross-reference listing by invoking the assembler with the --cross_reference option (see Section 3.3).

- The .page directive causes a page eject in the output listing.
- The source code listing includes substitution symbol expansions. The .sslist and .ssnolist directives turn this listing on and off. You can use the .sslist directive to print all substitution symbol expansions to the listing, and the .ssnolist directive to suppress this listing. These directives are useful for debugging the expansion of substitution symbols.
- The .tab directive defines tab size.
- The .title directive supplies a title that the assembler prints at the top of each page.
- The .width directive controls the page width of the listing file. You can use this directive to adjust listings for various output devices.

4.6 Directives That Reference Other Files

These directives supply information for or about other files that can be used in the assembly of the current file:

- The .copy and .include directives tell the assembler to begin reading source statements from another file. When the assembler finishes reading the source statements in the copy/include file, it resumes reading source statements from the current file. The statements read from a copied file are printed in the listing file; the statements read from an included file are not printed in the listing file.
- The .def directive identifies a symbol that is defined in the current module and that can be used in another module. The assembler includes the symbol in the symbol table.
- The .global directive declares a symbol external so that it is available to other modules at link time. (For more information about global symbols, see Section 2.7.1). The .global directive does double duty, acting as a .def for defined symbols and as a .ref for undefined symbols. The linker resolves an undefined global symbol reference only if the symbol is used in the program. The .global directive declares a 16-bit symbol.
- The .mlib directive supplies the assembler with the name of an archive library that contains macro definitions. When the assembler encounters a macro that is not defined in the current module, it searches for it in the macro library specified with .mlib.
- The .ref directive identifies a symbol that is used in the current module but is defined in another module. The assembler marks the symbol as an undefined external symbol and enters it in the object symbol table so the linker can resolve its definition. The .ref directive forces the linker to resolve a symbol reference.
- The .symdepend directive creates an artificial reference from the section defining the source symbol name to the destination symbol. The .symdepend directive prevents the linker from removing the section containing the destination symbol if the source symbol section is included in the output module.
- The .weak directive identifies a symbol that is used in the current module but is defined in another module. It is equivalent to the .ref directive, except that the reference has weak linkage.
4.7 Directives That Enable Conditional Assembly

Conditional assembly directives enable you to instruct the assembler to assemble certain sections of code according to a true or false evaluation of an expression. Two sets of directives allow you to assemble conditional blocks of code:

- The `.if/.elseif/.else/.endif` directives tell the assembler to conditionally assemble a block of code according to the evaluation of an expression.

  `.if well-defined expression` marks the beginning of a conditional block and assembles code if the `.if well-defined expression` is true.

  `[.elseif well-defined expression]` marks a block of code to be assembled if the `.if well-defined expression` is false and the .elseif condition is true.

  `.else` marks a block of code to be assembled if the `.if well-defined expression` is false and any .elseif conditions are false.

  `.endif` marks the end of a conditional block and terminates the block.

- The `.loop/.break/.endloop` directives tell the assembler to repeatedly assemble a block of code according to the evaluation of an expression.

  `.loop [well-defined expression]` marks the beginning of a repeatable block of code. The optional expression evaluates to the loop count.

  `.break [well-defined expression]` tells the assembler to assemble repeatedly when the `.break well-defined expression` is false and to go to the code immediately after `.endloop` when the expression is true or omitted.

  `.endloop` marks the end of a repeatable block.

The assembler supports several relational operators that are useful for conditional expressions. For more information about relational operators, see Section 3.10.4.

4.8 Directives That Define Union or Structure Types

These directives set up specialized types for later use with the .tag directive, allowing you to use symbolic names to refer to portions of a complex object. The types created are analogous to the struct and union types of the C language.

The .struct, .union, .cstruct, and .cunion directives group related data into an aggregate structure which is more easily accessed. These directives do not allocate space for any object. Objects must be separately allocated, and the .tag directive must be used to assign the type to the object.

```
COORDT .struct ; structure tag definition
  X .byte ;
  Y .byte
  T_LEN .endstruct

COORD .tag COORDT ; declare COORD (coordinate)
  .bss COORD, T_LEN ; actual memory allocation

LDB *+B14(COORD.Y), A2 ; move member Y of structure
                         ; COORD into register A2
```

The .cstruct and .cunion directives guarantee that the data structure will have the same alignment and padding as if the structure were defined in analogous C code. This allows structures to be shared between C and assembly code. See Chapter 12. For .struct and .union, element offset calculation is left up to the assembler, so the layout may be different than .cstruct and .cunion.

4.9 Directives That Define Enumerated Types

These directives set up specialized types for later use in expressions allowing you to use symbolic names to refer to compile-time constants. The types created are analogous to the enum type of the C language. This allows enumerated types to be shared between C and assembly code. See Chapter 12.

See Section 12.2.10 for an example of using .enum.
4.10 Directives That Define Symbols at Assembly Time

Assembly-time symbol directives equate meaningful symbol names to constant values or strings.

- The `.asg` directive assigns a character string to a substitution symbol. The value is stored in the substitution symbol table. When the assembler encounters a substitution symbol, it replaces the symbol with its character string value. Substitution symbols can be redefined.

  ```
  .asg "10, 20, 30, 40", coefficients
  ; Assign string to substitution symbol.
  .byte coefficients
  ; Place the symbol values 10, 20, 30, and 40
  ; into consecutive bytes in current section.
  ```

- The `.eval` directive evaluates a well-defined expression, translates the results into a character string, and assigns the character string to a substitution symbol. This directive is most useful for manipulating counters:

  ```
  .asg 1 , x ; x = 1
  .loop ; Begin conditional loop.
  .byte x*10h ; Store value into current section.
  .break x = 4 ; Break loop if x = 4.
  .eval x+1, x ; Increment x by 1.
  .endloop ; End conditional loop.
  ```

- The `.define` directive assigns a character string to a substitution symbol. The value is stored in the substitution symbol table. When the assembler encounters a substitution symbol, it replaces the symbol with its character string value. Substitution symbols created with `.define` cannot be redefined.

- The `.label` directive defines a special symbol that refers to the load-time address within the current section. This is useful when a section loads at one address but runs at a different address. For example, you may want to load a block of performance-critical code into slower off-chip memory to save space and move the code to high-speed on-chip memory to run. See the `.label` topic for an example using a load-time address label.

- The `.set` and `.equ` directives set a constant value to a symbol. The symbol is stored in the symbol table and cannot be redefined; for example:

  ```
  bval .set 0100h ; Set bval = 0100h
  .long bval, bval*2, bval+12
  ; Store the values 0100h, 0200h, and 010Ch
  ; into consecutive words in current section.
  ```

  The `.set` and `.equ` directives produce no object code. The two directives are identical and can be used interchangeably.

- The `.unasg` directive turns off substitution symbol assignment made with `.asg`.

- The `.undefine` directive turns off substitution symbol assignment made with `.define`.

- The `.var` directive allows you to use substitution symbols as local variables within a macro.
### 4.11 Miscellaneous Directives

These directives enable miscellaneous functions or features:

- The `.asmfunc` and `.endasmfunc` directives mark function boundaries. These directives are used with the compiler --symdebug:dwarf (-g) option to generate debug information for assembly functions.
- The `.cdecls` directive enables programmers in mixed assembly and C/C++ environments to share C headers containing declarations and prototypes between C and assembly code.
- The `.clink` directive enables conditional linking by telling the linker to leave the named section out of the final object module output of the linker if there are no references found to any symbol in the section. The `.clink` directive can be applied to initialized or uninitialized sections.
- The `.end` directive terminates assembly. If you use the `.end` directive, it should be the last source statement of a program. This directive has the same effect as an end-of-file character.
- The `.group`, `.gmember`, and `.endgroup` directives define a common data section for member of an ELF group section.
- The `.import`, `.export`, `.hidden`, and `.protected` directives set the dynamic visibility of a global symbol for ELF only. See for an explanation of symbol visibility.
- The `.newblock` directive resets local labels. Local labels are symbols of the form $n, where n is a decimal digit, or of the form NAME?, where you specify NAME. They are defined when they appear in the label field. Local labels are temporary labels that can be used as operands for jump instructions. The `.newblock` directive limits the scope of local labels by resetting them after they are used. See Section 3.9.2 for information on local labels.
- The `.nocmp` directive for C6400+ and C6740 instructs the tools to not utilize 16-bit instructions for the section `.nocmp` appears in.
- The `.noremark` directive begins a block of code in which the assembler suppresses the specified assembler remark. A remark is an informational assembler message that is less severe than a warning. The `.remark` directive re-enables the remark(s) previously suppressed by `.noremark`.

These three directives enable you to define your own error and warning messages:

- The `.emsg` directive sends error messages to the standard output device. The `.emsg` directive generates errors in the same manner as the assembler, incrementing the error count and preventing the assembler from producing an object file.
- The `.mmsg` directive sends assembly-time messages to the standard output device. The `.mmsg` directive functions in the same manner as the `.emsg` and `.wmsg` directives but does not set the error count or the warning count. It does not affect the creation of the object file.
- The `.wmsg` directive sends warning messages to the standard output device. The `.wmsg` directive functions in the same manner as the `.emsg` directive but increments the warning count rather than the error count. It does not affect the creation of the object file.

For more information about using the error and warning directives in macros, see Section 5.7.
The remainder of this chapter is a reference. Generally, the directives are organized alphabetically, one directive per topic. Related directives (such as .if/.else/.endif), however, are presented together in one topic.

.align

**Align SPC on the Next Boundary**

**Syntax**

```
.align [size in bytes]
```

**Description**

The `.align` directive aligns the section program counter (SPC) on the next boundary, depending on the `size in bytes` parameter. The `size` can be any power of 2, although only certain values are useful for alignment. An operand of 1 aligns the SPC on the next byte boundary, and this is the default if no `size in bytes` is given. The assembler assembles words containing null values (0) up to the next `size in bytes` boundary:

- `1` aligns SPC to byte boundary
- `2` aligns SPC to halfword boundary
- `4` aligns SPC to word boundary
- `8` aligns SPC to doubleword boundary
- `128` aligns SPC to page boundary

Using the `.align` directive has two effects:

- The assembler aligns the SPC on an x-byte boundary within the current section.
- The assembler sets a flag that forces the linker to align the section so that individual alignments remain intact when a section is loaded into memory.

**Example**

This example shows several types of alignment, including `.align 2`, `.align 8`, and a default `.align`.

```
1 00000000 00000004 .byte 4
2
3 00000002 00000045 .align 2
   00000003 00000072
   00000004 00000072
   00000005 0000006F
   00000006 00000072
   00000007 00000063
   00000008 0000006E
   00000009 00000074
4
5 00000008 0003746E .align
6 00000008 002B746E .field 3,3
7
8 0000000C 00000003 .field 3,3
9
10 00000010 00000005 .field 5,4
11
12 00000011 00000004 .byte 4
```
Assign a Substitution Symbol

Syntax

```
.asg "character string",substitution symbol
.define "character string",substitution symbol
.eval well-defined expression,substitution symbol
```

Description

The `.asg` and `.define` directives assign character strings to substitution symbols. Substitution symbols are stored in the substitution symbol table. The `.asg` directive can be used in many of the same ways as the `.set` directive, but while `.set` assigns a constant value (which cannot be redefined) to a symbol, `.asg` assigns a character string (which can be redefined) to a substitution symbol.

- The assembler assigns the `character string` to the substitution symbol.
- The `substitution symbol` must be a valid symbol name. The substitution symbol is up to 128 characters long and must begin with a letter. Remaining characters of the symbol can be a combination of alphanumeric characters, the underscore (`_`), and the dollar sign (`$`).

The `.define` directive functions in the same manner as the `.asg` directive, except that `.define` disallows creation of a substitution symbol that has the same name as a register symbol or mnemonic. It does not create a new symbol name space in the assembler, rather it uses the existing substitution symbol name space. The `.define` directive is used to prevent corruption of the assembly environment when converting C/C++ headers. See Chapter 12 for more information about using C/C++ headers in assembly source.

The `.eval` directive performs arithmetic on substitution symbols, which are stored in the substitution symbol table. This directive evaluates the `well-defined expression` and assigns the string value of the result to the substitution symbol. The `.eval` directive is especially useful as a counter in `.loop/.endloop` blocks.

- The `well-defined expression` is an alphanumeric expression in which all symbols have been previously defined in the current source module, so that the result is an absolute.
- The `substitution symbol` must be a valid symbol name. The substitution symbol is up to 128 characters long and must begin with a letter. Remaining characters of the symbol can be a combination of alphanumeric characters, the underscore (`_`), and the dollar sign (`$`).

See the `.unasg/.undefine` topic for information on turning off a substitution symbol.
This example shows how .asg and .eval can be used.

1. 
2. sslist ; show expanded substitution symbols
3. .asg +B14(100), GLOB100
4. .asg +B15(4), ARG0
5. 00000000 003B22E4 LDW GLOB100,A0
6. 00000004 00BC22E4 LDW ARG0,A1
7. 00000008 00006000 NOP 4
8. 0000000C 010401E0 ADD A0,A1,A2
9. 00000010 00000000 .word 100*x
10. 00000014 00000064 .word 100*x
11. 00000018 00000C8 .word 100*x
12. .eval x+1,x
13. 0000001C 0000012C .word 100*x
14. .eval x+1,x
15. 00000020 00000190 .word 100*x
16. .eval 4+1,x
.asmfunc/.endasmfunc  Mark Function Boundaries

Syntax

\[\text{symbol} \ \text{.asmfunc} \ [\text{stack\_usage}(\text{num})]\]
\[-\text{endasmfunc}\]

Description

The .asmfunc and .endasmfunc directives mark function boundaries. These directives are used with the compiler -g option (--symdebug:dwarf) to allow assembly code sections to be debugged in the same manner as C/C++ functions.

You should not use the same directives generated by the compiler (see ) to accomplish assembly debugging; those directives should be used only by the compiler to generate symbolic debugging information for C/C++ source files.

The .asmfunc and .endasmfunc directives cannot be used when invoking the compiler with the backwards-compatibility --symdebug:coff option. This option instructs the compiler to use the obsolete COFF symbolic debugging format, which does not support these directives.

The symbol is a label that must appear in the label field.

The .asmfunc directive has an optional parameter, stack_usage, which sets the stack to num bytes.

Consecutive ranges of assembly code that are not enclosed within a pair of .asmfunc and .endasmfunc directives are given a default name in the following format:

$ \text{filename} : \text{beginning source line} : \text{ending source line} \$

Example

In this example the assembly source generates debug information for the user_func section.

```
1 00000000 .sect "\text{.text}\"
2 00000000 00000010! CALL .S1 _printf
3 00000004 01BC94F6 STW .D2T2 B3,*B15--(16)
4 00000008 01800E2A' MVKL .S2 RL0,B3
5 0000000c 01800028+ MVKL .S1 SL1+0,A3
6 00000010 01800068+ MVKH .S1 SL1+0,A3
7 00000014 01BC22F5 STW .D2T1 A3,*+B15(4)
8 00000018 0180006A' || MVKH .S2 RL0,B3
9 0000001c 01BC92E6 RL0: LDW .D2T2 *++B15(16),B3
10 00000020 020008C0 ZERO .D1 A4
11 00000024 00040000 NOP 3
12 00000028 000C0362 RET .S2 B3
13 0000002c 00080000 NOP 5
14 00000030 01BC92E6 RL0: LDW .D2T2 **+B15(16),B3
15 00000034 020008C0 ZERO .D1 A4
16 00000038 00040000 NOP 3
17 0000003c 000C0362 RET .S2 B3
18 00000040 00080000 NOP 5
19 00000044 01BC92E6 RL0: LDW .D2T2 **+B15(16),B3
20 00000048 .endasmfunc
21 0000004c .sect "\text{.const}\"
22 00000050 00000048 SL1: .string "\text{Hello World!}\",10,0
00000001 00000065
00000002 0000006C
00000003 0000006C
00000004 0000006F
00000005 00000020
00000006 00000057
00000007 0000006F
00000008 00000072
00000009 0000006C
0000000a 00000064
0000000b 00000021
0000000c 0000000A
0000000d 00000000
```
.bss

Reserve Space in the .bss Section

Syntax

```
.bss symbol, size in bytes[, alignment[, bank offset]]
```

Description

The .bss directive reserves space for variables in the .bss section. This directive is usually used to allocate space in RAM.

- **The symbol is a required parameter.** It defines a label that points to the first location reserved by the directive. The symbol name must correspond to the variable that you are reserving space for.
- **The size in bytes is a required parameter:** it must be an absolute expression. The assembler allocates size bytes in the .bss section. There is no default size.
- **The alignment is an optional parameter** that ensures that the space allocated to the symbol occurs on the specified boundary. This boundary indicates the size of the slot in bytes and must be set to a power of 2. If the SPC is aligned to the specified boundary, it is not incremented.
- **The bank offset is an optional parameter** that ensures that the space allocated to the symbol occurs on a specific memory bank boundary. The bank offset value measures the number of bytes to offset from the alignment specified before assigning the symbol to that location.

For more information about sections, see Chapter 2.

Example

In this example, the .bss directive allocates space for a variable, array. The symbol array points to 100 bytes of uninitialized space (at .bss SPC = 0). Symbols declared with the .bss directive can be referenced in the same manner as other symbols and can also be declared global.

```
1 *******************************************
2 ** Start assembling into .text section. **
3 *******************************************
4 00000000 .text
5 00000000 008001A0 MV A0,A1
6
7 *******************************************
8 ** Allocate 100 bytes in .bss. **
9 *******************************************
10 00000000 .bss array,100
11
12 *******************************************
13 ** Still in .text **
14 *******************************************
15 00000004 010401A0 MV A1,A2
16
17 *******************************************
18 ** Declare external .bss symbol **
19 *******************************************
20 .global array
```
**.byte/.char  Initialize Byte**

**Syntax**

```
.byte value[, ..., value_n]
.char value[, ..., value_n]
```

**Description**

The `.byte` and `.char` directives place one or more values into consecutive bytes of the current section. A `value` can be one of the following:

- An expression that the assembler evaluates and treats as an 8-bit signed number
- A character string enclosed in double quotes. Each character in a string represents a separate value, and values are stored in consecutive bytes. The entire string must be enclosed in quotes.

The first byte occupies the eight least significant bits of a full 32-bit word. The second byte occupies bits eight through 15 while the third byte occupies bits 16 through 23. The assembler truncates values greater than eight bits.

If you use a label, it points to the location of the first byte that is initialized.

When you use these directives in a `.struct/.endstruct` sequence, they define a member's size; they do not initialize memory. For more information, see the `.struct/.endstruct/.tag` topic.

**Example**

In this example, 8-bit values (10, -1, abc, and a) are placed into consecutive bytes in memory with `.byte`. Also, 8-bit values (8, -3, def, and b) are placed into consecutive bytes in memory with `.char`. The label STRX has the value 0h, which is the location of the first initialized byte. The label STRY has the value 6h, which is the first byte initialized by the `.char` directive.

```
1 00000000 0000000A STRX .byte 10,-1,"abc","a"
   00000001 000000FF
   00000002 00000061
   00000003 00000062
   00000004 00000063
   00000005 00000061

2 00000006 00000008 STRY .char 8,-3,"def","b"
```
.cdecls  Share C Headers Between C and Assembly Code

Syntax

Single Line:

```
 cdecls [options] " filename"[, " filename2"[,...]]
```

Syntax

Multiple Lines:

```
 cdecls [options]
{
    /*------------------------------------------------------------------*/
    /* C/C++ code - Typically a list of #includes and a few defines */
    /*------------------------------------------------------------------*/
}
```

Description

The .cdecls directive allows programmers in mixed assembly and C/C++ environments to share C headers containing declarations and prototypes between the C and assembly code. Any legal C/C++ can be used in a .cdecls block and the C/C++ declarations cause suitable assembly to be generated automatically, allowing you to reference the C/C++ constructs in assembly code; such as calling functions, allocating space, and accessing structure members; using the equivalent assembly mechanisms. While function and variable definitions are ignored, most common C/C++ elements are converted to assembly, for instance: enumerations, (non-function-like) macros, function and variable prototypes, structures, and unions.

The .cdecls options control whether the code is treated as C or C++ code; and how the .cdecls block and converted code are presented. Options must be separated by commas; they can appear in any order:

- **C**: Treat the code in the .cdecls block as C source code (default).
- **CPP**: Treat the code in the .cdecls block as C++ source code. This is the opposite of the C option.
- **NOLIST**: Do not include the converted assembly code in any listing file generated for the containing assembly file (default).
- **LIST**: Include the converted assembly code in any listing file generated for the containing assembly file. This is the opposite of the NOLIST option.
- **NOWARN**: Do not emit warnings on STDERR about C/C++ constructs that cannot be converted while parsing the .cdecls source block (default).
- **WARN**: Generate warnings on STDERR about C/C++ constructs that cannot be converted while parsing the .cdecls source block. This is the opposite of the NOWARN option.

In the single-line format, the options are followed by one or more filenames to include. The filenames and options are separated by commas. Each file listed acts as if #include "filename" was specified in the multiple-line format.

In the multiple-line format, the line following .cdecls must contain the opening .cdecls block indicator {%: Everything after the %, up to the closing block indicator %}, is treated as C/C++ source and processed. Ordinary assembler processing then resumes on the line following the closing %}.

The text within {% and %} is passed to the C/C++ compiler to be converted into assembly language. Much of C language syntax, including function and variable definitions as well as function-like macros, is not supported and is ignored during the conversion. However, all of what traditionally appears in C header files is supported, including function and variable prototypes; structure and union declarations; non-function-like macros; enumerations; and #define's.
The resulting assembly language is included in the assembly file at the point of the .cdecls directive. If the LIST option is used, the converted assembly statements are printed in the listing file.

The assembly resulting from the .cdecls directive is treated similarly to a .include file. Therefore the .cdecls directive can be nested within a file being copied or included. The assembler limits nesting to ten levels; the host operating system may set additional restrictions. The assembler precedes the line numbers of copied files with a letter code to identify the level of copying. An A indicates the first copied file, B indicates a second copied file, etc.

The .cdecls directive can appear anywhere in an assembly source file, and can occur multiple times within a file. However, the C/C++ environment created by one .cdecls is not inherited by a later .cdecls; the C/C++ environment starts new for each .cdecls.

See Chapter 12 for more information on setting up and using the .cdecls directive with C header files.

Example

In this example, the .cdecls directive is used call the C header.h file.

C header file:

```c
#define WANT_ID 10
#define NAME "John\n"
 extern int a_variable;
 extern float cvt_integer(int src);
 struct myCstruct { int member_a; float member_b; };
 enum status_enum { OK = 1, FAILED = 256, RUNNING = 0 };
```

Source file:

```assembly
 cdecls C,LIST,"myheader.h"
```

Listing File:

```assembly
1     .cdecls C,LIST,"myheader.h"
 A  2     ; Assembly Generated from C/C++ Source Code
 A  3     ; ------------------------------------------
 A  4     ; =========== MACRO DEFINITIONS ===========
 A  5     .define "10",WANT_ID
 A  6     .define """"John\n""",NAME
 A  7     ; =========== TYPE DEFINITIONS ===========
 A  8     status_enum .enum
 A  9     00000001 OK .emember 1
 A 10     00000100 FAILED .emember 256
 A 11     00000000 RUNNING .emember 0
 A 12     .endenum
 A 13     myCstruct .struct 0,4
 A 14     .field 32
 A 15     00000000 member_a .field 32
 A 16     19     ; int member_a - offset 0 bytes, size (4 bytes|32 bits)
 A 17     00000000 member_b .field 32
 A 18     21     ; float member_b - offset 4 bytes, size (4 bytes|32 bits)
 A 19     22     ; final size=(8 bytes|64 bits)
```
A 24
A 25 ; =========== EXTERNAL FUNCTIONS ===========
A 26 .global _cvt_integer
A 27
A 28 ; =========== EXTERNAL VARIABLES ===========
A 29 .global _a_variable
2 00000000 00000008 size: .int $sizeof(myCstruct)
3 00000004 00000000 aoffset: .int myCstruct.member_a
4 00000008 00000004 boffset: .int myCstruct.member_b
5 0000000c 00000001 okvalue: .int status_enum.OK
6 00000010 00000100 failval: .int status_enum.FAILED
7 .if $defined(WANT_ID)
8 00000014 0000004A id .cstring NAME
   00000015 0000006F
   00000016 00000068
   00000017 0000006E
   00000018 0000000A
   00000019 00000000
9 .endif
.clink  

**Conditionally Leave Section Out of Object Module Output**

**Syntax**

```
.clink
```

**Description**

The `.clink` directive enables conditional linking by telling the linker to leave a section out of the final object module output of the linker if there are no references found to any symbol in that section. The `.clink` directive can be applied to initialized sections.

The `.clink` directive can be used only with the COFF object file format. Conditional linking is the default behavior when the ELF object format is used, and can be disabled with the --retain or --unused_section_elimination=off link step option.

The `.clink` directive applies to the current initialized section. It tells the linker to leave the section out of the final object module output of the linker if there are no references found in a linked section to any symbol defined in the specified section. The --absolute_exe linker option produces the final output in the form of an absolute, executable output module.

A section in which the entry point of a C program is defined cannot be marked as a conditionally linked section.

**Example**

In this example, the Vars and Counts sections are set for conditional linking.

```
1 00000000 .sect "Vars"
2 .clink
3 ; Vars section is conditionally linked
4
5 00000000 0000001A X: .word 01Ah
6 00000004 0000001A Y: .word 01Ah
7 00000008 0000001A Z: .word 01Ah
8 00000000 .sect "Counts"
9 .clink
10 ; Counts section is conditionally linked
11
12 00000000 0000001A XCount: .word 01Ah
13 00000004 0000001A YCount: .word 01Ah
14 00000008 0000001A ZCount: .word 01Ah
15 00000000 .text
16 ; By default, .text is unconditionally linked
17
18 00000000 00B802C4 LDH *B14,A1
19 00000004 00000028+ MVKL X,A0
20 00000008 00000068+ MVKH X,A0
21 ; These references to symbol X cause the Vars section to be linked into the object output
22
23 0000000c 00040AF8 CMPLT A0,A1,A0
```
.copy/.include

Syntax

```
.copy "filename"
.include "filename"
```

Description

The .copy and .include directives tell the assembler to read source statements from a different file. The statements that are assembled from a copy file are printed in the assembly listing. The statements that are assembled from an included file are not printed in the assembly listing, regardless of the number of .list/.nolist directives assembled.

When a .copy or .include directive is assembled, the assembler:

1. Stops assembling statements in the current source file
2. Assembles the statements in the copied/included file
3. Resumes assembling statements in the main source file, starting with the statement that follows the .copy or .include directive

The filename is a required parameter that names a source file. It is enclosed in double quotes and must follow operating system conventions.

You can specify a full pathname (for example, /320tools/file1.asm). If you do not specify a full pathname, the assembler searches for the file in:

1. The directory that contains the current source file
2. Any directories named with the --include_path assembler option
3. Any directories specified by the C6X_A_DIR environment variable
4. Any directories specified by the C6X_C_DIR environment variable

For more information about the --include_path option and C6X_A_DIR, see Section 3.5. For more information about C6X_C_DIR, see the TMS320C6000 Optimizing Compiler User’s Guide.

The .copy and .include directives can be nested within a file being copied or included. The assembler limits nesting to 32 levels; the host operating system may set additional restrictions. The assembler precedes the line numbers of copied files with a letter code to identify the level of copying. A indicates the first copied file, B indicates a second copied file, etc.

Example 1

In this example, the .copy directive is used to read and assemble source statements from other files; then, the assembler resumes assembling into the current file.

The original file, copy.asm, contains a .copy statement copying the file byte.asm. When copy.asm assembles, the assembler copies byte.asm into its place in the listing (note listing below). The copy file byte.asm contains a .copy statement for a second file, word.asm.

When it encounters the .copy statement for word.asm, the assembler switches to word.asm to continue copying and assembling. Then the assembler returns to its place in byte.asm to continue copying and assembling. After completing assembly of byte.asm, the assembler returns to copy.asm to assemble its remaining statement.

<table>
<thead>
<tr>
<th>copy.asm</th>
<th>byte.asm</th>
<th>word.asm</th>
</tr>
</thead>
<tbody>
<tr>
<td>(source file)</td>
<td>(first copy file)</td>
<td>(second copy file)</td>
</tr>
<tr>
<td>.space 29</td>
<td>** In byte.asm .byte 32,1+ 'A' .copy &quot;word.asm&quot;</td>
<td>** In word.asm .word 0ABCDh, 56q</td>
</tr>
<tr>
<td>.copy &quot;byte.asm&quot;</td>
<td>.string &quot;done&quot;</td>
<td>** Back in original file</td>
</tr>
</tbody>
</table>
| ** Back in original file | ** Back in byte.asm .byte 67h + 3q | }
In this example, the .include directive is used to read and assemble source statements from other files; then, the assembler resumes assembling into the current file. The mechanism is similar to the .copy directive, except that statements are not printed in the listing file.

<table>
<thead>
<tr>
<th>include.asm (source file)</th>
<th>byte2.asm (first copy file)</th>
<th>word2.asm (second copy file)</th>
</tr>
</thead>
<tbody>
<tr>
<td>.space 29</td>
<td>** In byte2.asm</td>
<td>** In word2.asm</td>
</tr>
<tr>
<td>.include &quot;byte2.asm&quot;</td>
<td>.byte 32,1+ 'A'</td>
<td>.word 0ABCDh, 56q</td>
</tr>
<tr>
<td>** Back in original file</td>
<td>.include &quot;word2.asm&quot;</td>
<td>** Back in byte2.asm</td>
</tr>
<tr>
<td>.string &quot;done&quot;</td>
<td>.byte 67h + 3q</td>
<td>.word 0ABCDh, 56q</td>
</tr>
</tbody>
</table>

Listing file:

```
1 00000000 .space 29
2                   .copy "byte.asm"
A 1 ** In byte.asm
A 2 0000001d 00000020 .byte 32,1+ 'A'
    0000001e 00000042
A 3 .copy "word.asm"
B 1 ** In word.asm
B 2 00000020 0000ABCD .word 0ABCDh, 56q
    00000024 0000002E
A 4 ** Back in byte.asm
A 5 00000028 0000006A .byte 67h + 3q
    0000002a 0000006f
    0000002b 0000006e
    0000002c 00000065
4 ** Back in original file
5 00000029 00000064 .string "done"
```

Example 2
**declare C Structure Type**

**Syntax**

```
[stag] .cstruct/.cunion [expr]
[mem]_0 element [expr_0]
[mem]_1 element [expr_1]
  .  .  .
[mem]_n .tag stag [expr_n]
[mem]_{N} element [expr_{N}]
[size] .endstruct/.endunion
label .tag stag
```

**Description**

The `.cstruct` and `.cunion` directives have been added to support ease of sharing of common data structures between assembly and C code. The `.cstruct` and `.cunion` directives can be used exactly like the existing `.struct` and `.union` directives except that they are guaranteed to perform data layout matching the layout used by the C compiler for C struct and union data types.

In particular, the `.cstruct` and `.cunion` directives force the same alignment and padding as used by the C compiler when such types are nested within compound data structures.

The `.endstruct` directive terminates the structure definition. The `.endunion` directive terminates the union definition.

The `.tag` directive gives structure characteristics to a `label`, simplifying the symbolic representation and providing the ability to define structures that contain other structures. The `.tag` directive does not allocate memory. The structure tag (`stag`) of a `.tag` directive must have been previously defined.

Following are descriptions of the parameters used with the `.struct`, `.endstruct`, and `.tag` directives:

- The `stag` is the structure's tag. Its value is associated with the beginning of the structure. If no stag is present, the assembler puts the structure members in the global symbol table with the value of their absolute offset from the top of the structure. A `.stag` is optional for `.struct`, but is required for `.tag`.
- The `element` is one of the following descriptors: `.byte`, `.char`, `.int`, `.long`, `.word`, `.double`, `.half`, `.short`, `.string`, `.float`, and `.field`. All of these except `.tag` are typical directives that initialize memory. Following a `.struct` directive, these directives describe the structure element's size. They do not allocate memory. A `.tag` directive is a special case because `stag` must be used (as in the definition of `stag`).
- The `expr` is an optional expression indicating the beginning offset of the structure. The default starting point for a structure is 0.
- The `expr_n/N` is an optional expression for the number of elements described. This value defaults to 1. A `.string` element is considered to be one byte in size, and a `.field` element is one bit.
- The `mem_n/N` is an optional label for a member of the structure. This label is absolute and equates to the present offset from the beginning of the structure. A label for a structure member cannot be declared global.
- The `size` is an optional label for the total size of the structure.

**Example**

This example illustrates a structure in C that will be accessed in assembly code.

```c
typedef struct STRUCT1
{    int i0; /* offset 0 */
    short s0; /* offset 4 */
} struct1; /* size 8, alignment 4 */
```

```c
typedef struct STRUCT2
```
The structure will get the following offsets once the C compiler lays out the structure elements according to the C standard rules:

- `offsetof(struct1, i0) = 0`
- `offsetof(struct1, s0) = 4`
- `sizeof(struct1) = 8`

- `offsetof(struct2, s1) = 0`
- `offsetof(struct2, i1) = 8`
- `sizeof(struct2) = 12`

Attempts to replicate this structure in assembly using the `.struct/union directives will not create the correct offsets because the assembler tries to use the most compact arrangement:

```assembly
struct1 .struct
  i0 .int ; bytes 0-3
  s0 .short ; bytes 4-5
struct1len .endstruct ; size 6, alignment 4

struct2 .struct
  st1 .tag struct1 ; bytes 0-5
  s1 .short ; bytes 6-7
endstruct2 .endstruct ; size 8, alignment 4
```

The `.cstruct/.cunion directives calculate the offsets in the same manner as the C compiler. The resulting assembly structure can be used to access the elements of the C structure.

```assembly
cstruct1 .cstruct
  i0 .int ; bytes 0-3
  s0 .short ; bytes 4-5
cstruct1len .endstruct ; size 8, alignment 4
cstruct2 .cstruct
  st1 .tag cstruct1 ; bytes 0-7
  s1 .short ; bytes 8-9
cendstruct2 .endstruct ; size 12, alignment 4
```

The `.cstruct/.cunion directives calculate the offsets in the same manner as the C compiler. The resulting assembly structure can be used to access the elements of the C structure.

Compare the difference in the offsets of those structures defined via `.struct` above and the offsets for the C code.

```assembly
cstruct1 .cstruct
  i0 .int ; bytes 0-3
  s0 .short ; bytes 4-5
cstruct1len .endstruct ; size 8, alignment 4
cstruct2 .cstruct
  st1 .tag cstruct1 ; bytes 0-7
  s1 .short ; bytes 8-9
cendstruct2 .endstruct ; size 12, alignment 4
```

The `.cstruct/.cunion directives calculate the offsets in the same manner as the C compiler. The resulting assembly structure can be used to access the elements of the C structure.

Compare the difference in the offsets of those structures defined via `.struct` above and the offsets for the C code.
.data

Assemble Into the .data Section

Syntax

.data

Description

The .data directive tells the assembler to begin assembling source code into the .data section; .data becomes the current section. The .data section is normally used to contain tables of data or preinitialized variables.

For more information about sections, see Chapter 2.

Example

In this example, code is assembled into the .data and .text sections.

```
1 **********************************************
2 ** Reserve space in .data                  **
3 **********************************************
4 00000000 .data
5 00000000 .space 0CCh
6 7
8 ** Assemble into .text                    **
9 **********************************************
10 00000000 .text
11 00000000 00800358 ABS A0,A1
12 13
14 ** Assemble into .data                    **
15 **********************************************
16 000000cc table: .data
17 000000cc FFFFFFFF .word -1
18 000000dd 000000FF .byte 0FFh
19 20
21 ** Assemble into .text                    **
22 **********************************************
23 00000004 .text
24 00000004 008001A0 MV A0,A1
25 26
27 ** Resume assembling into the .data section **
28 **********************************************
29 000000d1 .data
30 000000d4 00000000 coeff .word 00h,0ah,0bh
   000000d8 0000000A
   000000dc 0000000B
```
.double

Initialize Double-Precision Floating-Point Value

Syntax

`.double value[, ... , value]`

Description

The `.double` directive places the IEEE double-precision floating-point representation of one or more floating-point values into the current section. Each `value` must be a floating-point constant or a symbol that has been equated to a floating-point constant. Each constant is converted to a floating-point value in IEEE double-precision 64-bit format. Double-precision floating point constants are aligned to a double word boundary.

The 64-bit value is stored in the format shown in Figure 4-5.

Figure 4-5. Double-Precision Floating-Point Format

```
31 20 0
M M M M M M M M M M M M M M M M M M M M M M M M M M M M M M M M
031
Legend: S□=□sign
E□=□exponent□(11-bit□biased)
M□=□mantissa□(52-bit□fraction)
```

When you use `.double` in a `.struct/.endstruct` sequence, `.double` defines a member’s size; it does not initialize memory. For more information, see the `.struct/.endstruct/.tag` topic.

Example

This example shows the `.double` directive.

```
1 00000000 2C280291 .double -2.0e25
  00000004 C5308B2A
  00000008 00000000
  0000000c 40180000
  00000010 00000000
  00000014 407C8000
2 00000000 00000000 .double 6
  00000004 40180000
  00000008 00000000
  00000010 00000000
  00000014 407C8000
3 00000000 00000000 .double 456
  00000004 40180000
  00000008 00000000
  00000010 00000000
  00000014 407C8000
```
### .drlist/.drnolist

**Control Listing of Directives**

**Syntax**

- `.drlist`
- `.drnolist`

**Description**

Two directives enable you to control the printing of assembler directives to the listing file:

- The `.drlist` directive enables the printing of all directives to the listing file.
- The `.drnolist` directive suppresses the printing of the following directives to the listing file. The `.drnolist` directive has no affect within macros.

- `.asg`
- `.break`
- `.emsg`
- `.eval`
- `.fclist`
- `.fnolist`
- `.sslist`

By default, the assembler acts as if the `.drlist` directive had been specified.

**Example**

This example shows how `.drnolist` inhibits the listing of the specified directives.

**Source file:**

```assembly
.length 65
.width 85
.asg 0, x
.loop 2
.eval x+1, x
.endloop

.drnolist
.length 55
.width 95
.asg 1, x
.loop 3
.eval x+1, x
.endloop
```

**Listing file:**

```
3 .asg 0, x
4 .loop 2
5 .eval x+1, x
6 .endloop
1 .eval 0+1, x
1 .eval 1+1, x
7
8 .drnolist
12 .loop 3
13 .eval x+1, x
14 .endloop
```
.emsg/.mmsg/.wmsg  Define Messages

Syntax

<table>
<thead>
<tr>
<th>Directive</th>
<th>Syntax</th>
</tr>
</thead>
<tbody>
<tr>
<td>.emsg</td>
<td>string</td>
</tr>
<tr>
<td>.mmsg</td>
<td>string</td>
</tr>
<tr>
<td>.wmsg</td>
<td>string</td>
</tr>
</tbody>
</table>

Description

These directives allow you to define your own error and warning messages. When you use these directives, the assembler tracks the number of errors and warnings it encounters and prints these numbers on the last line of the listing file.

The .emsg directive sends an error message to the standard output device in the same manner as the assembler. It increments the error count and prevents the assembler from producing an object file.

The .mmsg directive sends an assembly-time message to the standard output device in the same manner as the .emsg and .wmsg directives. It does not, however, set the error or warning counts, and it does not prevent the assembler from producing an object file.

The .wmsg directive sends a warning message to the standard output device in the same manner as the .emsg directive. It increments the warning count rather than the error count, however. It does not prevent the assembler from producing an object file.

Example

In this example, the message ERROR -- MISSING PARAMETER is sent to the standard output device.

Source file:

```assembly
.global PARAM
MSG_EX .macro parm1
  .if $symlen(parm1) = 0
    .emsg "ERROR -- MISSING PARAMETER"
  .else
    MVK parm1, A1
  .endif
.endm
MSG_EX PARAM
MSG_EX
```

Listing file:

```assembly
  .global PARAM
  MSG_EX .macro parm1
    .if $symlen(parm1) = 0
      .emsg "ERROR -- MISSING PARAMETER"
    .else
      MVK parm1, A1
    .endif
  .endm

  00000000 MSG_EX PARAM
  .if $symlen(parm1) = 0
  .emsg "ERROR -- MISSING PARAMETER"
  .else
    00800000 MVK PARAM, A1
  .endif

  00000000 00800000

  00000004 MSG_EX
  .if $symlen(parm1) = 0
  .emsg "ERROR -- MISSING PARAMETER"

  ***** USER ERROR ***** - : ERROR -- MISSING PARAMETER
  .else
    MVK parm1, A1
  .endif
```

1 Error, No Warnings

In addition, the following messages are sent to standard output by the assembler:
**.end**

**End Assembly**

**Syntax**

`.end`

**Description**

The `.end` directive is optional and terminates assembly. The assembler ignores any source statements that follow a `.end` directive. If you use the `.end` directive, it must be the last source statement of a program.

This directive has the same effect as an end-of-file character. You can use `.end` when you are debugging and you want to stop assembling at a specific point in your code.

---

**Ending a Macro**

**NOTE:** Do not use the `.end` directive to terminate a macro; use the `.endm` macro directive instead.

---

**Example**

This example shows how the `.end` directive terminates assembly. If any source statements follow the `.end` directive, the assembler ignores them.

**Source file:**

```assembly
start: .text
ZERO A0
ZERO A1
ZERO A3
.end
ZERO A4
```

**Listing file:**

```
1 00000000 start: .text
2 00000000 000005E0 ZERO A0
3 00000004 008425E0 ZERO A1
4 00000008 018C65E0 ZERO A3
5 .end
```
.fclist/.fcnolist

Control Listing of False Conditional Blocks

Syntax

.fclist
.fcnolist

Description

Two directives enable you to control the listing of false conditional blocks:

The .fclist directive allows the listing of false conditional blocks (conditional blocks that do not produce code).

The .fcnolist directive suppresses the listing of false conditional blocks until a .fclist directive is encountered. With .fcnolist, only code in conditional blocks that are actually assembled appears in the listing. The .if, .elseif, .else, and .endif directives do not appear.

By default, all conditional blocks are listed; the assembler acts as if the .fclist directive had been used.

Example

This example shows the assembly language and listing files for code with and without the conditional blocks listed.

Source file:

a .set 0
b .set 1
.fclist ; list false conditional blocks
.if a
MVK 5,A0
.else
MVK 0,A0
.endif
.fcnolist ; do not list false conditional blocks
.if a
MVK 5,A0
.else
MVK 0,A0
.endif

Listing file:

1 00000000 a .set 0
2 00000001 b .set 1
3 .fclist ; list false conditional blocks
4 .if a
5 MVK 5,A0
6 .else
7 00000000 00000028 MVK 0,A0
8 .endif
9 .fcnolist ; do not list false conditional blocks
13 00000004 00000028 MVK 0,A0
.field  

Initialize Field

Syntax

.field value[, size in bits]

Description

The .field directive initializes a multiple-bit field within a single word (32 bits) of memory. This directive has two operands:

- The **value** is a required parameter; it is an expression that is evaluated and placed in the field. The value must be absolute.
- The **size in bits** is an optional parameter; it specifies a number from 1 to 32, which is the number of bits in the field. If you do not specify a size, the assembler assumes the size is 32 bits. If you specify a value that cannot fit in size in bits, the assembler truncates the value and issues a warning message. For example, .field 3, 1 causes the assembler to truncate the value 3 to 1; the assembler also prints the message:

  *** WARNING! line 21: W0001: Field value truncated to 1
  .field 3, 1

Successive .field directives pack values into the specified number of bits starting at the current 32-bit slot. Fields are packed starting at the least significant bit (bit 0), moving toward the most significant bit (bit 31) as more fields are added. If the assembler encounters a field size that does not fit in the current 32-bit word, it fills the remaining bits of the current byte with 0s, increments the SPC to the next word boundary, and begins packing fields into the next word.

You can use the .align directive to force the next .field directive to begin packing into a new word.

If you use a label, it points to the byte that contains the specified field.

When you use .field in a .struct/.endstruct sequence, .field defines a member's size; it does not initialize memory. For more information, see the .struct/.endstruct/.tag topic.

Example

This example shows how fields are packed into a word. The SPC does not change until a word is filled and the next word is begun. Figure 4-6 shows how the directives in this example affect memory.

```assembly
1  ************************************
2  ** Initialize a 24-bit field. **
3  ************************************
4 00000000 00BBCCDD .field 0BBCCDDh, 24
5 6  ************************************
7  ** Initialize a 5-bit field **
8  ************************************
9 00000000 0ABBCCDD .field 0Ah, 5
10 11  ************************************
12  ** Initialize a 4-bit field **
13  ** in a new word. **
14  ************************************
15 00000004 0000000C .field 0Ch, 4
16 17  ************************************
18  ** Initialize a 3-bit field **
19  ************************************
20 00000004 0000001C x: .field 01h, 3
21 22  ************************************
23  ** Initialize a 32-bit field **
24  ** relocatable field in the **
25  ** next word **
26  ************************************
27 00000008 00000004' .field x
```
Figure 4-6. The .field Directive

<table>
<thead>
<tr>
<th>Word</th>
<th>Contents</th>
<th>Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>(a) 0</td>
<td>1 0 1 1 1 1 0 1 1 1 0 0 1 1 0 1 1 1 0 1 0 1 1 1 0 1 0 1 1 1 0 1</td>
<td>.field 0BBCCD0, 24</td>
</tr>
<tr>
<td>(b) 0</td>
<td>0 1 0 1 0 1 0 1 1 1 0 1 1 1 0 0 1 1 0 0 1 1 0 1 1 1 0 1 0 1 1 1 0 1</td>
<td>.field 0Ah, 5</td>
</tr>
<tr>
<td>(c) 0</td>
<td>0 0 0 0 1 0 1 0 1 0 1 1 1 0 1 1 1 0 0 1 1 0 0 1 1 0 1 1 1 0 1</td>
<td>.field 0Ch, 4</td>
</tr>
<tr>
<td>(d) 1</td>
<td>1 1 0 0</td>
<td>.field 0Zh, 3</td>
</tr>
<tr>
<td>(e) 1</td>
<td>0 0 0 1 1 0 0</td>
<td>.field x</td>
</tr>
</tbody>
</table>

24-bit field
5-bit field
4-bit field
3-bit field
.float

Initialize Single-Precision Floating-Point Value

Syntax

.float value[, ... , value_n]

Description

The .float directive places the IEEE single-precision floating-point representation of a single floating-point constant into a word in the current section. The value must be a floating-point constant or a symbol that has been equated to a floating-point constant. Each constant is converted to a floating-point value in IEEE single-precision 32-bit format.

The 32-bit value is stored exponent byte first, most significant byte of fraction second, and least significant byte of fraction third, in the format shown in Figure 4-7.

Figure 4-7. Single-Precision Floating-Point Format

| S | E | E | E | E | E | E | E | M | M | M | M | M | M | M | M | M | M | M | M | M | M | M |
| 31 | 23 | 0 |

value = (-1)^S x (1.0 + mantissa) x (2)^exponent-127

Legend:

S = sign (1 bit)
E = exponent (8-bit biased)
M = mantissa (23-bit fraction)

When you use .float in a .struct/.endstruct sequence, .float defines a member's size; it does not initialize memory. For more information, see the .struct/.endstruct/tag topic.

Example

Following are examples of the .float directive:

1 00000000 E9045951 .float -1.0e25
2 00000004 40400000 .float 3
3 00000008 42F60000 .float 123
.global/.def/.ref

Identify Global Symbols

Syntax

```
.globaI symbol[, ..., symbol]
.def symbol[, ..., symbol]
.ref symbol[, ..., symbol]
```

Description

Three directives identify global symbols that are defined externally or can be referenced externally:

The .def directive identifies a symbol that is defined in the current module and can be accessed by other files. The assembler places this symbol in the symbol table.

The .ref directive identifies a symbol that is used in the current module but is defined in another module. The linker resolves this symbol's definition at link time.

The .global directive acts as a .ref or a .def, as needed.

A global symbol is defined in the same manner as any other symbol; that is, it appears as a label or is defined by the .set, .equ, .bss, or .usect directive. As with all symbols, if a global symbol is defined more than once, the linker issues a multiple-definition error. The .ref directive always creates a symbol table entry for a symbol, whether the module uses the symbol or not; .global, however, creates an entry only if the module actually uses the symbol.

A symbol can be declared global for either of two reasons:

- If the symbol is not defined in the current module (which includes macro, copy, and include files), the .global or .ref directive tells the assembler that the symbol is defined in an external module. This prevents the assembler from issuing an unresolved reference error. At link time, the linker looks for the symbol's definition in other modules.
- If the symbol is defined in the current module, the .global or .def directive declares that the symbol and its definition can be used externally by other modules. These types of references are resolved at link time.

Example

This example shows four files. The file1.lst and file2.lst refer to each other for all symbols used; file3.lst and file4.lst are similarly related.

The file1.lst and file3.lst files are equivalent. Both files define the symbol INIT and make it available to other modules; both files use the external symbols X, Y, and Z. Also, file1.lst uses the .global directive to identify these global symbols; file3.lst uses .ref and .def to identify the symbols.

The file2.lst and file4.lst files are equivalent. Both files define the symbols X, Y, and Z and make them available to other modules; both files use the external symbol INIT. Also, file2.lst uses the .global directive to identify these global symbols; file4.lst uses .ref and .def to identify the symbols.

file1.lst

```
1 ; Global symbol defined in this file
2 .global INIT
3 ; Global symbols defined in file2.lst
4 .global X, Y, Z
5 00000000 INIT:
6 00000000 00902058 ADD.L1 0x01,A4,A1
7 00000004 00000000! .word X
8 ;
9 ;
10 ;
11 .end
```
file2.lst

1 ; Global symbols defined in this file
2 .global X, Y, Z
3 ; Global symbol defined in file1.lst
4 .global INIT
5 00000001 X: .set 1
6 00000002 Y: .set 2
7 00000003 Z: .set 3
8 00000000 00000000! .word INIT
9 ;
10 ;
11 ;
12 .end

file3.lst

1 ; Global symbol defined in this file
2 .def INIT
3 ; Global symbols defined in file4.lst
4 .ref X, Y, Z
5 00000000 INIT:
6 00000000 00902058 ADD.L1 0x01,A4,A1
7 00000004 00000000! .word X
8 ;
9 ;
10 ;
11 .end

file4.lst

1 ; Global symbols defined in this file
2 .def X, Y, Z
3 ; Global symbol defined in file3.lst
4 .ref INIT
5 00000001 X: .set 1
6 00000002 Y: .set 2
7 00000003 Z: .set 3
8 00000000 00000000! .word INIT
9 ;
10 ;
11 ;
12 .end

.group/.gmember/.endgroup Define Common Data Section

Syntax

.group  group section name  group type
.gmember  section name
.endgroup

Description

Three directives instruct the assembler to make certain sections members of an ELF group section (see ELF specification for more information on group sections).

The.group directive begins the group declaration. The group section name designates the name of the group section. The group type designates the type of the group. The following types are supported:

0x0 Regular ELF group
0x1 COMDAT ELF group

The.gmember directive designates section name as a member of the group.

The.endgroup directive ends the group declaration.
.half/.short/.uhalf/.ushort  Initialize 16-Bit Integers

Syntax

```
.half  value[, ..., value_n]
.short  value[, ..., value_n]
.uhalf  value[, ..., value_n]
.ushort  value[, ..., value_n]
```

Description

The .half, .uhalf, .short, and .ushort directives place one or more values into consecutive halfwords in the current section. Each value is placed in a 2-byte slot by itself. A value can be either:

- An expression that the assembler evaluates and treats as a 16-bit signed or unsigned number
- A character string enclosed in double quotes. Each character in a string represents a separate value and is stored alone in the least significant eight bits of a 16-bit field, which is padded with 0s.

The assembler truncates values greater than 16 bits.

If you use a label with .half, .short, .uhalf, or .ushort; it points to the location where the assembler places the first byte.

These directives perform a halfword (16-bit) alignment before data is written to the section. This guarantees that data resides on a 16-bit boundary.

When you use .half, .short, .uhalf, or .ushort in a .struct/.endstruct sequence, they define a member's size; they do not initialize memory. For more information, see the .struct/.endstruct/.tag topic.

Example

In this example, .half is used to place 16-bit values (10, -1, abc, and a) into consecutive halfwords in memory; .short is used to place 16-bit values (8, -3, def, and b) into consecutive halfwords in memory. The label STRN has the value 100ch, which is the location of the first initialized halfword for .short.

```
1 00000000 .space 100h * 16
2 00001000 0000000A .half 10, -1, "abc", 'a'
  00001006 00000061
  00001008 00000062
  0000100a 00000063
  0000100c 00000061
3 0000100c 00000008 STRN .short 8, -3, "def", 'b'
  00001012 00000064
  00001014 00000065
  00001016 00000062
```
.if/.elseif/.else/.endif  Assemble Conditional Blocks

Syntax

```
.if  well-defined expression
   [ .elseif  well-defined expression ]
   [ .else ]
 .endif
```

Description

Four directives provide conditional assembly:

The .if directive marks the beginning of a conditional block. The well-defined expression is a required parameter:

- If the expression evaluates to true (nonzero), the assembler assembles the code that follows the expression (up to a .elseif, .else, or .endif).
- If the expression evaluates to false (0), the assembler assembles code that follows a .elseif (if present), .else (if present), or .endif (if no .elseif or .else is present).

The .elseif directive identifies a block of code to be assembled when the .if expression is false (0) and the .elseif expression is true (nonzero). When the .elseif expression is false, the assembler continues to the next .elseif (if present), .else (if present), or .endif (if no .elseif or .else is present). The .elseif directive is optional in the conditional block, and more than one .elseif can be used. If an expression is false and there is no .elseif statement, the assembler continues with the code that follows a .else (if present) or a .endif.

The .else directive identifies a block of code that the assembler assembles when the .if expression and all .elseif expressions are false (0). The .else directive is optional in the conditional block; if an expression is false and there is no .else statement, the assembler continues with the code that follows the .endif.

The .endif directive terminates a conditional block.

The .elseif and .else directives can be used in the same conditional assembly block, and the .elseif directive can be used more than once within a conditional assembly block.

See Section 3.10.4 for information about relational operators.

Example

This example shows conditional assembly:

```
1 0000001 SYM1  .set 1
2 0000002 SYM2  .set 2
3 0000003 SYM3  .set 3
4 0000004 SYM4  .set 4
5
6 If_4:  .if  SYM4 = SYM2 * SYM2
7       .byte  SYM4       ; Equal values
8       .else
9       .byte  SYM2 * SYM2 ; Unequal values
10      .endif
11
12 If_5:  .if  SYM1 <= 10
13       .byte  10        ; Less than / equal
14       .else
15       .byte  SYM1       ; Greater than
16       .endif
17
18 If_6:  .if  SYM3 * SYM2 != SYM4 + SYM2
19       .byte  SYM3 * SYM2 ; Unequal value
20       .else
21       .byte  SYM4 + SYM4 ; Equal values
22       .endif
23
24 If_7:  .if  SYM1 = SYM2
25       .byte  SYM1
26       .elseif SYM2 + SYM3 = 5
27       .byte  SYM2 + SYM3
28      .endif
```
.import/.export/.hidden/.protected  Set Dynamic Visibility of Global Symbol

Syntax

```plaintext
.import "symbolname"
.export "symbolname"
.hidden "symbolname"
.protected "symbolname"
```

Description

These directives set the dynamic visibility of a global symbol. Each takes a single symbol name, optionally enclosed in double-quotes.

- The .import directive sets the visibility of `symbolname` to STV_IMPORT.
- The .export directive sets the visibility of `symbolname` to STV_EXPORT.
- The .hidden directive sets the visibility of `symbolname` to STV_HIDDEN.
- The .protected directive sets the visibility of `symbolname` to STV_PROTECTED.

See for an explanation of symbol visibility.
.int/.long/.word/.uint/.uword  Initialize 32-BitIntegers

Syntax

```
.int value[, ..., value_n]
.long value[, ..., value_n]
.word value[, ..., value_n]
.uint value[, ..., value_n]
.uword value[, ..., value_n]
```

Description

The .int, .uint, .long, .word, and .uword directives place one or more values into consecutive words in the current section. Each value is placed in a 32-bit word by itself and is aligned on a word boundary. A value can be either:

- An expression that the assembler evaluates and treats as a 32-bit signed or unsigned number
- A character string enclosed in double quotes. Each character in a string represents a separate value and is stored alone in the least significant eight bits of a 32-bit field, which is padded with 0s.

A value can be either an absolute or a relocatable expression. If an expression is relocatable, the assembler generates a relocation entry that refers to the appropriate symbol; the linker can then correctly patch (relocate) the reference. This allows you to initialize memory with pointers to variables or labels.

If you use a label with these directives, it points to the first word that is initialized.

When you use these directives in a .struct/.endstruct sequence, they define a member's size; they do not initialize memory. See the .struct/.endstruct/.tag topic.

Example 1

This example uses the .int directive to initialize words. Notice that the symbol SYMPTR puts the symbol's address in the object code and generates a relocatable reference (indicated by the - character appended to the object word).

```
1 00000000 .space 73h
2 00000000 .bss PAGE, 128
3 00000080 .bss SYMPTR, 3
4 00000074 003C12E4 INST: LDW.D2 *++B15[0],A0
5 00000078 0000000A .int 10, SYMPTR, -1, 35 + 'a', INST
0000007c 00000080-
00000080 FFFFFFFF
00000084 00000074'
```

Example 2

This example initializes two 32-bit fields and defines DAT1 to point to the first location. The contents of the resulting 32-bit fields are FFFABCDh and 141h.

```
1 00000000 FFFABCD DAT1: .long 0FFFBABCDh,'A'+100h
00000004 00000141
```

Example 3

This example initializes five words. The symbol WordX points to the first word.

```
1 00000000 00000C80 ;WordX .word 3200,1+'AB','-AF',0F410h,'A'
00000004 00004242
00000008 FFFB9BF
0000000C 0000F410
00000010 00000041
```
The `.label` directive defines a special `symbol` that refers to the load-time address rather than the run-time address within the current section. Most sections created by the assembler have relocatable addresses. The assembler assembles each section as if it started at 0, and the linker relocates it to the address at which it loads and runs.

For some applications, it is desirable to have a section load at one address and run at a different address. For example, you may want to load a block of performance-critical code into slower memory to save space and then move the code to high-speed memory to run it. Such a section is assigned two addresses at link time: a load address and a run address. All labels defined in the section are relocated to refer to the run-time address so that references to the section (such as branches) are correct when the code runs.

The `.label` directive creates a special label that refers to the load-time address. This function is useful primarily to designate where the section was loaded for purposes of the code that relocates the section.

### Example

This example shows the use of a load-time address label.

```assembly
sect ".examp"
    .label examp_load ; load address of section
    start: ; run address of section
    <code>
    finish: ; run address of section end
    .label examp_end ; load address of section end
```

See Section 7.5.5 for more information about assigning run-time and load-time addresses in the linker.
.length/.width

Set Listing Page Size

Syntax

- .length [page length]
- .width [page width]

Description

Two directives allow you to control the size of the output listing file.

The .length directive sets the page length of the output listing file. It affects the current and following pages. You can reset the page length with another .length directive.

- Default length: 60 lines. If you do not use the .length directive or if you use the .length directive without specifying the page length, the output listing length defaults to 60 lines.
- Minimum length: 1 line
- Maximum length: 32 767 lines

The .width directive sets the page width of the output listing file. It affects the next line assembled and the lines following. You can reset the page width with another .width directive.

- Default width: 132 characters. If you do not use the .width directive or if you use the .width directive without specifying a page width, the output listing width defaults to 132 characters.
- Minimum width: 80 characters
- Maximum width: 200 characters

The width refers to a full line in a listing file; the line counter value, SPC value, and object code are counted as part of the width of a line. Comments and other portions of a source statement that extend beyond the page width are truncated in the listing.

The assembler does not list the .width and .length directives.

Example

The following example shows how to change the page length and width.

```
********************************************
** Page length = 65 lines **
** Page width = 85 characters **
********************************************
.length 65
.width 85

********************************************
** Page length = 55 lines **
** Page width = 100 characters **
********************************************
.length 55
.width 100
```
Directives Reference

`list/.nolist`  

**Syntax**

- `.list`
- `.nolist`

**Description**

Two directives enable you to control the printing of the source listing:

The `.list` directive allows the printing of the source listing.

The `.nolist` directive suppresses the source listing output until a `.list` directive is encountered. The `.nolist` directive can be used to reduce assembly time and the source listing size. It can be used in macro definitions to suppress the listing of the macro expansion.

The assembler does not print the `.list` or `.nolist` directives or the source statements that appear after a `.nolist` directive. However, it continues to increment the line counter. You can nest the `.list/.nolist` directives; each `.nolist` needs a matching `.list` to restore the listing.

By default, the source listing is printed to the listing file; the assembler acts as if the `.list` directive had been used. However, if you do not request a listing file when you invoke the assembler by including the `--asm_listing` option on the command line (see Section 3.3), the assembler ignores the `.list` directive.

**Example**

This example shows how the `.list` and `.nolist` directives turn the output listing on and off. The `.nolist`, the table: `.data` through `.byte` lines, and the `.list` directives do not appear in the listing file. Also, the line counter is incremented even when source statements are not listed.

**Source file:**

```assembly
.data
.space 0CCh
.text
ABS A0,A1
.nolist

table: .data
.word -1
.byte 0FFh
.list

.text
MV A0,A1
.data
coeff .word 00h,0ah,0bh
```

**Listing file:**

```plaintext
1 00000000 .data
2 00000000 .space 0CCh
3 00000000 .text
4 00000000 00800358 ABS A0,A1
5 13
14 00000004 .text
15 00000004 008001A0 MV A0,A1
16 000000d1 .data
17 000000d4 00000000 coeff .word 00h,0ah,0bh
000000d8 00000000A
000000dc 00000000B
```
.loop/.endloop/.break  Assemble Code Block Repeatedly

Syntax

```
.loop [well-defined expression]
.break [well-defined expression]
.endloop
```

Description

Three directives allow you to repeatedly assemble a block of code:

The .loop directive begins a repeatable block of code. The optional expression evaluates to the loop count (the number of loops to be performed). If there is no well-defined expression, the loop count defaults to 1024, unless the assembler first encounters a .break directive with an expression that is true (nonzero) or omitted.

The .break directive, along with its expression, is optional. This means that when you use the .loop construct, you do not have to use the .break construct. The .break directive terminates a repeatable block of code only if the well-defined expression is true (nonzero) or omitted, and the assembler breaks the loop and assembles the code after the .endloop directive. If the expression is false (evaluates to 0), the loop continues.

The .endloop directive terminates a repeatable block of code; it executes when the .break directive is true (nonzero) or when the number of loops performed equals the loop count given by .loop.

Example

This example illustrates how these directives can be used with the .eval directive. The code in the first six lines expands to the code immediately following those six lines.

```
1  .eval  0,x
2  COEF .loop
3       .word    x*100
4  5       .eval   x+1, x
6  .break   x = 6
    .endloop
1 00000000 00000000 .word 0*100
1 00000004 00000064 .word 1*100
1 00000008 000000C8 .word 2*100
1 0000000C 0000012C .word 3*100
1 00000010 00000190 .word 4*100
1 00000014 000001F4 .word 5*100
1 0000001C 00000260 .word 6*100
```
.macro/.endm  Define Macro

Syntax

    macname .macro [parameter1, ... , parameterN]

    model statements or macro directives

    .endm

Description

The .macro and .endm directives are used to define macros.

You can define a macro anywhere in your program, but you must define the macro
before you can use it. Macros can be defined at the beginning of a source file, in an
.include/.copy file, or in a macro library.

macname  names the macro. You must place the name in the source
statement’s label field.

.macro  identifies the source statement as the first line of a macro
definition. You must place .macro in the opcode field.

[parameters]  are optional substitution symbols that appear as operands for the
.macro directive.

model statements  are instructions or assembler directives that are executed each
time the macro is called.

macro directives  are used to control macro expansion.

.endm  marks the end of the macro definition.

Macros are explained in further detail in Chapter 5.
Assign a Variable to a Register

Syntax

```
.map symbol, / register, [, symbol2 / register2, ...]
.clearmap
```

Description

The `.map` directive is used by the compiler when the input is linear assembly. The compiler tries to keep your symbolic names for registers defined with `.reg` by creating substitution symbols with `.map`.

The `.map` directive is similar to `.asg`, but uses a forward slash instead of a comma; and allows single quote characters in the symbolic names. For example, this linear assembly input:

```
fn: .cproc a, b, c
    .reg x, y, z
    ADD a, b, z
    ADD z, c, z
    .return z
    .endproc
```

Becomes this assembly code output:

```
fn:
    .map a/A4
    .map b/B4
    .map c/A6
    .map z/A4
    .map z'/A3
    RET .S2 B3
    ADD .L1X a,b,z'
    ADD .L1 z',c,z
    NOP 3
```

The `.clearmap` directive is used by the compiler to undefine all current `.map` substitution symbols.

See the *TMS320C6000 Optimizing Compiler v 7.0 User's Guide* for details on using the `.map` directive in linear assembly code.
.mlib

Define Macro Library

Syntax

.mlilb "filename"

Description

The .mlib directive provides the assembler with the filename of a macro library. A macro library is a collection of files that contain macro definitions. The macro definition files are bound into a single file (called a library or archive) by the archiver.

Each file in a macro library contains one macro definition that corresponds to the name of the file. The filename of a macro library member must be the same as the macro name, and its extension must be .asm. The filename must follow host operating system conventions; it can be enclosed in double quotes. You can specify a full pathname (for example, c:\320tools\macs.lib). If you do not specify a full pathname, the assembler searches for the file in the following locations in the order given:

1. The directory that contains the current source file
2. Any directories named with the --include_path assembler option
3. Any directories specified by the C6X_A_DIR environment variable
4. Any directories specified by the C6X_C_DIR environment variable

See Section 3.5 for more information about the --include_path option.

When the assembler encounters a .mlib directive, it opens the library specified by the filename and creates a table of the library's contents. The assembler enters the names of the individual library members into the opcode table as library entries. This redefines any existing opcodes or macros that have the same name. If one of these macros is called, the assembler extracts the entry from the library and loads it into the macro table. The assembler expands the library entry in the same way it expands other macros, but it does not place the source code into the listing. Only macros that are actually called from the library are extracted, and they are extracted only once.

See Chapter 5 for more information on macros and macro libraries.

Example

The code creates a macro library that defines two macros, inc1.asm and dec1.asm. The file inc1.asm contains the definition of inc1 and dec1.asm contains the definition of dec1.

Use the archiver to create a macro library:

```
ar6x -a mac inc1.asm dec1.asm
```

Now you can use the .mlib directive to reference the macro library and define the inc1.asm and dec1.asm macros:

```
1 .mlib "mac.lib"
2
3
4 00000000
5
```

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.mlist/.mnolist  

Start/Stop Macro Expansion Listing

Syntax

.mlister

.mnolist

Description

Two directives enable you to control the listing of macro and repeatable block expansions in the listing file:

The .mlist directive allows macro and .loop/.endloop block expansions in the listing file.

The .mnolist directive suppresses macro and .loop/.endloop block expansions in the listing file.

By default, the assembler behaves as if the .mlist directive had been specified.

See Chapter 5 for more information on macros and macro libraries. See the .loop/.break/.endloop topic for information on conditional blocks.

Example

This example defines a macro named STR_3. The first time the macro is called, the macro expansion is listed (by default). The second time the macro is called, the macro expansion is not listed, because a .mnolist directive was assembled. The third time the macro is called, the macro expansion is again listed because a .mlist directive was assembled.

```
1 STR_3 .macro P1, P2, P3
2    .string ":p1:", ":p2:", ":p3:"
3    .endm
4
5 00000000
1 00000000 0000003A
2 00000001 00000070
3 00000002 00000031
4 00000003 0000003A
5 00000004 0000003A
6 00000005 00000070
7 00000006 00000032
8 00000007 0000003A
9 00000008 0000003A
10 00000009 00000070
11 0000000a 00000033
12 0000000b 0000003A
13 0000000c 0000003A
14 0000000d 0000003A
15 0000000e 0000003A
16 0000000f 00000070
17 00000010 00000033
18 00000011 0000003A
19 00000012 0000003A
20 00000013 0000003A
21 00000014 00000070
22 00000015 00000032
23 00000016 0000003A
24 00000017 0000003A
25 00000018 0000003A
26 00000019 00000070
27 0000001a 00000031
28 0000001b 0000003A
29 0000001c 0000003A
30 0000001d 00000070
31 0000001e 00000032
32 0000001f 0000003A
33 00000020 0000003A
34 00000021 00000070
35 00000022 00000033
36 00000023 0000003A
```

1 STR_3 "as", "I", "am"
2 .string ":p1:", ":p2:", ":p3:"
3 .mlist
4
5 STR_3 "as", "I", "am"
6 .mnolist
7 STR_3 "as", "I", "am"
8 .mlist
9 STR_3 "as", "I", "am"
10 .string ":p1:", ":p2:", ":p3:"
11
.newblock

**Terminate Local Symbol Block**

**Syntax**

```
.newblock
```

**Description**

The **.newblock** directive undefines any local labels currently defined. Local labels, by nature, are temporary; the **.newblock** directive resets them and terminates their scope.

A local label is a label in the form $n$, where $n$ is a single decimal digit, or name?, where name is a legal symbol name. Unlike other labels, local labels are intended to be used locally, cannot be used in expressions, and do not qualify for branch expansion if used with a branch. They can be used only as operands in 8-bit jump instructions. Local labels are not included in the symbol table.

After a local label has been defined and (perhaps) used, you should use the **.newblock** directive to reset it. The **.text**, **.data**, and **.sect** directives also reset local labels. Local labels that are defined within an include file are not valid outside of the include file.

See Section 3.9.2 for more information on the use of local labels.

**Example**

This example shows how the local label $1$ is declared, reset, and then declared again.

```
1 .global table1, table2
2
3 00000000 00000028! MVKL table1,A0
4 00000004 00000068! MVKH table1,A0
5 00000008 008031A9 MVK 99, A1
6 0000000c 010848C0 || ZERO A2
7
8 00000010 80000212 $1:[A1] B $1
9 00000014 01003674 STW A2, *A0++
10 00000018 0087E1A0 SUB A1,1,A1
11 0000001c 00004000 NOP 3
12
13 .newblock ; undefine $1
14
15 00000020 00000028! MVKL table2,A0
16 00000024 00000068! MVKH table2,A0
17 00000028 008031A9 MVK 99, A1
18 0000002c 010829C0 || SUB A2,1,A2
19
20 00000030 80000212 $1:[A1] B $1
21 00000034 01003674 STW A2, *A0++
22 00000038 0087E1A0 SUB A1,1,A1
23 0000003c 00004000 NOP 3
```
Do Not Utilize 16-Bit Instructions in Section

Syntax

```
.nocmp
```

Description

The C6400+ and C6740 .nocmp directive instructs the compiler to not utilize 16-bit instructions for the code section .nocmp appears in. The .nocmp directive can appear anywhere in the section.

Example

In the example, the section one is not compressed, whereas section two is compressed.

```
.sect "one"
LDW *A4, A5
LDW *B4, A5
.nocmp
NOP 4
ADD A4, A5, A6
ADD B4, B5, B6
NOP
...

.sect "two"
ADD A4, A5, A6
NOP
NOP
...```
**Syntax**

- `.noremark num`
- `.remark [num]`

**Description**

The `.noremark` directive suppresses the assembler remark identified by `num`. A remark is an informational assembler message that is less severe than a warning.

This directive is equivalent to using the `-ar[num]` assembler option.

The `.remark` directive re-enables the remark(s) previously suppressed.

**Example**

This example shows how to suppress the R5002 remark:

**Partial source file:**

```
;;; cl6x -mv6700+ usenoremark.asm
.noremark 5002
ADDSP A4, A4, A4
```

**Resulting listing file:**

```
"usenoremark.asm", REMARK at line 4: [R5002] An ADDSP/SUBSP, ADDDP/SUBDP instruction has no unit specifier, but the assembler can place it on the .L or .S unit on C6700+. On C6700+, the lack of unit specifier may cause an unintended functional unit conflict in 4/7th cycle on the .L or .S unit. Please check and add unit specifiers to these instructions to avoid this hazard. Details can be found in section "Constrains on Floating-Point Instructions" and "Functional Unit Constraints" in document SPRU733

ADDSP A4, A4, A4
```
.option Select Listing Options

Syntax

`.option` `option_1[, option_2... ]`

Description

The `.option` directive selects options for the assembler output listing. The options must be separated by commas; each option selects a listing feature. These are valid options:

- **A**: turns on listing of all directives and data, and subsequent expansions, macros, and blocks.
- **B**: limits the listing of `.byte` and `.char` directives to one line.
- **D**: turns off the listing of certain directives (same effect as `.drnolist`).
- **H**: limits the listing of `.half` and `.short` directives to one line.
- **L**: limits the listing of `.long` directives to one line.
- **M**: turns off macro expansions in the listing.
- **N**: turns off listing (performs `.nolist`).
- **O**: turns on listing (performs `.list`).
- **T**: limits the listing of `.string` directives to one line.
- **W**: limits the listing of `.word` and `.int` directives to one line.
- **X**: produces a cross-reference listing of symbols. You can also obtain a cross-reference listing by invoking the assembler with the --cross_reference option (see Section 3.3).

Options are not case sensitive.

Example

This example shows how to limit the listings of the `.byte`, `.char`, `.int`, `.long`, `.word`, and `.string` directives to one line each.

```
1 ****************************************
2 ** Limit the listing of .byte, .char, **
3 ** .int, .word, and .string **
4 ** directives to 1 line each. **
5 ****************************************
6 .option B, W, T
7 00000000 000000BD .byte -'C', 0B0h, 5
8 00000003 000000BC .char -'D', 0C0h, 6
9 00000008 0000000A .int 10, 35 + 'a', "abc"
10 0000001c AABBCCDD .long 0AABBCCDDh, 536 + 'A'
11 00000024 0000015AA .word 5546, 78h
12 0000002c 00000052 .string "Registers"
13
14 ****************************************
15 ** Reset the listing options. **
16 ****************************************
17 .option R
18 00000035 000000BD .byte -'C', 0B0h, 5
19 00000036 000000B0 00000037 00000005
20 00000038 000000BC .char -'D', 0C0h, 6
21 00000039 000000C0 0000003a 00000006
22 0000003c 0000000A .int 10, 35 + 'a', "abc"
23 00000040 00000084 00000044 00000061
24 00000048 00000062 0000004c 00000063
25 00000050 AABBCCDD .long 0AABBCCDDh, 536 + 'A'
26 00000054 00000052 00000058 000015AA
27 00000056 00000078 .word 5546, 78h
28 00000060 00000052 .string "Registers"
29 00000061 00000065 00000062 00000067
```
.page

**Eject Page in Listing**

**Syntax**

```
.page
```

**Description**

The `.page` directive produces a page eject in the listing file. The `.page` directive is not printed in the source listing, but the assembler increments the line counter when it encounters the `.page` directive. Using the `.page` directive to divide the source listing into logical divisions improves program readability.

**Example**

This example shows how the `.page` directive causes the assembler to begin a new page of the source listing.

**Source file:**

Source file (generic)
```
.title  "**** Page Directive Example *****"
;   .
;   .
;   .
.page
```

**Listing file:**

```
**** Page Directive Example ***** PAGE 1

TMS320C6000 Assembler Version x.xx Day Time Year
Copyright (c) 1996-2009 Texas Instruments Incorporated
2 ;
3 ;
4 ;
```

```
**** Page Directive Example ***** PAGE 2

TMS320C6000 Assembler Version x.xx Day Time Year
Copyright (c) 1996-2009 Texas Instruments Incorporated
```

No Errors, No Warnings
.sect

Assemble Into Named Section

Syntax

.sect " section name "
.sect " section name " [ ,[RO|RW] ] [ ,[ALLOC|NOALLOC] ]

Description

The .sect directive defines a named section that can be used like the default .text and .data sections. The .sect directive tells the assembler to begin assembling source code into the named section.

The section name identifies the section. The section name must be enclosed in double quotes. A section name can contain a subsection name in the form section name : subsection name.

In ELF mode the sections can be marked read-only (RO) or read-write (RW). Also, the sections can be marked for allocation (ALLOC) or no allocation (NOALLOC). These attributes can be specified in any order, but only one attribute from each set can be selected. RO conflicts with RW, and ALLOC conflicts with NOALLOC. If conflicting attributes are specified the assembler generates an error, for example:

"t.asm", ERROR! at line 1:[E0000] Attribute RO cannot be combined with attr RW
.sect "illegal_sect",RO,RW

The extra operands are allowed only in ELF mode. They are ignored but generate a warning in COFF mode. For example:

"t.asm", WARNING! at line 1:[W0000] Trailing operands ignored
.sect "cosnt_sect",RO

See Chapter 2 for more information about sections.

Example

This example defines two special-purpose sections, Sym_Defs and Vars, and assembles code into them.

1 **********************************************
2 ** Begin assembling into .text section. **
3 **********************************************
4 00000000 .text
5 00000000 000005E0 ZERO A0
6 00000004 008425E0 ZERO A1
7
8 **********************************************
9 ** Begin assembling into vars section. **
10 **********************************************
11 00000000 .sect "vars"
12 00000000 4048F5C3 pi .float 3.14
13 00000004 000007D0 max .int 2000
14 00000008 00000001 min .int 1
15
16 **********************************************
17 ** Resume assembling into .text section. **
18 **********************************************
19 00000000 .text
20 00000008 010000A8 MVK 1,A2
21 0000000c 018000A8 MVK 1,A3
22
23 **********************************************
24 ** Resume assembling into vars section. **
25 **********************************************
26 0000000c .sect "vars"
27 0000000c 00000019 count .short 25
.set/.equ

Define Assembly-Time Constant

Syntax

symbol .set value

symbol .equ value

Description

The .set and .equ directives equate a constant value to a symbol. The symbol can then be used in place of a value in assembly source. This allows you to equate meaningful names with constants and other values. The .set and .equ directives are identical and can be used interchangeably.

- The symbol is a label that must appear in the label field.
- The value must be a well-defined expression, that is, all symbols in the expression must be previously defined in the current source module.

Undefined external symbols and symbols that are defined later in the module cannot be used in the expression. If the expression is relocatable, the symbol to which it is assigned is also relocatable.

The value of the expression appears in the object field of the listing. This value is not part of the actual object code and is not written to the output file.

Symbols defined with .set or .equ can be made externally visible with the .def or .global directive (see the .global/.def/.ref topic). In this way, you can define global absolute constants.

Example

This example shows how symbols can be assigned with .set and .equ.

```assembly
1 **********************************************
2 ** Equate symbol AUX_R1 to register A1 **
3 ** and use it instead of the register. **
4 **********************************************
5 00000001 AUX_R1 .set A1
6 00000000 00B802D4 STH AUX_R1,*+B14
7
8 **********************************************
9 ** Set symbol index to an integer expr. **
10 ** and use it as an immediate operand. **
11 **********************************************
12 00000035 INDEX .equ 100/2 +3
13 00000004 01001AD0 ADDK INDEX, A2
14
15 **********************************************
16 ** Set symbol SYMTAB to a relocatable expr. **
17 ** and use it as a relocatable operand. **
18 **********************************************
19 00000008 000000A LABEL .word 10
20 00000009' SYMTAB .set LABEL + 1
21
22 **********************************************
23 ** Set symbol NSYMS equal to the symbol **
24 ** INDEX and use it as you would INDEX. **
25 **********************************************
26 00000035 NSYMS .set INDEX
27 0000000c 00000035 .word NSYMS
```
.space/.bes

** Reserve Space **

** Syntax **

```
[label] .space  size in bytes
[label] .bes   size in bytes
```

** Description **

The .space and .bes directives reserve the number of bytes given by size in bytes in the current section and fill them with 0s. The section program counter is incremented to point to the word following the reserved space.

When you use a label with the .space directive, it points to the first byte reserved. When you use a label with the .bes directive, it points to the last byte reserved.

** Example **

This example shows how memory is reserved with the .space and .bes directives.

```
1  ****************************************************
2  ** Begin assembling into the .text section. **
3  ****************************************************
4 00000000 .text
5  ****************************************************
6  ** Reserve 0F0 bytes (60 words in .text section). **
7  ****************************************************
8 00000000 .space 0F0h
9 000000f0 00000100 .word 100h, 200h
10 ****************************************************
11  ** Begin assembling into the .data section. **
12  ****************************************************
13 00000000 .data
14 00000000 00000049 .string "In .data"
15 00000001 0000006E
16 00000002 00000020
17 00000003 0000002E
18 00000004 00000064
19 00000005 00000061
20 00000006 00000074
21 00000007 00000061
22  ****************************************************
23  ** Reserve 100 bytes in the .data section; **
24  ** RES_1 points to the first word that contains reserved bytes. **
25  ****************************************************
26 00000008 RES_1: .space 100
27 0000000c 0000000f .word 15
28 00000070 00000008" .word RES_1
29  ****************************************************
30  ** Reserve 20 bytes in the .data section; **
31  ** RES_2 points to the last word that contains reserved bytes. **
32  ****************************************************
33 00000087 RES_2: .bes 20
34 00000088 00000036 .word 36h
35 0000008c 00000087" .word RES_2
```

Control Listing of Substitution Symbols

Syntax

.sslist

.ssnnolist

Description

Two directives allow you to control substitution symbol expansion in the listing file:

The .sslist directive allows substitution symbol expansion in the listing file. The expanded line appears below the actual source line.

The .ssnnolist directive suppresses substitution symbol expansion in the listing file.

By default, all substitution symbol expansion in the listing file is suppressed; the assembler acts as if the .ssnnolist directive had been used.

Lines with the pound (#) character denote expanded substitution symbols.

Example

This example shows code that, by default, suppresses the listing of substitution symbol expansion, and it shows the .sslist directive assembled, instructing the assembler to list substitution symbol code expansion.

```
1 00000000 .bss x,4
2 00000004 .bss y,4
3 00000008 .bss z,4
4 5 addm .macro src1,src2,dst
6 LDW *+B14(:src1:), A0
7 LDW *+B14(:src2:), A1
8 NOP 4
9 ADD A0,A1,A0
10 STW A0,**B14(:dst:)
11 .endm
12
13 00000000 addm x,y,z
1 00000000 0000006C- LDW *+B14(x), A0
1 00000004 0080016C- LDW *+B14(y), A1
1 00000008 00006000 NOP 4
1 00000010 00004016C- ADD A0,A1,A0
1 00000014 0000027C- STW A0,**B14(z)
14 15 .sslist
16 00000014 addm x,y,z
1 00000014 0000006C- LDW *+B14(:src1:), A0
# LDW *+B14(x), A0
1 00000018 0080016C- LDW *+B14(:src2:), A1
# LDW *+B14(y), A1
1 0000001c 00006000 NOP 4
1 00000020 00004016C- ADD A0,A1,A0
1 00000024 0000027C- STW A0,**B14(:dst:)
# STW A0,**B14(z)
17
```
.string/.cstring  

**Syntax**

```plaintext
.string \{expr | "string,"\} [ , ... , \{expr | "string,"\} ]
.cstring \{expr | "string,"\} [ , ... , \{expr | "string,"\} ]
```

**Description**

The `.string` and `.cstring` directives place 8-bit characters from a character string into the current section. The `expr` or `string` can be one of the following:

- An expression that the assembler evaluates and treats as an 8-bit signed number.
- A character string enclosed in double quotes. Each character in a string represents a separate value, and values are stored in consecutive bytes. The entire string must be enclosed in quotes.

The `.cstring` directive adds a NUL character needed by C; the `.string` directive does not add a NUL character. In addition, `.cstring` interprets C escapes (\`\` \a \b \f \n \r \t \v \<octal>\).

The assembler truncates any values that are greater than eight bits. Operands must fit on a single source statement line.

If you use a label, it points to the location of the first byte that is initialized.

When you use `.string` and `.cstring` in a `.struct/.endstruct` sequence, the directive only defines a member's size; it does not initialize memory. For more information, see the `.struct/.endstruct/.tag` topic.

**Example**

In this example, 8-bit values are placed into consecutive bytes in the current section. The label `Str_Ptr` has the value 0h, which is the location of the first initialized byte.

```plaintext
1 00000000 00000041 Str_Ptr: .string "ABCD"
  00000001 00000042
  00000002 00000043
  00000003 00000044
2 00000004 00000041 .string 41h, 42h, 43h, 44h
  00000005 00000042
  00000006 00000043
  00000007 00000044
3 00000008 00000041 .string "Austin", "Houston"
  00000009 00000075
  0000000a 00000073
  0000000b 00000074
  0000000c 00000069
  0000000d 0000006e
  0000000e 00000048
  0000000f 0000006f
  00000010 00000075
  00000011 00000073
  00000012 00000074
  00000013 0000006f
  00000014 0000006e
4 00000015 00000030 .string 36 + 12
```
.struct/.endstruct/.tag  Declare Structure Type

Syntax

\[
\begin{align*}
\text{[stag]} & \quad \text{.struct} & \quad \text{[expr]} \\
\text{[mem]} & \quad \text{element} & \quad \text{[expr]} \\
\text{[mem]} & \quad \text{element} & \quad \text{[expr]} \\
\cdot & \quad \cdot & \quad \cdot \\
\cdot & \quad \cdot & \quad \cdot \\
\text{[mem]} & \quad \text{.tag} & \quad \text{stag} & \quad \text{[expr]} \\
\cdot & \quad \cdot & \quad \cdot \\
\cdot & \quad \cdot & \quad \cdot \\
\text{[mem]} & \quad \text{element} & \quad \text{[expr]} \\
\text{[size]} & \quad \text{.endstruct} \\
\text{label} & \quad \text{.tag} & \quad \text{stag}
\end{align*}
\]

Description

The .struct directive assigns symbolic offsets to the elements of a data structure definition. This allows you to group similar data elements together and let the assembler calculate the element offset. This is similar to a C structure or a Pascal record. The .struct directive does not allocate memory; it merely creates a symbolic template that can be used repeatedly.

The .endstruct directive terminates the structure definition.

The .tag directive gives structure characteristics to a label, simplifying the symbolic representation and providing the ability to define structures that contain other structures. The .tag directive does not allocate memory. The structure tag (stag) of a .tag directive must have been previously defined.

Following are descriptions of the parameters used with the .struct, .endstruct, and .tag directives:

- The stag is the structure's tag. Its value is associated with the beginning of the structure. If no stag is present, the assembler puts the structure members in the global symbol table with the value of their absolute offset from the top of the structure. A .stag is optional for .struct, but is required for .tag.
- The expr is an optional expression indicating the beginning offset of the structure. The default starting point for a structure is 0.
- The memn/N is an optional label for a member of the structure. This label is absolute and equates to the present offset from the beginning of the structure. A label for a structure member cannot be declared global.
- The element is one of the following descriptors: .byte, .char, .int, .long, .word, .double, .half, .short, .string, .float, .field, and .tag. All of these except .tag are typical directives that initialize memory. Following a .struct directive, these directives describe the structure element's size. They do not allocate memory. The .tag directive is a special case because stag must be used (as in the definition of stag).
- The exprn/N is an optional expression for the number of elements described. This value defaults to 1. A .string element is considered to be one byte in size, and a .field element is one bit.
- The size is an optional label for the total size of the structure.

Directives That Can Appear in a .struct/.endstruct Sequence

NOTE: The only directives that can appear in a .struct/.endstruct sequence are element descriptors, conditional assembly directives, and the .align directive, which aligns the member offsets on word boundaries. Empty structures are illegal.
The following examples show various uses of the .struct, .tag, and .endstruct directives.

Example 1

1  real_rec .struct ; stag
2   00000000 nom .int ; member1 = 0
3   00000004 den .int ; member2 = 1
4   00000008 real_len .endstruct ; real_len = 2
5
6 00000000 0080016C- LDW *+B14(real+real_rec.den), A1
7 ; access structure
8
9 00000000 .bss real, real_len ; allocate mem rec
10

Example 2

11 cplx_rec .struct ; stag
12 00000000 reali .tag real_rec ; member1 = 0
13 00000008 imagi .tag real_rec ; member2 = 2
14 00000010 cplx_len .endstruct ; cplx_len = 4
15
16 complex .tag cplx_rec ; assign structure
17 ; attribute
18 00000008 .bss complex, cplx_len ; allocate mem rec
19
20 00000004 0100046C- LDW *+B14(complex.imagi.nom), A2
21 ; access structure
22 00000008 0100036C- LDW *+B14(complex.reali.den), A2
23 ; access structure
24 0000000c 018C4A78 CMPEQ A2, A3, A3

Example 3

1 .struct ; no stag puts
2 ; mems into global
3 ; symbol table
4
5 00000000 X .byte ; create 3 dim
6 00000001 Y .byte ; templates
7 00000002 Z .byte
8 00000003 .endstruct

Example 4

1  bit_rec .struct ; stag
2   00000000 stream .string 64
3   00000040 bit7 .field 7 ; bit7 = 64
4   00000040 bit9 .field 9 ; bit9 = 64
5   00000042 bit5 .field 10 ; bit5 = 64
6   00000044 x_int .byte ; x_int = 68
7   00000045 bit_len .endstruct ; length = 72
8
9   bits .tag bit_rec
10 00000000 .bss bits, bit_len
11
12 00000000 0100106C- LDW *+B14(bits.bit7), A2
13 ; load field
14 00000004 0109E7A0 AND 0Fh, A2, A2 ; mask off garbage
.symdepend/.weak

Effect Symbol Linkage and Visibility

Syntax

- **.symdepend** dst symbol name[, src symbol name]
- **.weak** symbol name

Description

These directives are used to effect symbol linkage and visibility. The .weak directive is only valid when ELF mode is used.

The .symdepend directive creates an artificial reference from the section defining src symbol name to the symbol dst symbol name. This prevents the linker from removing the section containing dst symbol name if the section defining src symbol name is included in the output module. If src symbol name is not specified, a reference from the current section is created.

The .weak directive identifies a symbol that is used in the current module but is defined in another module. The linker resolves this symbol’s definition at link time. The .weak directive is equivalent to the .ref directive, except that the reference has weak linkage.

A global symbol is defined in the same manner as any other symbol; that is, it appears as a label or is defined by the .set, .equ, .bss, or .usect directive. As with all symbols, if a global symbol is defined more than once, the linker issues a multiple-definition error. The .weak directive always creates a symbol table entry for a symbol, whether the module uses the symbol or not; .symdepend, however, creates an entry only if the module actually uses the symbol.

A symbol can be declared global for either of two reasons:

- If the symbol is not defined in the current module (which includes macro, copy, and include files), the .weak directive tells the assembler that the symbol is defined in an external module. This prevents the assembler from issuing an unresolved reference error. At link time, the linker looks for the symbol’s definition in other modules.

- If the symbol is defined in the current module, the .symdepend directive declares that the symbol and its definition can be used externally by other modules. These types of references are resolved at link time.
.tab Define Tab Size

Syntax

.tab size

Description

The .tab directive defines the tab size. Tabs encountered in the source input are translated to size character spaces in the listing. The default tab size is eight spaces.

Example

In this example, each of the lines of code following a .tab statement consists of a single tab character followed by an NOP instruction.

Source file:

; default tab size
NOP
NOP
NOP
.tab 4
NOP
NOP
NOP
.tab 16
NOP
NOP
NOP

Listing file:

1 ; default tab size
  00000000 00000000 NOP
  00000004 00000000 NOP
  00000008 00000000 NOP
  0000000c 00000000 NOP
  00000010 00000000 NOP
  00000014 00000000 NOP
  00000018 00000000 NOP
  0000001c 00000000 NOP
  00000020 00000000 NOP
Assemble Into the .text Section

Syntax

.text

Description

The .text directive tells the assembler to begin assembling into the .text section, which usually contains executable code. The section program counter is set to 0 if nothing has yet been assembled into the .text section. If code has already been assembled into the .text section, the section program counter is restored to its previous value in the section.

The .text section is the default section. Therefore, at the beginning of an assembly, the assembler assembles code into the .text section unless you use a .data or .sect directive to specify a different section.

For more information about sections, see Chapter 2.

Example

This example assembles code into the .text and .data sections.

```
1 ******************************************
2 ** Begin assembling into .data section. **
3 ******************************************
4 00000000 .data
5 00000000 00000005 .byte 5,6
6 00000001 00000006
7 ******************************************
8 ** Begin assembling into .text section. **
9 ******************************************
10 00000000 .text
11 00000000 00000001 .byte 1
12 00000001 00000002 .byte 2,3
13 00000002 00000003
14 ******************************************
15 ** Resume assembling into .data section. **
16 ******************************************
17 00000002 .data
18 00000002 00000007 .byte 7,8
19 00000003 00000008
20 ******************************************
21 ** Resume assembling into .text section. **
22 ******************************************
23 00000003 .text
24 00000003 00000004 .byte 4
```
.title  Define Page Title

Syntax  .title "string"

Description  The .title directive supplies a title that is printed in the heading on each listing page. The source statement itself is not printed, but the line counter is incremented.

The string is a quote-enclosed title of up to 64 characters. If you supply more than 64 characters, the assembler truncates the string and issues a warning:

*** WARNING! line x: W0001: String is too long - will be truncated

The assembler prints the title on the page that follows the directive and on subsequent pages until another .title directive is processed. If you want a title on the first page, the first source statement must contain a .title directive.

Example  In this example, one title is printed on the first page and a different title is printed on succeeding pages.

Source file:

```
.title "**** Fast Fourier Transforms ****"
;
;
.
.title "**** Floating-Point Routines ****"
.page
```

Listing file:

```
**** Fast Fourier Transforms **** PAGE 1

2 ;
3 ;
4 ;

**** Floating-Point Routines **** PAGE 2
```

No Errors, No Warnings
**.union/.endunion/.tag Declare Union Type**

**Syntax**

```
[stag] .union [expr]
[mem₀] element [expr₀]
[mem₁] element [expr₁]
. . .
[memₙ] element [exprₙ]
[mem_N] .tag stag [exprₙ]
. . .
[mem_N] element [exprₙ]
[size] .endunion
label .tag stag
```

**Description**

The `.union` directive assigns symbolic offsets to the elements of alternate data structure definitions to be allocated in the same memory space. This enables you to define several alternate structures and then let the assembler calculate the element offset. This is similar to a C union. The `.union` directive does not allocate any memory; it merely creates a symbolic template that can be used repeatedly.

A `.struct` definition can contain a `.union` definition, and `.structs` and `.unions` can be nested.

The `.endunion` directive terminates the union definition.

The `.tag` directive gives structure or union characteristics to a `label`, simplifying the symbolic representation and providing the ability to define structures or unions that contain other structures or unions. The `.tag` directive does not allocate memory. The structure or union tag of a `.tag` directive must have been previously defined.

Following are descriptions of the parameters used with the `.struct`, `.endstruct`, and `.tag` directives:

- The `utag` is the union's tag. It is the union's tag. Its value is associated with the beginning of the union. If no `utag` is present, the assembler puts the union members in the global symbol table with the value of their absolute offset from the top of the union. In this case, each member must have a unique name.
- The `expr` is an optional expression indicating the beginning offset of the union. Unions default to start at 0. This parameter can only be used with a top-level union. It cannot be used when defining a nested union.
- The `memᵢ` is an optional label for a member of the union. This label is absolute and equates to the present offset from the beginning of the union. A label for a union member cannot be declared global.
- The `element` is one of the following descriptors: `.byte`, `.char`, `.int`, `.long`, `.word`, `.double`, `.half`, `.short`, `.string`, `.float`, and `.field`. An element can also be a complete declaration of a nested structure or union, or a structure or union declared by its tag. Following a `.union` directive, these directives describe the element's size. They do not allocate memory.
- The `exprᵢ` is an optional expression for the number of elements described. This value defaults to 1. A `.string` element is considered to be one byte in size, and a `.field` element is one bit.
- The `size` is an optional label for the total size of the union.
Directives That Can Appear in a .union/.endunion Sequence

**NOTE:** The only directives that can appear in a .union/.endunion sequence are element descriptors, structure and union tags, and conditional assembly directives. Empty structures are illegal.

These examples show unions with and without tags.

**Example 1**

```
1 .global employid
2    xample .union ; utag
3 0000 ival .word ; member1 = int
4 0000 fval .float ; member2 = float
5 0000 sval .string ; member3 = string
6 0002 real_len .endunion ; real_len = 2
7
8 000000 .bss employid, real_len ; allocate memory
9
10 employid .tag xample ; name an instance
11 000000 0000- ADD employid.fval, A ; access union element
```

**Example 2**

```
1
2    ; utag
3 0000 x .long ; member1 = long
4 0000 y .float ; member2 = float
5 0000 z .word ; member3 = word
6 0002 size_u .endunion ; real_len = 2
7
```
.usect **Reserve Uninitialized Space**

**Syntax**

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

**Description**

The .usect directive reserves space for variables in an uninitialized, named section. This directive is similar to the .bss directive; both simply reserve space for data and that space has no contents. However, .usect defines additional sections that can be placed anywhere in memory, independently of the .bss section.

- The **symbol** points to the first location reserved by this invocation of the .usect directive. The symbol corresponds to the name of the variable for which you are reserving space.

- The **section name** must be enclosed in double quotes. This parameter names the uninitialized section. A section name can contain a subsection name in the form section name : subsection name.

- The **size in bytes** is an expression that defines the number of bytes that are reserved in section name.

- The **alignment** is an optional parameter that ensures that the space allocated to the symbol occurs on the specified boundary. This boundary indicates the size of the slot in bytes and must be set to a power of 2.

- The **bank offset** is an optional parameter that ensures that the space allocated to the symbol occurs on a specific memory bank boundary. The bank offset value measures the number of bytes to offset from the alignment specified before assigning the symbol to that location.

Initialized sections directives (.text, .data, and .sect) end the current section and tell the assembler to begin assembling into another section. A .usect or .bss directive encountered in the current section is simply assembled, and assembly continues in the current section.

Variables that can be located contiguously in memory can be defined in the same specified section; to do so, repeat the .usect directive with the same section name and the subsequent symbol (variable name).

For more information about sections, see Chapter 2.

**Example**

This example uses the .usect directive to define two uninitialized, named sections, var1 and var2. The symbol ptr points to the first byte reserved in the var1 section. The symbol array points to the first byte in a block of 100 bytes reserved in var1, and dflag points to the first byte in a block of 50 bytes in var1. The symbol vec points to the first byte reserved in the var2 section.
Figure 4-8 shows how this example reserves space in two uninitialized sections, var1 and var2.

```
1  ***************************************************
2  ** Assemble into .text section **
3  ***************************************************
4  00000000 .text
5  00000000 008001A0 MV A0,A1
6  ***************************************************
7  ** Reserve 2 bytes in var1. **
8  ***************************************************
9  00000000 ptr .usect "var1",2
10 00000000 0100004C- LDH *+B14(ptr),A2 ; still in .text
11 ***************************************************
12  ** Reserve 100 bytes in var1 **
13  ***************************************************
14  00000000 array .usect "var1",100
15 00000000 01800128- MVK array,A3 ; still in .text
16 00000000 01800068- MVKH array,A3
17  ***************************************************
18  ** Reserve 50 bytes in var1 **
19  ***************************************************
20  00000000 dflag .usect "var1",50
21 00000000 02003328- MVK dflag,A4
22 00000000 02000068- MVKH dflag,A4
23  ***************************************************
24  ** Reserve 100 bytes in var1 **
25  ***************************************************
26  00000000 vec .usect "var2",100
27 00000000 0000002A- MVK vec,B0 ; still in .text
28 00000000 0000006A- MVKH vec,B0
29  ***************************************************
```

Figure 4-8. The .usect Directive
### .unasg/.undefine  
**Turn Off Substitution Symbol**

**Syntax**  

```
.unasg symbol
.undefine symbol
```

**Description**  

The `.unasg` and `.undefine` directives remove the definition of a substitution symbol created using `.asg` or `.define`. The named `symbol` will be removed from the substitution symbol table from the point of the `.undefine` or `.unasg` to the end of the assembly file.

These directives can be used to remove from the assembly environment any C/C++ macros that may cause a problem. See Chapter 12 for more information about using C/C++ headers in assembly source.

### .var  
**Use Substitution Symbols as Local Variables**

**Syntax**  

```
.var sym_1 [, sym_2, ..., sym_n ]
```

**Description**  

The `.var` directive allows you to use substitution symbols as local variables within a macro. With this directive, you can define up to 32 local macro substitution symbols (including parameters) per macro.

The `.var` directive creates temporary substitution symbols with the initial value of the null string. These symbols are not passed in as parameters, and they are lost after expansion.

See Chapter 5 for information on macros.
The TMS320C6000™ assembler supports a macro language that enables you to create your own instructions. This is especially useful when a program executes a particular task several times. The macro language lets you:

- Define your own macros and redefine existing macros
- Simplify long or complicated assembly code
- Access macro libraries created with the archiver
- Define conditional and repeatable blocks within a macro
- Manipulate strings within a macro
- Control expansion listing

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<td>5.10 Macro Directives Summary</td>
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</tbody>
</table>
5.1 Using Macros

Programs often contain routines that are executed several times. Instead of repeating the source statements for a routine, you can define the routine as a macro, then call the macro in the places where you would normally repeat the routine. This simplifies and shortens your source program.

If you want to call a macro several times but with different data each time, you can assign parameters within a macro. This enables you to pass different information to the macro each time you call it. The macro language supports a special symbol called a substitution symbol, which is used for macro parameters. See Section 5.3 for more information.

Using a macro is a 3-step process.

- **Step 1. Define the macro.** You must define macros before you can use them in your program. There are two methods for defining macros:
  - (a) Macros can be defined at the beginning of a source file or in a copy/include file. See Section 5.2, Defining Macros, for more information.
  - (b) Macros can also be defined in a macro library. A macro library is a collection of files in archive format created by the archiver. Each member of the archive file (macro library) may contain one macro definition corresponding to the member name. You can access a macro library by using the .mlib directive. For more information, see Section 5.4.

- **Step 2. Call the macro.** After you have defined a macro, call it by using the macro name as a mnemonic in the source program. This is referred to as a macro call.

- **Step 3. Expand the macro.** The assembler expands your macros when the source program calls them. During expansion, the assembler passes arguments by variable to the macro parameters, replaces the macro call statement with the macro definition, then assembles the source code. By default, the macro expansions are printed in the listing file. You can turn off expansion listing by using the .mnolist directive. For more information, see Section 5.8.

When the assembler encounters a macro definition, it places the macro name in the opcode table. This redefines any previously defined macro, library entry, directive, or instruction mnemonic that has the same name as the macro. This allows you to expand the functions of directives and instructions, as well as to add new instructions.

5.2 Defining Macros

You can define a macro anywhere in your program, but you must define the macro before you can use it. Macros can be defined at the beginning of a source file or in a .copy/.include file (see Copy Source File); they can also be defined in a macro library. For more information about macro libraries, see Section 5.4.

Macro definitions can be nested, and they can call other macros, but all elements of the macro must be defined in the same file. Nested macros are discussed in Section 5.9.

A macro definition is a series of source statements in the following format:

```plaintext
macname .macro [parameter1, ] [ ... , parameterN] 
model statements or macro directives 
[.mexit]
.endm
```

- `macname` names the macro. You must place the name in the source statement's label field. Only the first 128 characters of a macro name are significant. The assembler places the macro name in the internal opcode table, replacing any instruction or previous macro definition with the same name.
- `.macro` is the directive that identifies the source statement as the first line of a macro definition. You must place .macro in the opcode field.
- `parameter1`, `parameterN` are optional substitution symbols that appear as operands for the .macro directive. Parameters are discussed in Section 5.3.
**Model Statements** are instructions or assembler directives that are executed each time the macro is called.

**Macro Directives** are used to control macro expansion.

**.mexit** is a directive that functions as a **goto .endm**. The .mexit directive is useful when error testing confirms that macro expansion fails and completing the rest of the macro is unnecessary.

**.endm** is the directive that terminates the macro definition.

If you want to include comments with your macro definition but do not want those comments to appear in the macro expansion, use an exclamation point to precede your comments. If you do want your comments to appear in the macro expansion, use an asterisk or semicolon. See Section 5.7 for more information about macro comments.

**Example 5-1** shows the definition, call, and expansion of a macro.

**Example 5-1. Macro Definition, Call, and Expansion**

Macro definition: The following code defines a macro, sadd4, with four parameters:

```
   sadd4 .macro r1,r2,r3,r4
   !
   ! sadd4  r1, r2 ,r3, r4
   ! r1 = r1 + r2 + r3 + r4 (saturated)
   !
   SADD  r1, r2, r1
   SADD  r1, r3, r1
   SADD  r1, r4, r1
   .endm
```

Macro call: The following code calls the sadd4 macro with four arguments:

```
10  00000000 sadd4  A0,A1,A2,A3
```

Macro expansion: The following code shows the substitution of the macro definition for the macro call. The assembler substitutes A0, A1, A2, and A3 for the r1, r2, r3, and r4 parameters of sadd4.

```
1  00000000 00040278  SADD  A0,A1,A0
1  00000004 00080278  SADD  A0,A2,A0
1  00000008 000C0278  SADD  A0,A3,A0
```
5.3 Macro Parameters/Substitution Symbols

If you want to call a macro several times with different data each time, you can assign parameters within the macro. The macro language supports a special symbol, called a substitution symbol, which is used for macro parameters.

Macro parameters are substitution symbols that represent a character string. These symbols can also be used outside of macros to equate a character string to a symbol name (see Section 3.9.6).

Valid substitution symbols can be up to 128 characters long and must begin with a letter. The remainder of the symbol can be a combination of alphanumeric characters, underscores, and dollar signs.

Substitution symbols used as macro parameters are local to the macro they are defined in. You can define up to 32 local substitution symbols (including substitution symbols defined with the .var directive) per macro. For more information about the .var directive, see Section 5.3.6.

During macro expansion, the assembler passes arguments by variable to the macro parameters. The character-string equivalent of each argument is assigned to the corresponding parameter. Parameters without corresponding arguments are set to the null string. If the number of arguments exceeds the number of parameters, the last parameter is assigned the character-string equivalent of all remaining arguments.

If you pass a list of arguments to one parameter or if you pass a comma or semicolon to a parameter, you must surround these terms with quotation marks.

At assembly time, the assembler replaces the macro parameter/substitution symbol with its corresponding character string, then translates the source code into object code.

Example 5-2 shows the expansion of a macro with varying numbers of arguments.

Example 5-2. Calling a Macro With Varying Numbers of Arguments

<table>
<thead>
<tr>
<th>Macro definition:</th>
<th>Calling the macro:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parms .macro a,b,c</td>
<td>Parms 100,label Parms 100,label,x,y</td>
</tr>
<tr>
<td>; a = :a:</td>
<td>; a = 100 ; a = 100</td>
</tr>
<tr>
<td>; b = :b:</td>
<td>; b = label ; b = label</td>
</tr>
<tr>
<td>; c = :c:</td>
<td>; c = x,y</td>
</tr>
<tr>
<td>.endm</td>
<td></td>
</tr>
<tr>
<td>Parms 100, , x</td>
<td>Parms &quot;100,200,300&quot;,x,y</td>
</tr>
<tr>
<td>; a = 100</td>
<td>; a = 100,200,300</td>
</tr>
<tr>
<td>; b = &quot; &quot;</td>
<td>; b = x</td>
</tr>
<tr>
<td>; c = x</td>
<td>; c = y</td>
</tr>
<tr>
<td>Parms &quot;&quot;&quot;string&quot;&quot;,x,y</td>
<td></td>
</tr>
<tr>
<td>; a = &quot;string&quot;</td>
<td></td>
</tr>
<tr>
<td>; b = x</td>
<td></td>
</tr>
<tr>
<td>; c = y</td>
<td></td>
</tr>
</tbody>
</table>
5.3.1 Directives That Define Substitution Symbols

You can manipulate substitution symbols with the .asg and .eval directives.

- The .asg directive assigns a character string to a substitution symbol. For the .asg directive, the quotation marks are optional. If there are no quotation marks, the assembler reads characters up to the first comma and removes leading and trailing blanks. In either case, a character string is read and assigned to the substitution symbol. The syntax of the .asg directive is:

  `.asg["character string"], substitution symbol`

Example 5-3 shows character strings being assigned to substitution symbols.

**Example 5-3. The .asg Directive**

```
.asg "A4", RETVAL ; return value
```

- The .eval directive performs arithmetic on numeric substitution symbols. The .eval directive evaluates the expression and assigns the string value of the result to the substitution symbol. If the expression is not well defined, the assembler generates an error and assigns the null string to the symbol. The syntax of the .eval directive is:

  `.eval well-defined expression , substitution symbol`

Example 5-4 shows arithmetic being performed on substitution symbols.

**Example 5-4. The .eval Directive**

```
.asg 1,counter
.loop 100
.word counter
.eval counter + 1, counter
.endloop
```

In Example 5-4, the .asg directive could be replaced with the .eval directive (.eval 1, counter) without changing the output. In simple cases like this, you can use .eval and .asg interchangeably. However, you must use .eval if you want to calculate a value from an expression. While .asg only assigns a character string to a substitution symbol, .eval evaluates an expression and then assigns the character string equivalent to a substitution symbol.

See Assign a Substitution Symbol for more information about the .asg and .eval assembler directives.
5.3.2 Built-In Substitution Symbol Functions

The following built-in substitution symbol functions enable you to make decisions on the basis of the string value of substitution symbols. These functions always return a value, and they can be used in expressions. Built-in substitution symbol functions are especially useful in conditional assembly expressions. Parameters of these functions are substitution symbols or character-string constants.

In the function definitions shown in Table 5-1, $a$ and $b$ are parameters that represent substitution symbols or character-string constants. The term string refers to the string value of the parameter. The symbol ch represents a character constant.

Table 5-1. Substitution Symbol Functions and Return Values

<table>
<thead>
<tr>
<th>Function</th>
<th>Return Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\text{symlen} (a)$</td>
<td>Length of string $a$</td>
</tr>
<tr>
<td>$\text{symcmp} (a,b)$</td>
<td>$&lt; 0$ if $a &lt; b$; $0$ if $a = b$; $&gt; 0$ if $a &gt; b$</td>
</tr>
<tr>
<td>$\text{firstch} (a,ch)$</td>
<td>Index of the first occurrence of character constant ch in string $a$</td>
</tr>
<tr>
<td>$\text{lastch} (a,ch)$</td>
<td>Index of the last occurrence of character constant ch in string $a$</td>
</tr>
<tr>
<td>$\text{isdefined} (a)$</td>
<td>1 if string $a$ is defined in the symbol table</td>
</tr>
<tr>
<td></td>
<td>0 if string $a$ is not defined in the symbol table</td>
</tr>
<tr>
<td>$\text{ismember} (a,b)$</td>
<td>Top member of list $b$ is assigned to string $a$</td>
</tr>
<tr>
<td></td>
<td>0 if $b$ is a null string</td>
</tr>
<tr>
<td>$\text{iscons} (a)$</td>
<td>1 if string $a$ is a binary constant</td>
</tr>
<tr>
<td></td>
<td>2 if string $a$ is an octal constant</td>
</tr>
<tr>
<td></td>
<td>3 if string $a$ is a hexadecimal constant</td>
</tr>
<tr>
<td></td>
<td>4 if string $a$ is a character constant</td>
</tr>
<tr>
<td></td>
<td>5 if string $a$ is a decimal constant</td>
</tr>
<tr>
<td>$\text{isname} (a)$</td>
<td>1 if string $a$ is a valid symbol name</td>
</tr>
<tr>
<td></td>
<td>0 if string $a$ is not a valid symbol name</td>
</tr>
<tr>
<td>$\text{isreg} (a)$</td>
<td>1 if string $a$ is a valid predefined register name</td>
</tr>
<tr>
<td></td>
<td>0 if string $a$ is not a valid predefined register name</td>
</tr>
</tbody>
</table>

For more information about predefined register names, see Section 3.9.5.

Example 5-5 shows built-in substitution symbol functions.

Example 5-5. Using Built-In Substitution Symbol Functions

```
pushx .macro list
! Push more than one item
! $\text{ismember}$ removes the first item in the list

  .var item
  .loop
  .break ($\text{ismember}(item, list) = 0)
  STW item,*B15--[1]
  .endloop
  .endm

pushx A0,A1,A2,A3
```

Example 5-5 shows built-in substitution symbol functions.
5.3.3 Recursive Substitution Symbols

When the assembler encounters a substitution symbol, it attempts to substitute the corresponding character string. If that string is also a substitution symbol, the assembler performs substitution again. The assembler continues doing this until it encounters a token that is not a substitution symbol or until it encounters a substitution symbol that it has already encountered during this evaluation.

In Example 5-6, the x is substituted for z; z is substituted for y; and y is substituted for x. The assembler recognizes this as infinite recursion and ceases substitution.

Example 5-6. Recursive Substitution

```
.asg "x",z ; declare z and assign z = "x"
.asg "z",y ; declare y and assign y = "z"
.asg "y",x ; declare x and assign x = "y"
MVKL x, A1
MVKH x, A1
*MVKL x, A1 ; recursive expansion
*MVKH x, A1 ; recursive expansion
```

5.3.4 Forced Substitution

In some cases, substitution symbols are not recognizable to the assembler. The forced substitution operator, which is a set of colons surrounding the symbol, enables you to force the substitution of a symbol's character string. Simply enclose a symbol with colons to force the substitution. Do not include any spaces between the colons and the symbol.

The syntax for the forced substitution operator is:

```
:symbol:
```

The assembler expands substitution symbols surrounded by colons before expanding other substitution symbols.

You can use the forced substitution operator only inside macros, and you cannot nest a forced substitution operator within another forced substitution operator.

Example 5-7 shows how the forced substitution operator is used.

Example 5-7. Using the Forced Substitution Operator

```
force .macro x
    .loop 8
    PORT:x: .set x*4
    .eval x+1, x
    .endloop
    .endm
    .global portbase
force
PORT0 .set 0
PORT1 .set 4
         .
         .
PORT7 .set 28
```
5.3.5 Accessing Individual Characters of Subscripted Substitution Symbols

In a macro, you can access the individual characters (substrings) of a substitution symbol with subscripted substitution symbols. You must use the forced substitution operator for clarity.

You can access substrings in two ways:

- `:symbol (well-defined expression)`:
  - This method of subscripting evaluates to a character string with one character.
- `:symbol (well-defined expression , well-defined expression)`:
  - In this method, expression represents the substring's starting position, and expression represents the substring's length. You can specify exactly where to begin subscripting and the exact length of the resulting character string. The index of substring characters begins with 1, not 0.

Example 5-8 and Example 5-9 show built-in substitution symbol functions used with subscripted substitution symbols.

In Example 5-8, subscripted substitution symbols redefine the STW instruction so that it handles immediates. In Example 5-9, the subscripted substitution symbol is used to find a substring strg1 beginning at position start in the string strg2. The position of the substring strg1 is assigned to the substitution symbol pos.

Example 5-8. Using Subscripted Substitution Symbols to Redefine an Instruction

```assembly
storex .macro x
  .var tmp
  .asg :x(1):, tmp
  .if $symcmp(tmp,"A") == 0
  STW x,*A15--(4)
  .elseif $symcmp(tmp,"B") == 0
  STW x,*A15--(4)
  .elseif $iscons(x)
  MVK x,A0
  STW A0,*A15--(4)
  .else
  .emsg "Bad Macro Parameter"
  .endif
.endm

storex 10h
storex A15
```

Example 5-9. Using Subscripted Substitution Symbols to Find Substrings

```assembly
substr .macro start,strg1,strg2,pos
  .var len1,len2,i,tmp
  .if $symlen(start) = 0
  .eval 1,start
  .endif
  .eval 0,pos
  .eval start,i
  .eval $symlen(strg1),len1
  .eval $symlen(strg2),len2
  .loop
    .break I = (len2 - len1 + 1)
    .asg ":strg2(i,len1):",tmp
    .if $symcmp(strg1,tmp) = 0
    .eval i,pos
    .break
    .else
    .eval I + 1,i
    .endif
  .endloop
  .asg 0,pos
  .asg "ar1 ar2 ar3 ar4",regs
.endm
```

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Example 5-9. Using Subscripted Substitution Symbols to Find Substrings (continued)

```
substr   1,"ar2",regs,pos
.word    pos
```

5.3.6 Substitution Symbols as Local Variables in Macros

If you want to use substitution symbols as local variables within a macro, you can use the `.var` directive to define up to 32 local macro substitution symbols (including parameters) per macro. The `.var` directive creates temporary substitution symbols with the initial value of the null string. These symbols are not passed in as parameters, and they are lost after expansion.

```
.var    sym1,[sym2, ... ,symn]
```

The `.var` directive is used in Example 5-8 and Example 5-9.

5.4 Macro Libraries

One way to define macros is by creating a macro library. A macro library is a collection of files that contain macro definitions. You must use the archiver to collect these files, or members, into a single file (called an archive). Each member of a macro library contains one macro definition. The files in a macro library must be unassembled source files. The macro name and the member name must be the same, and the macro filename's extension must be .asm. For example:

<table>
<thead>
<tr>
<th>Macro Name</th>
<th>Filename in Macro Library</th>
</tr>
</thead>
<tbody>
<tr>
<td>simple</td>
<td>simple.asm</td>
</tr>
<tr>
<td>add3</td>
<td>add3.asm</td>
</tr>
</tbody>
</table>

You can access the macro library by using the `.mlib` assembler directive (described in Define Macro Library). The syntax is:

```
.mlib    filename
```

When the assembler encounters the `.mlib` directive, it opens the library named by filename and creates a table of the library's contents. The assembler enters the names of the individual members within the library into the opode tables as library entries; this redefines any existing opcodes or macros that have the same name. If one of these macros is called, the assembler extracts the entry from the library and loads it into the macro table.

The assembler expands the library entry in the same way it expands other macros. See Section 5.1 for how the assembler expands macros. You can control the listing of library entry expansions with the `.mlist` directive. For more information about the `.mlist` directive, see Section 5.8 and Start/Stop Macro Expansion Listing. Only macros that are actually called from the library are extracted, and they are extracted only once.

You can use the archiver to create a macro library by including the desired files in an archive. A macro library is no different from any other archive, except that the assembler expects the macro library to contain macro definitions. The assembler expects only macro definitions in a macro library; putting object code or miscellaneous source files into the library may produce undesirable results. For information about creating a macro library archive, see Section 6.1.
5.5 Using Conditional Assembly in Macros

The conditional assembly directives are .if/.elseif/.else/.endif and .loop/.break/.endloop. They can be nested within each other up to 32 levels deep. The format of a conditional block is:

```
.if well-defined expression
  [.elseif well-defined expression]
  [.else]
.endif
```

The .elseif and .else directives are optional in conditional assembly. The .elseif directive can be used more than once within a conditional assembly code block. When .elseif and .else are omitted and when the .if expression is false (0), the assembler continues to the code following the .endif directive. See Assemble Conditional Blocks for more information on the .if/.elseif/.else/.endif directives.

The .loop/.break/.endloop directives enable you to assemble a code block repeatedly. The format of a repeatable block is:

```
.loop [well-defined expression]
  [.break [well-defined expression]]
.endloop
```

The .loop directive's optional well-defined expression evaluates to the loop count (the number of loops to be performed). If the expression is omitted, the loop count defaults to 1024 unless the assembler encounters a .break directive with an expression that is true (nonzero). See Assemble Conditional Blocks Repeatedly for more information on the .loop/.break/.endloop directives.

The .break directive and its expression are optional in repetitive assembly. If the expression evaluates to false, the loop continues. The assembler breaks the loop when the .break expression evaluates to true or when the .break expression is omitted. When the loop is broken, the assembler continues with the code after the .endloop directive.

For more information, see Section 4.7.

Example 5-10, Example 5-11, and Example 5-12 show the .loop/.break/.endloop directives, properly nested conditional assembly directives, and built-in substitution symbol functions used in a conditional assembly code block.

**Example 5-10. The .loop/.break/.endloop Directives**

```
.asg 1,x
.loop
  .break (x == 10) ; if x == 10, quit loop/break with expression
  .eval x+1,x
.endloop
```
Example 5-11. Nested Conditional Assembly Directives

```assembly
.asg 1,x
.loop
  .if (x == 10) ; if x == 10, quit loop
  .break (x == 10) ; force break
  .endif
  .eval x+1,x
.endloop
```

Example 5-12. Built-In Substitution Symbol Functions in a Conditional Assembly Code Block

```assembly
MACK3 .macro src1, src2, sum, k
  dst = dst + k * (src1 * src2)
  .if k = 0
    MPY src1, src2, src2
    NOP
    ADD src2, sum, sum
  .else
    MPY src1, src2, src2
    MVK k, src1
    MPY src1, src2, src2
    NOP
    ADD src2, sum, sum
  .endif
.endm
MACK3 A0,A1,A3,0
MACK3 A0,A1,A3,100
```
5.6 Using Labels in Macros

All labels in an assembly language program must be unique. This includes labels in macros. If a macro is expanded more than once, its labels are defined more than once. **Defining a label more than once is illegal.** The macro language provides a method of defining labels in macros so that the labels are unique. Simply follow each label with a question mark, and the assembler replaces the question mark with a period followed by a unique number. When the macro is expanded, *you do not see the unique number in the listing file.* Your label appears with the question mark as it did in the macro definition. You cannot declare this label as global. The syntax for a unique label is:

```
label ?
```

**Example 5-13** shows unique label generation in a macro. The maximum label length is shortened to allow for the unique suffix. For example, if the macro is expanded fewer than 10 times, the maximum label length is 126 characters. If the macro is expanded from 10 to 99 times, the maximum label length is 125. The label with its unique suffix is shown in the cross-listing file. To obtain a cross-listing file, invoke the assembler with the `--cross_reference` option (see Section 3.3).

**Example 5-13. Unique Labels in a Macro**

```assembly
1 min .macro x,y,z
2
3 MV y,z
4 || CMPLT x,y,y
5 [y] B l?
6 NOP 5
7 MV x,z
8 l?
9 .endm
10
11 00000000 MIN A0,A1,A2
12
```

<table>
<thead>
<tr>
<th>LABEL</th>
<th>VALUE</th>
<th>DEFN</th>
<th>REF</th>
</tr>
</thead>
<tbody>
<tr>
<td>.TMS320C60</td>
<td>00000001</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>.tms320C60</td>
<td>00000001</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>$15</td>
<td>00000014'</td>
<td>12</td>
<td>12</td>
</tr>
</tbody>
</table>
5.7 Producing Messages in Macros

The macro language supports three directives that enable you to define your own assembly-time error and warning messages. These directives are especially useful when you want to create messages specific to your needs. The last line of the listing file shows the error and warning counts. These counts alert you to problems in your code and are especially useful during debugging.

.emsg sends error messages to the listing file. The .emsg directive generates errors in the same manner as the assembler, incrementing the error count and preventing the assembler from producing an object file.

.mmsg sends assembly-time messages to the listing file. The .mmsg directive functions in the same manner as the .emsg directive but does not set the error count or prevent the creation of an object file.

.wmsg sends warning messages to the listing file. The .wmsg directive functions in the same manner as the .emsg directive, but it increments the warning count and does not prevent the generation of an object file.

Macro comments are comments that appear in the definition of the macro but do not show up in the expansion of the macro. An exclamation point in column 1 identifies a macro comment. If you want your comments to appear in the macro expansion, precede your comment with an asterisk or semicolon.

Example 5-14 shows user messages in macros and macro comments that do not appear in the macro expansion.

For more information about the .emsg, .mmsg, and .wmsg assembler directives, see Define Messages.

Example 5-14. Producing Messages in a Macro

```assembly
TEST .macro x,y
! This macro checks for the correct number of parameters.
! It generates an error message if x and y are not present.
! The first line tests for proper input.
! .if ($symlen(x) + ||$symlen(y) == 0)
.emsg "ERROR --missing parameter in call to TEST"
.mexit
.else
 .
 .endif
.if
 .
 .endif
.endm
```
5.8 Using Directives to Format the Output Listing

Macros, substitution symbols, and conditional assembly directives may hide information. You may need to see this hidden information, so the macro language supports an expanded listing capability.

By default, the assembler shows macro expansions and false conditional blocks in the list output file. You may want to turn this listing off or on within your listing file. Four sets of directives enable you to control the listing of this information:

- **Macro and loop expansion listing**
  - `.mlist` expands macros and `.loop/.endloop` blocks. The `.mlist` directive prints all code encountered in those blocks.
  - `.mnolist` suppresses the listing of macro expansions and `.loop/.endloop` blocks.
  
  For macro and loop expansion listing, `.mlist` is the default.

- **False conditional block listing**
  - `.fclist` causes the assembler to include in the listing file all conditional blocks that do not generate code (false conditional blocks). Conditional blocks appear in the listing exactly as they appear in the source code.
  - `.fcnolist` suppresses the listing of false conditional blocks. Only the code in conditional blocks that actually assemble appears in the listing. The `.if`, `.elseif`, `.else`, and `.endif` directives do not appear in the listing.

  For false conditional block listing, `.fclist` is the default.

- **Substitution symbol expansion listing**
  - `.sslist` expands substitution symbols in the listing. This is useful for debugging the expansion of substitution symbols. The expanded line appears below the actual source line.
  - `.ssnolist` turns off substitution symbol expansion in the listing.

  For substitution symbol expansion listing, `.ssnolist` is the default.

- **Directive listing**
  - `.drlist` causes the assembler to print to the listing file all directive lines.
  - `.drnolist` suppresses the printing of certain directives in the listing file. These directives are `.asg`, `.eval`, `.var`, `.sslist`, `.mlist`, `.fclist`, `.ssnolist`, `.mnolist`, `.fcnolist`, `.emsg`, `.wmsg`, `.mmsg`, `.length`, `.width`, and `.break`.

  For directive listing, `.drlist` is the default.
5.9 Using Recursive and Nested Macros

The macro language supports recursive and nested macro calls. This means that you can call other macros in a macro definition. You can nest macros up to 32 levels deep. When you use recursive macros, you call a macro from its own definition (the macro calls itself).

When you create recursive or nested macros, you should pay close attention to the arguments that you pass to macro parameters because the assembler uses dynamic scoping for parameters. This means that the called macro uses the environment of the macro from which it was called.

Example 5-15 shows nested macros. The y in the in_block macro hides the y in the out_block macro. The x and z from the out_block macro, however, are accessible to the in_block macro.

Example 5-15. Using Nested Macros

```
in_block .macro y,a
    ; visible parameters are y,a and x,z from the calling macro
.endm
out_block .macro x,y,z
    ; visible parameters are x,y,z
    in_block x,y ; macro call with x and y as arguments
    .endm
out_block ; macro call
```

Example 5-16 shows recursive and fact macros. The fact macro produces assembly code necessary to calculate the factorial of n, where n is an immediate value. The result is placed in the A1 register. The fact macro accomplishes this by calling fact1, which calls itself recursively.

Example 5-16. Using Recursive Macros

```
.fcnolist
fact1 .macro n
    .if n == 1
        MVK globcnt, A1 ; Leave the answer in the A1 register.
    .else
        .eval 1, temp ; Compute the decrement of symbol n.
        .eval globcnt*temp, globcnt ; Multiply to get a new result.
        fact1 temp ; Recursive call.
    .endif
.endm
fact .macro n
    .if ! $iscons(n) ; Test that input is a constant.
        .emsg "Parm not a constant"
    .elseif n < 1 ; Type check input.
        MVK 0, A1
    .else
        .var temp
        .asg n, globcnt
        fact1 n ; Perform recursive procedure
    .endif
.endm
```

Macro Description

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5.10 Macro Directives Summary

The directives listed in Table 5-2 through Table 5-6 can be used with macros. The .macro, .mexit, .endm and .var directives are valid only with macros; the remaining directives are general assembly language directives.

Table 5-2. Creating Macros

<table>
<thead>
<tr>
<th>Mnemonic and Syntax</th>
<th>Description</th>
<th>See</th>
</tr>
</thead>
<tbody>
<tr>
<td>.endm</td>
<td>End macro definition</td>
<td>Section 5.2 .endm</td>
</tr>
<tr>
<td><code>macname .macro [parameter, ... , parameter_n]</code></td>
<td>Define macro by <code>macname</code></td>
<td>Section 5.2 .macro</td>
</tr>
<tr>
<td>.mexit</td>
<td>Go to .endm</td>
<td>Section 5.2</td>
</tr>
<tr>
<td>.mlib filename</td>
<td>Identify library containing macro definitions</td>
<td>Section 5.4 .mlib</td>
</tr>
</tbody>
</table>

Table 5-3. Manipulating Substitution Symbols

<table>
<thead>
<tr>
<th>Mnemonic and Syntax</th>
<th>Description</th>
<th>See</th>
</tr>
</thead>
<tbody>
<tr>
<td>.asg &quot;character string&quot;, substitution symbol</td>
<td>Assign character string to substitution symbol</td>
<td>Section 5.3.1 .asg</td>
</tr>
<tr>
<td>.eval well-defined expression, substitution symbol</td>
<td>Perform arithmetic on numeric substitution symbols</td>
<td>Section 5.3.1 .eval</td>
</tr>
<tr>
<td>.var <code>sym_1, sym_2, ..., sym_n</code></td>
<td>Define local macro symbols</td>
<td>Section 5.3.6 .var</td>
</tr>
</tbody>
</table>

Table 5-4. Conditional Assembly

<table>
<thead>
<tr>
<th>Mnemonic and Syntax</th>
<th>Description</th>
<th>See</th>
</tr>
</thead>
<tbody>
<tr>
<td>.break [well-defined expression]</td>
<td>Optional repeatable block assembly</td>
<td>Section 5.5 .break</td>
</tr>
<tr>
<td>.endif</td>
<td>End conditional assembly</td>
<td>Section 5.5 .endif</td>
</tr>
<tr>
<td>.endloop</td>
<td>End repeatable block assembly</td>
<td>Section 5.5 .endloop</td>
</tr>
<tr>
<td>.else</td>
<td>Optional conditional assembly block</td>
<td>Section 5.5 .else</td>
</tr>
<tr>
<td>.elseif well-defined expression</td>
<td>Optional conditional assembly block</td>
<td>Section 5.5 .elseif</td>
</tr>
<tr>
<td>.if well-defined expression</td>
<td>Begin conditional assembly</td>
<td>Section 5.5 .if</td>
</tr>
<tr>
<td>.loop [well-defined expression]</td>
<td>Begin repeatable block assembly</td>
<td>Section 5.5 .loop</td>
</tr>
</tbody>
</table>

Table 5-5. Producing Assembly-Time Messages

<table>
<thead>
<tr>
<th>Mnemonic and Syntax</th>
<th>Description</th>
<th>See</th>
</tr>
</thead>
<tbody>
<tr>
<td>.emsg</td>
<td>Send error message to standard output</td>
<td>Section 5.7 .emsg</td>
</tr>
<tr>
<td>.mmsg</td>
<td>Send assembly-time message to standard output</td>
<td>Section 5.7 .mmsg</td>
</tr>
<tr>
<td>.wmsg</td>
<td>Send warning message to standard output</td>
<td>Section 5.7 .wmsg</td>
</tr>
</tbody>
</table>

Table 5-6. Formatting the Listing

<table>
<thead>
<tr>
<th>Mnemonic and Syntax</th>
<th>Description</th>
<th>See</th>
</tr>
</thead>
<tbody>
<tr>
<td>.fclist</td>
<td>Allow false conditional code block listing (default)</td>
<td>Section 5.8 .fclist</td>
</tr>
<tr>
<td>.fcnolist</td>
<td>Suppress false conditional code block listing</td>
<td>Section 5.8 .fcnolist</td>
</tr>
<tr>
<td>.mlist</td>
<td>Allow macro listings (default)</td>
<td>Section 5.8 .mlist</td>
</tr>
<tr>
<td>.mnolist</td>
<td>Suppress macro listings</td>
<td>Section 5.8 .mnolist</td>
</tr>
<tr>
<td>.sslist</td>
<td>Allow expanded substitution symbol listing</td>
<td>Section 5.8 .sslist</td>
</tr>
<tr>
<td>.ssnolist</td>
<td>Suppress expanded substitution symbol listing (default)</td>
<td>Section 5.8 .ssnolist</td>
</tr>
</tbody>
</table>
Archiver Description

The TMS320C6000™ archiver lets you combine several individual files into a single archive file. For example, you can collect several macros into a macro library. The assembler searches the library and uses the members that are called as macros by the source file. You can also use the archiver to collect a group of object files into an object library. The linker includes in the library the members that resolve external references during the link. The archiver allows you to modify a library by deleting, replacing, extracting, or adding members.

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<tr>
<th>Topic</th>
<th>Page</th>
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<tbody>
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</tr>
</tbody>
</table>
6.1 Archiver Overview

You can build libraries from any type of files. Both the assembler and the linker accept archive libraries as input; the assembler can use libraries that contain individual source files, and the linker can use libraries that contain individual object files.

One of the most useful applications of the archiver is building libraries of object modules. For example, you can write several arithmetic routines, assemble them, and use the archiver to collect the object files into a single, logical group. You can then specify the object library as linker input. The linker searches the library and includes members that resolve external references.

You can also use the archiver to build macro libraries. You can create several source files, each of which contains a single macro, and use the archiver to collect these macros into a single, functional group. You can use the .mlib directive during assembly to specify that macro library to be searched for the macros that you call. Chapter 5 discusses macros and macro libraries in detail, while this chapter explains how to use the archiver to build libraries.

6.2 The Archiver's Role in the Software Development Flow

Figure 6-1 shows the archiver's role in the software development process. The shaded portion highlights the most common archiver development path. Both the assembler and the linker accept libraries as input.
Figure 6-1. The Archiver in the TMS320C6000 Software Development Flow

- C/C++ source files
- Assembler source
- Assembly optimizer
- Library-build process
- Run-time-support library
- EPROM programmer
- Absolute lister
- Cross-reference lister
- Object file utilities
- C6000
6.3 Invoking the Archiver

To invoke the archiver, enter:

```
ar6x [-command [options] libname [filename, ... filename, ]]
```

- `ar6x` is the command that invokes the archiver.
- `[-command` tells the archiver how to manipulate the existing library members and any specified. A command can be preceded by an optional hyphen. You must use one of the following commands when you invoke the archiver, but you can use only one command per invocation. The archiver commands are as follows:
  - `@` uses the contents of the specified file instead of command line entries. You can use this command to avoid limitations on command line length imposed by the host operating system. Use a `;` at the beginning of a line in the command file to include comments. (See Example 6-1 for an example using an archiver command file.)
  - `a` adds the specified files to the library. This command does not replace an existing member that has the same name as an added file; it simply appends new members to the end of the archive.
  - `d` deletes the specified members from the library.
  - `r` replaces the specified members in the library. If you do not specify filenames, the archiver replaces the library members with files of the same name in the current directory. If the specified file is not found in the library, the archiver adds it instead of replacing it.
  - `t` prints a table of contents of the library. If you specify filenames, only those files are listed. If you do not specify any filenames, the archiver lists all the members in the specified library.
  - `x` extracts the specified files. If you do not specify member names, the archiver extracts all library members. When the archiver extracts a member, it simply copies the member into the current directory; it does not remove it from the library.

- `options` In addition to one of the `commands`, you can specify options. To use options, combine them with a command; for example, to use the `a` command and the `s` option, enter `-as` or `as`. The hyphen is optional for archiver options only. These are the archiver options:
  - `-q` (quiet) suppresses the banner and status messages.
  - `-s` prints a list of the global symbols that are defined in the library. (This option is valid only with the `a`, `r`, and `d` commands.)
  - `-u` replaces library members only if the replacement has a more recent modification date. You must use the `r` command with the `-u` option to specify which members to replace.
  - `-v` (verbose) provides a file-by-file description of the creation of a new library from an old library and its members.

- `libname` names the archive library to be built or modified. If you do not specify an extension for `libname`, the archiver uses the default extension `.lib`.

- `filenames` names individual files to be manipulated. These files can be existing library members or new files to be added to the library. When you enter a filename, you must enter a complete filename including extension, if applicable.

---

**Naming Library Members**

**NOTE:** It is possible (but not desirable) for a library to contain several members with the same name. If you attempt to delete, replace, or extract a member whose name is the same as another library member, the archiver deletes, replaces, or extracts the first library member with that name.
6.4 Archiver Examples

The following are examples of typical archiver operations:

- If you want to create a library called function.lib that contains the files sine.obj, cos.obj, and flt.obj, enter:

  \texttt{ar6x -a function sine.obj cos.obj flt.obj}

  The archiver responds as follows:

  \texttt{==> new archive 'function.lib' ==> building new archive 'function.lib'}

- You can print a table of contents of function.lib with the -t command, enter:

  \texttt{ar6x -t function}

  The archiver responds as follows:

  \begin{tabular}{llll}
  \textbf{FILE NAME} & \textbf{SIZE} & \textbf{DATE} \\
  \hline
  sine.obj & 300 & Wed Jun 14 10:00:24 2006 \\
  cos.obj & 300 & Wed Jun 14 10:00:30 2006 \\
  flt.obj & 300 & Wed Jun 14 09:59:56 2006 \\
  \end{tabular}

- If you want to add new members to the library, enter:

  \texttt{ar6x -as function atan.obj}

  The archiver responds as follows:

  \texttt{==> symbol defined: '_sin'}
  \texttt{==> symbol defined: '_cos'}
  \texttt{==> symbol defined: '_tan'}
  \texttt{==> symbol defined: '_atan'}
  \texttt{==> building archive 'function.lib'}

  Because this example does not specify an extension for the libname, the archiver adds the files to the library called function.lib. If function.lib does not exist, the archiver creates it. (The -s option tells the archiver to list the global symbols that are defined in the library.)

- If you want to modify a library member, you can extract it, edit it, and replace it. In this example, assume there is a library named macros.lib that contains the members push.asm, pop.asm, and swap.asm.

  \texttt{ar6x -x macros push.asm}

  The archiver makes a copy of push.asm and places it in the current directory; it does not remove push.asm from the library. Now you can edit the extracted file. To replace the copy of push.asm in the library with the edited copy, enter:

  \texttt{ar6x -r macros push.asm}

- If you want to use a command file, specify the command filename after the -@ command. For example:

  \texttt{ar6x -@modules.cmd}

  The archiver responds as follows:

  \texttt{==> building archive 'modules.lib'}

\textbf{Example 6-1} is the modules.cmd command file. The r command specifies that the filenames given in the command file replace files of the same name in the modules.lib library. The -u option specifies that these files are replaced only when the current file has a more recent revision date than the file that is in the library.
Example 6-1. Archiver Command File

```plaintext
; Command file to replace members of the modules library with updated files
; Use r command and u option:
ru
; Specify library name:
modules.lib
; List filenames to be replaced if updated:
align.asm
bss.asm
data.asm
text.asm
sect.asm
clink.asm
copy.asm
double.asm
drnolist.asm
emsg.asm
end.asm
```

6.5 Library Information Archiver Description

Section 6.1 explains how to use the archiver to create libraries of object files for use in the linker of one or more applications. You can have multiple versions of the same object file libraries, each built with different sets of build options. For example, you might have different versions of your object file library for big and little endian, for different architecture revisions, or for different ABIs depending on the typical build environments of client applications. Unfortunately, if there are several different versions of your library it can become cumbersome to keep track of which version of the library needs to be linked in for a particular application.

When several versions of a single library are available, the library information archiver can be used to create an index library of all of the object file library versions. This index library is used in the linker in place of a particular version of your object file library. The linker looks at the build options of the application being linked, and uses the specified index library to determine which version of your object file library to include in the linker. If one or more compatible libraries were found in the index library, the most suitable compatible library is linked in for your application.

6.5.1 Invoking the Library Information Archiver

To invoke the library information archiver, enter:

```
libinfo6x [options] -o=libname libname1 libname2 ...
```

`libinfo6x` is the command that invokes the library information archiver.

`options` changes the default behavior of the library information archiver. These options are:

- `-o libname` specifies the name of the index library to create or update. This option is required.
- `-u` updates any existing information in the index library specified with the `-o` option instead of creating a new index.

`libnames` names individual object file libraries to be manipulated. When you enter a `libname`, you must enter a complete filename including extension, if applicable.
6.5.2 Library Information Archiver Example:

Consider these object file libraries that all have the same members, but are built with different build options:

<table>
<thead>
<tr>
<th>Object File Library Name</th>
<th>Build Options</th>
</tr>
</thead>
<tbody>
<tr>
<td>mylib_6200_be.lib</td>
<td>-mv6200 --endian=big</td>
</tr>
<tr>
<td>mylib_6200_le.lib</td>
<td>-mv6200 --endian=little</td>
</tr>
<tr>
<td>mylib_64plus_be.lib</td>
<td>-mv64plus --endian=big</td>
</tr>
<tr>
<td>mylib_64plus_le.lib</td>
<td>-mv64plus --endian=little</td>
</tr>
</tbody>
</table>

Using the library information archiver, you can create an index library called mylib.lib from the above libraries:

```
libinfo62 -o mylib.lib mylib_6200_be.lib mylib_6200_le.lib
            mylib_64plus_be.lib mylib_64plus_le.lib
```

You can now specify mylib.lib as a library for the linker of an application. The linker uses the index library to choose the appropriate version of the library to use. If the --issue_remarks option is specified before the --run_linker option, the linker reports which library was chosen.

- **Example 1** (ISA 64plus, little endian):
  
  ```
  cl6x -mv64plus --endian=little --issue_remarks main.c -z -l lnk.cmd ./mylib.lib
  <Linking>
  remark: linking in "mylib_64plus_le.lib" in place of "mylib.lib"
  ```

- **Example 2** (ISA 6700, big endian):
  
  ```
  cl6x -mv6700 --endian=big --issue_remarks main.c -z -l lnk.cmd ./mylib.lib
  <Linking>
  remark: linking in "mylib_6200_be.lib" in place of "mylib.lib"
  ```

In Example 2, there was no version of the library for C6700, but a C6200 library was available and is compatible, so it was used.

6.5.3 Listing the Contents of an Index Library

The archiver’s -t option can be used on an index library to list the archives indexed by an index library:

```
ar6x t mylib.lib
```

<table>
<thead>
<tr>
<th>SIZE</th>
<th>DATE</th>
<th>FILE NAME</th>
</tr>
</thead>
<tbody>
<tr>
<td>119</td>
<td>Wed Feb 03 12:45:22 2010</td>
<td>mylib_6200_be.lib</td>
</tr>
<tr>
<td>119</td>
<td>Wed Feb 03 12:45:22 2010</td>
<td>mylib_6200_le.lib</td>
</tr>
<tr>
<td>119</td>
<td>Wed Feb 03 12:45:22 2010</td>
<td>mylib_64plus_be.lib</td>
</tr>
<tr>
<td>119</td>
<td>Wed Feb 03 12:45:22 2010</td>
<td>mylib_64plus_le.lib</td>
</tr>
<tr>
<td>0</td>
<td>Wed Sep 30 12:45:22 2009</td>
<td><strong>TI</strong>$SLIBINFO</td>
</tr>
</tbody>
</table>

The indexed object file libraries have an additional .libinfo extension in the archiver listing. The __TI__$SLIBINFO member is a special member that designates mylib.lib as an index library, rather than a regular library.

If the archiver’s -d command is used on an index library to delete a .libinfo member, the linker will no longer choose the corresponding library when the index library is specified.

Using any other archiver option with an index library, or using -d to remove the __TI__$SLIBINFO member, results in undefined behavior, and is not supported.

6.5.4 Requirements

You must follow these requirements to use library index files:

- At least one of the application’s object files must appear on the linker command line before the index library.
- Each object file library specified as input to the library information archiver must only contain object file members that are built with the same build options.
- The linker expects the index library and all of the libraries it indexes to be in a single directory.
The TMS320C6000™ linker creates executable modules by combining object modules. This chapter describes the linker options, directives, and statements used to create executable modules. Object libraries, command files, and other key concepts are discussed as well.

The concept of sections is basic to linker operation; Chapter 2 discusses the object module sections in detail.

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<tr>
<th>Topic</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
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<tr>
<td>7.2  The Linker’s Role in the Software Development Flow</td>
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</tr>
<tr>
<td>7.3  Invoking the Linker</td>
<td>158</td>
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<tr>
<td>7.4  Linker Options</td>
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<tr>
<td>7.8  Linker-Generated Copy Tables</td>
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<tr>
<td>7.11 Linker Example</td>
<td>229</td>
</tr>
</tbody>
</table>
7.1 Linker Overview

The TMS320C6000 linker allows you to configure system memory by allocating output sections efficiently into the memory map. As the linker combines object files, it performs the following tasks:

- Allocates sections into the target system's configured memory
- Relocates symbols and sections to assign them to final addresses
- Resolves undefined external references between input files

The linker command language controls memory configuration, output section definition, and address binding. The language supports expression assignment and evaluation. You configure system memory by defining and creating a memory model that you design. Two powerful directives, MEMORY and SECTIONS, allow you to:

- Allocate sections into specific areas of memory
- Combine object file sections
- Define or redefine global symbols at link time
7.2 The Linker's Role in the Software Development Flow

Figure 7-1 illustrates the linker's role in the software development process. The linker accepts several types of files as input, including object files, command files, libraries, and partially linked files. The linker creates an executable object module that can be downloaded to one of several development tools or executed by a TMS320C6000 device.

Figure 7-1. The Linker in the TMS320C6000 Software Development Flow
Invoking the Linker

The general syntax for invoking the linker is:

```
cl6x --run_linker [options] filename, ..., filename
```

- **cl6x --run_linker** is the command that invokes the linker. The --run_linker option's short form is -z.
- **options** can appear anywhere on the command line or in a link command file. (Options are discussed in Section 7.4.)
- **filename**, **filename** can be object files, link 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.

There are two methods for invoking the linker:

- **Specify options and filenames on the command line.** This example links two files, file1.obj and file2.obj, and creates an output module named link.out.
  
  ```
  cl6x --run_linker file1.obj file2.obj --output_file=link.out
  ```

- **Put filenames and options in a link command file.** Filenames that are specified inside a link command file must begin with a letter. For example, assume the file linker.cmd contains the following lines:
  
  ```
  --output_file=link.out file1.obj file2.obj
  ```
  
  Now you can invoke the linker from the command line; specify the command filename as an input file:
  
  ```
  cl6x --run_linker linker.cmd
  ```
  
  When you use a command file, you can also specify other options and files on the command line. For example, you could enter:
  
  ```
  cl6x --run_linker --map_file=link.map linker.cmd file3.obj
  ```
  
  The linker reads and processes a command file as soon as it encounters the filename on the command line, so it links the files in this order: file1.obj, file2.obj, and file3.obj. This example creates an output file called link.out and a map file called link.map.

For information on invoking the linker for C/C++ files, see **Section 7.10.**
7.4 Linker Options

Linker options control linking operations. They can be placed on the command line or in a command file. Linker options must be preceded by a hyphen (-). Options can be separated from arguments (if they have them) by an optional space. Table 7-1 summarizes the linker options.

### Table 7-1. Basic Options Summary

<table>
<thead>
<tr>
<th>Option</th>
<th>Alias</th>
<th>Description</th>
<th>Section</th>
</tr>
</thead>
<tbody>
<tr>
<td>--output_file</td>
<td>-o</td>
<td>Names the executable output module. The default filename is a.out.</td>
<td>Section 7.4.21</td>
</tr>
<tr>
<td>--map_file</td>
<td>-m</td>
<td>Produces a map or listing of the input and output sections, including holes, and places the listing in filename</td>
<td>Section 7.4.16</td>
</tr>
<tr>
<td>--heap_size</td>
<td>-heap</td>
<td>Sets heap size (for the dynamic memory allocation in C) to size bytes and defines a global symbol that specifies the heap size. Default = 1K bytes</td>
<td>Section 7.4.12</td>
</tr>
<tr>
<td>--stack_size</td>
<td>-stack</td>
<td>Sets C system stack size to size bytes and defines a global symbol that specifies the stack size. Default = 1K bytes</td>
<td>Section 7.4.27</td>
</tr>
</tbody>
</table>

### Table 7-2. Command File Preprocessing Options Summary

<table>
<thead>
<tr>
<th>Option</th>
<th>Alias</th>
<th>Description</th>
<th>Section</th>
</tr>
</thead>
<tbody>
<tr>
<td>--define</td>
<td></td>
<td>Predefines name as a preprocessor macro.</td>
<td>Section 7.4.8</td>
</tr>
<tr>
<td>--undefine</td>
<td></td>
<td>Removes the preprocessor macro name.</td>
<td>Section 7.4.8</td>
</tr>
<tr>
<td>--disable_pp</td>
<td></td>
<td>Disables preprocessing for command files</td>
<td>Section 7.4.8</td>
</tr>
</tbody>
</table>

### Table 7-3. Diagnostic Options Summary

<table>
<thead>
<tr>
<th>Option</th>
<th>Alias</th>
<th>Description</th>
<th>Section</th>
</tr>
</thead>
<tbody>
<tr>
<td>--diag_error</td>
<td></td>
<td>Categorizes the diagnostic identified by num as an error</td>
<td>Section 7.4.5</td>
</tr>
<tr>
<td>--diag_remark</td>
<td></td>
<td>Categorizes the diagnostic identified by num as a remark</td>
<td>Section 7.4.5</td>
</tr>
<tr>
<td>--diag_suppress</td>
<td></td>
<td>Suppresses the diagnostic identified by num</td>
<td>Section 7.4.5</td>
</tr>
<tr>
<td>--diag_warning</td>
<td></td>
<td>Categorizes the diagnostic identified by num as a warning</td>
<td>Section 7.4.5</td>
</tr>
<tr>
<td>--display_error_number</td>
<td></td>
<td>Displays a diagnostic's identifiers along with its text</td>
<td>Section 7.4.5</td>
</tr>
<tr>
<td>--issueRemarks</td>
<td></td>
<td>Issues remarks (nonsensive warnings)</td>
<td>Section 7.4.5</td>
</tr>
<tr>
<td>--no_demangle</td>
<td></td>
<td>Disables demangling of symbol names in diagnostics</td>
<td>Section 7.4.18</td>
</tr>
<tr>
<td>--no_warnings</td>
<td></td>
<td>Suppresses warning diagnostics (errors are still issued)</td>
<td>Section 7.4.5</td>
</tr>
<tr>
<td>--set_error_limit</td>
<td></td>
<td>Sets the error limit to num. The linker abandons linking after this number of errors. (The default is 100.)</td>
<td>Section 7.4.5</td>
</tr>
<tr>
<td>--verbose_diagnostics</td>
<td></td>
<td>Provides verbose diagnostics that display the original source with line-wrap</td>
<td>Section 7.4.5</td>
</tr>
<tr>
<td>--warn_sections</td>
<td>-w</td>
<td>Displays a message when an undefined output section is created</td>
<td>Section 7.4.33</td>
</tr>
</tbody>
</table>

### Table 7-4. File Search Path Options Summary

<table>
<thead>
<tr>
<th>Option</th>
<th>Alias</th>
<th>Description</th>
<th>Section</th>
</tr>
</thead>
<tbody>
<tr>
<td>--library</td>
<td>-l</td>
<td>Names an archive library or link command filename as linker input</td>
<td>Section 7.4.14</td>
</tr>
<tr>
<td>--search_path</td>
<td>-I</td>
<td>Alters library-search algorithms to look in a directory named with pathname before looking in the default location. This option must appear before the --library option.</td>
<td>Section 7.4.14.1</td>
</tr>
<tr>
<td>--disable_auto_rts</td>
<td></td>
<td>Disables the automatic selection of a run-time-support library</td>
<td>Section 7.4.6</td>
</tr>
<tr>
<td>--priority</td>
<td>-priority</td>
<td>Satisfies unresolved references by the first library that contains a definition for that symbol</td>
<td>Section 7.4.14.3</td>
</tr>
<tr>
<td>--reread_libs</td>
<td>-x</td>
<td>Forces rereading of libraries, which resolves back references</td>
<td>Section 7.4.14.3</td>
</tr>
</tbody>
</table>
### Table 7-5. Linker Output Options Summary

<table>
<thead>
<tr>
<th>Option</th>
<th>Alias</th>
<th>Description</th>
<th>Section</th>
</tr>
</thead>
<tbody>
<tr>
<td>--output_file</td>
<td>-o</td>
<td>Names the executable output module. The default filename is a.out.</td>
<td>Section 7.4.21</td>
</tr>
<tr>
<td>--map_file</td>
<td>-m</td>
<td>Produces a map or listing of the input and output sections, including holes, and places the listing in filename</td>
<td>Section 7.4.16</td>
</tr>
<tr>
<td>--absolute_exe</td>
<td>-a</td>
<td>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.</td>
<td>Section 7.4.2.1</td>
</tr>
<tr>
<td>--generate_dead_funcs_list</td>
<td></td>
<td>Writes a list of the dead functions that were removed by the linker to file name.</td>
<td>Section 7.4.11</td>
</tr>
<tr>
<td>--mapfile_contents</td>
<td></td>
<td>Controls the information that appears in the map file.</td>
<td>Section 7.4.17</td>
</tr>
<tr>
<td>--relocatable</td>
<td>-r</td>
<td>Produces a nonexecutable, relocatable output module</td>
<td>Section 7.4.2.2</td>
</tr>
<tr>
<td>--run_abs</td>
<td>-abs</td>
<td>Produces an absolute listing file</td>
<td>Section 7.4.25</td>
</tr>
<tr>
<td>--xml_link_info</td>
<td></td>
<td>Generates a well-formed XML file containing detailed information about the result of a link</td>
<td>Section 7.4.34</td>
</tr>
</tbody>
</table>

### Table 7-6. Symbol Management Options Summary

<table>
<thead>
<tr>
<th>Option</th>
<th>Alias</th>
<th>Description</th>
<th>Section</th>
</tr>
</thead>
<tbody>
<tr>
<td>--entry_point</td>
<td>-e</td>
<td>Defines a global symbol that specifies the primary entry point for the output module</td>
<td>Section 7.4.9</td>
</tr>
<tr>
<td>--globalize</td>
<td></td>
<td>Changes the symbol linkage to global for symbols that match pattern</td>
<td>Section 7.4.15</td>
</tr>
<tr>
<td>--hide</td>
<td></td>
<td>Hides global symbols that match pattern</td>
<td>Section 7.4.13</td>
</tr>
<tr>
<td>--localize</td>
<td>-g</td>
<td>Changes the symbol linkage to local for symbols that match pattern</td>
<td>Section 7.4.15</td>
</tr>
<tr>
<td>--make_global</td>
<td>-g</td>
<td>Makes symbol global (overrides -h)</td>
<td>Section 7.4.15.2</td>
</tr>
<tr>
<td>--make_static</td>
<td>-h</td>
<td>Makes all global symbols static</td>
<td>Section 7.4.15.1</td>
</tr>
<tr>
<td>--no_sym_merge</td>
<td>-b</td>
<td>Disables merge of symbolic debugging information in COFF object files</td>
<td>Section 7.4.19</td>
</tr>
<tr>
<td>--no_sym_table</td>
<td>-s</td>
<td>Strips symbol table information and line number entries from the output module</td>
<td>Section 7.4.20</td>
</tr>
<tr>
<td>--retain</td>
<td></td>
<td>Retains a list of sections that otherwise would be discarded</td>
<td>Section 7.4.24</td>
</tr>
<tr>
<td>--scan_libraries</td>
<td>-scanlibs</td>
<td>Scans all libraries for duplicate symbol definitions</td>
<td>Section 7.4.26</td>
</tr>
<tr>
<td>--symbol_map</td>
<td></td>
<td>Maps symbol references to a symbol definition of a different name</td>
<td>Section 7.4.29</td>
</tr>
<tr>
<td>--undef_sym</td>
<td>-u</td>
<td>Places an unresolved external symbol into the output module's symbol table</td>
<td>Section 7.4.31</td>
</tr>
<tr>
<td>--unhide</td>
<td></td>
<td>Reveals (un-hides) global symbols that match pattern</td>
<td>Section 7.4.13</td>
</tr>
</tbody>
</table>

### Table 7-7. Run-Time Environment Options Summary

<table>
<thead>
<tr>
<th>Option</th>
<th>Alias</th>
<th>Description</th>
<th>Section</th>
</tr>
</thead>
<tbody>
<tr>
<td>--heap_size</td>
<td>-heap</td>
<td>Sets heap size (for the dynamic memory allocation in C) to size bytes and defines a global symbol that specifies the heap size. Default = 1K bytes</td>
<td>Section 7.4.12</td>
</tr>
<tr>
<td>--stack_size</td>
<td>-stack</td>
<td>Sets C system stack size to size bytes and defines a global symbol that specifies the stack size. Default = 1K bytes</td>
<td>Section 7.4.27</td>
</tr>
<tr>
<td>--arg_size</td>
<td>--args</td>
<td>Allocates memory to be used by the loader to pass arguments</td>
<td>Section 7.4.3</td>
</tr>
<tr>
<td>--fill_value</td>
<td>-f</td>
<td>Sets default fill values for holes within output sections; fill_value is a 32-bit constant</td>
<td>Section 7.4.10</td>
</tr>
<tr>
<td>--ram_model</td>
<td>-cr</td>
<td>Initializes variables at load time</td>
<td>Section 7.4.23</td>
</tr>
<tr>
<td>--rom_model</td>
<td>-c</td>
<td>Autoinitializes variables at run time</td>
<td>Section 7.4.23</td>
</tr>
<tr>
<td>--trampolines</td>
<td></td>
<td>Generates far call trampolines</td>
<td>Section 7.4.30</td>
</tr>
</tbody>
</table>
Table 7-8. Link-Time Optimization Options Summary

<table>
<thead>
<tr>
<th>Option</th>
<th>Alias</th>
<th>Description</th>
<th>Section</th>
</tr>
</thead>
<tbody>
<tr>
<td>--cinit_compression</td>
<td></td>
<td>Specifies the type of compression to apply to the c auto initialization data (default is rle)</td>
<td>Section 7.4.4</td>
</tr>
<tr>
<td>--copy_compression</td>
<td></td>
<td>Compresses data copied by linker copy tables</td>
<td>Section 7.4.4</td>
</tr>
<tr>
<td>--unused_section_elimination</td>
<td></td>
<td>Eliminates sections that are not needed in the executable module</td>
<td>Section 7.4.32</td>
</tr>
</tbody>
</table>

Table 7-9. Miscellaneous Options Summary

<table>
<thead>
<tr>
<th>Option</th>
<th>Alias</th>
<th>Description</th>
<th>Section</th>
</tr>
</thead>
<tbody>
<tr>
<td>--disable_clink</td>
<td>-j</td>
<td>Disables conditional linking of COFF object modules</td>
<td>Section 7.4.7</td>
</tr>
<tr>
<td>--linker_help</td>
<td>-help</td>
<td>Displays information about syntax and available options</td>
<td>–</td>
</tr>
<tr>
<td>--minimize_trampoline</td>
<td></td>
<td>Places sections to minimize number of far trampolines required</td>
<td>Section 7.4.30.3</td>
</tr>
<tr>
<td>--preferred_order</td>
<td></td>
<td>Prioritizes placement of functions</td>
<td>Section 7.4.22</td>
</tr>
<tr>
<td>--strict_compatibility</td>
<td></td>
<td>Performs more conservative and rigorous compatibility checking of input object files</td>
<td>Section 7.4.28</td>
</tr>
<tr>
<td>--trampoline_min_spacing</td>
<td></td>
<td>When trampoline reservations are spaced more closely than the specified limit, tries to make them adjacent</td>
<td>Section 7.4.30.4</td>
</tr>
<tr>
<td>--zero_init</td>
<td></td>
<td>Controls preinitialization of uninitialized variables. Default is on.</td>
<td>Section 7.4.35</td>
</tr>
</tbody>
</table>

7.4.1 **Wild Cards in File, Section, and Symbol Patterns**

The linker allows file, section, and symbol names to be specified using the asterisk (*) and question mark (?) wild cards. Using * matches any number of characters and using ? matches a single character. Using wild cards can make it easier to handle related objects, provided they follow a suitable naming convention.

For example:

```
mp3*.obj /* matches anything .obj that begins with mp3 */
task?.o* /* matches task1.obj, task2.obj, taskX.o55, etc. */

SECTIONS
{
  .fast_code: { *.obj(*fast*) } > FAST_MEM
  .vectors : { vectors.obj(.vector:part1:*) > 0xFFFFF00
  .str_code : { rts*.lib<str*.obj>{.text} } > S1ROM
}
```
7.4.2 Relocation Capabilities (--absolute_exe and --relocatable Options)

The linker performs relocation, which is the process of adjusting all references to a symbol when the symbol's address changes. The linker supports two options (--absolute_exe and --relocatable) that allow you to produce an absolute or a relocatable output module. The linker also supports a third option (-ar) that allows you to produce an executable, relocatable output module.

When the linker encounters a file that contains no relocation or symbol table information, it issues a warning message (but continues executing). Relinking an absolute file can be successful only if each input file contains no information that needs to be relocated (that is, each file has no unresolved references and is bound to the same virtual address that it was bound to when the linker created it).

7.4.2.1 Producing an Absolute Output Module (--absolute_exe option)

When you use the --absolute_exe option without the --relocatable option, the linker produces an absolute, executable output module. Absolute files contain no relocation information. Executable files contain the following:
- Special symbols defined by the linker (see Section 7.5.8.4)
- An optional header that describes information such as the program entry point
- No unresolved references

The following example links file1.obj and file2.obj and creates an absolute output module called a.out:

```
c16x --run_linker --absolute_exe file1.obj file2.obj
```

7.4.2.2 Producing a Relocatable Output Module (--relocatable option)

When you use the -ar option, the linker retains relocation entries in the output module. If the output module is relocated (at load time) or relinked (by another linker execution), use --relocatable to retain the relocation entries.

The linker produces a file that is not executable when you use the --relocatable option without the --absolute_exe option. A file that is not executable does not contain special linker symbols or an optional header. The file can contain unresolved references, but these references do not prevent creation of an output module.

This example links file1.obj and file2.obj and creates a relocatable output module called a.out:

```
c16x --run_linker --relocatable file1.obj file2.obj
```

The output file a.out can be relinked with other object files or relocated at load time. (Linking a file that will be relinked with other files is called partial linking. For more information, see Section 7.9.)

7.4.2.3 Producing an Executable, Relocatable Output Module (-ar Option)

If you invoke the linker with both the --absolute_exe and --relocatable options, the linker produces an executable, relocatable object module. The output file contains the special linker symbols, an optional header, and all resolved symbol references; however, the relocation information is retained.

This example links file1.obj and file2.obj and creates an executable, relocatable output module called xr.out:

```
c16x --run_linker -ar file1.obj file2.obj --output_file=xr.out
```
7.4.3 Allocate Memory for Use by the Loader to Pass Arguments (--arg_size Option)

The --arg_size option instructs the linker to allocate memory to be used by the loader to pass arguments from the command line of the loader to the program. The syntax of the --arg_size option is:

--arg_size= size

The size is a number representing the number of bytes to be allocated in target memory for command-line arguments.

By default, the linker creates the __c_args__ symbol and sets it to -1. When you specify --arg_size=size, the following occur:

- The linker creates an uninitialized section named .args of size bytes.
- The __c_args__ symbol contains the address of the .args section.

The loader and the target boot code use the .args section and the __c_args__ symbol to determine whether and how to pass arguments from the host to the target program. See the TMS320C6000 Optimizing Compiler User's Guide for information about the loader.

7.4.4 Compression (--cinit_compression and --copy_compression Option)

By default, the linker does not compress data. There are two options that specify compression through the linker.

The ELF mode --cinit_compression option specifies the compression type the linker applies to the C autoinitialization data. The default is rle.

Overlays can be managed by using linker-generated copy tables. To save ROM space the linker can compress the data copied by the copy tables. The compressed data is decompressed during copy. The --copy_compression option controls the compression of the copy data tables.

The syntax for the options are:

--cinit_compression[=compression_kind]
--copy_compression[=compression_kind]

The compression_kind can be one of the following types:

- off. Don't compress the data.
- rle. Compress data using Run Length Encoding.
7.4.5 Control Linker Diagnostics

The linker uses certain C/C++ compiler options to control 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 link. 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 link. 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 link. 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 link. 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 the TMS320C6000 Optimizing Compiler User's Guide for more information on understanding diagnostic messages.

--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 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 and indicate the position of the error in the source line

7.4.6 Disable Automatic Library Selection (--disable_auto_rts Option)

The --disable_auto_rts option disables the automatic selection of a run-time-support library. See the TMS320C6000 Optimizing Compiler User's Guide for details on the automatic selection process.

7.4.7 Disable Conditional Linking (--disable_clink Option)

The --disable_clink option disables removal of unreferenced sections in COFF object modules. Only sections marked as candidates for removal with the .clink assembler directive are affected by conditional linking. See Conditionally Leave Section Out of Object Module Output for details on setting up conditional linking using the .clink directive.
Link Command File Preprocessing (--disable_pp, --define and --undefine Options)

The linker preprocesses link command files using a standard C preprocessor. Therefore, the command files can contain well-known preprocessing directives such as #define, #include, and #if / #endif.

Three linker options control the preprocessor:

- **--disable_pp** Disables preprocessing for command files
- **--define**=name[=val] Predefines name as a preprocessor macro
- **--undefine**=name Removes the macro name

The compiler has --define and --undefine options with the same meanings. However, the linker options are distinct; only --define and --undefine options specified after --run_linker are passed to the linker. For example:

```bash
cl6x --define=FOO=1 main.c --run_linker --define=BAR=2 lnk.cmd
```

The linker sees only the --define for BAR; the compiler only sees the --define for FOO.

When one command file #includes another, preprocessing context is carried from parent to child in the usual way (that is, macros defined in the parent are visible in the child). However, when a command file is invoked other than through #include, either on the command line or by the typical way of being named in another command file, preprocessing context is not carried into the nested file. The exception to this is --define and --undefine options, which apply globally from the point they are encountered. For example:

```bash
--define GLOBAL
#define LOCAL
#include "incfile.cmd" /* sees GLOBAL and LOCAL */
nestfile.cmd /* only sees GLOBAL */
```

Two cautions apply to the use of --define and --undefine in command files. First, they have global effect as mentioned above. Second, since they are not actually preprocessing directives themselves, they are subject to macro substitution, probably with unintended consequences. This effect can be defeated by quoting the symbol name. For example:

```bash
--define MYSYM=123
--undefine MYSYM /* expands to --undefine 123 (!) */
--undefine "MYSYM" /* ahh, that's better */
```

The linker uses the same search paths to find #include files as it does to find libraries. That is, #include files are searched in the following places:

1. If the #include file name is in quotes (rather than <brackets>), in the directory of the current file
2. In the list of directories specified with --library options or environment variables (see Section 7.4.14)

There are two exceptions: relative pathnames (such as "./name") always search the current directory; and absolute pathnames (such as "/usr/tools/name") bypass search paths entirely.

The linker has the standard built-in definitions for the macros __FILE__, __DATE__, and __TIME__. It does not, however, have the compiler-specific options for the target (__TI_COMPILER_VERSION__), version (__TI_COMPILER_VERSION__), run-time model, and so on.
### 7.4.9 Define an Entry Point (--entry_point Option)

The memory address at which a program begins executing is called the *entry point*. When a loader loads a program into target memory, the program counter (PC) must be initialized to the entry point; the PC then points to the beginning of the program.

The linker can assign one of four values to the entry point. These values are listed below in the order in which the linker tries to use them. If you use one of the first three values, it must be an external symbol in the symbol table.

- The value specified by the `--entry_point` option. The syntax is:
  ```
  --entry_point= global_symbol
  ```
  where `global_symbol` defines the entry point and must be defined as an external symbol of the input files. The external symbol name of C or C++ objects may be different than the name as declared in the source language; refer to the *TMS320C6000 Optimizing Compiler User's Guide*.
- The value of symbol `_c_int00` (if present). The `_c_int00` symbol *must* be the entry point if you are linking code produced by the C compiler.
- The value of symbol `_main` (if present)
- 0 (default value)

This example links file1.obj and file2.obj. The symbol `begin` is the entry point; `begin` must be defined as external in file1 or file2.

```bash
cl6x --run_linker --entry_point=begin file1.obj file2.obj
```

### 7.4.10 Set Default Fill Value (--fill_value Option)

The `--fill_value` option fills the holes formed within output sections. The syntax for the option is:

```
--fill_value= value
```

The argument `value` is a 32-bit constant (up to eight hexadecimal digits). If you do not use `--fill_value`, the linker uses 0 as the default fill value.

This example fills holes with the hexadecimal value ABCDABCD:

```bash
cl6x --run_linker --fill_value=0xABCDABCD file1.obj file2.obj
```

### 7.4.11 Generate List of Dead Functions (--generate_dead_funcs_list Option)

The `--generate_dead_funcs_list` option creates a list of functions that are never referenced (dead) and writes the list to the specified file. If no filename is specified, the default filename `dead_funcs.txt` is used. The syntax for the option is:

```
--generate_dead_funcs_list=filename
```

Refer to the *TMS320C6000 Optimizing Compiler User's Guide* for details on the `--generate_dead_funcs_list` option.
7.4.12 Define Heap Size (--heap_size Option)

The C/C++ compiler uses an uninitialized section called .sysmem for the C run-time memory pool used by malloc(). You can set the size of this memory pool at link time by using the --heap_size option. The syntax for the --heap_size option is:

```--heap_size= size```

The size must be a constant. This example defines a 4K byte heap:

```cl6x --run_linker --heap_size=0x1000 /* defines a 4k heap (.sysmem section)*/```

The linker creates the .sysmem section only if there is a .sysmem section in an input file.

The linker also creates a global symbol __SYSMEM_SIZE and assigns it a value equal to the size of the heap. The default size is 1K bytes.

For more information about C/C++ linking, see Section 7.10.

7.4.13 Hiding Symbols

Symbol hiding prevents the symbol from being listed in the output file's symbol table. While localization is used to prevent name space clashes in a link unit, symbol hiding is used to obscure symbols which should not be visible outside a link unit. Such symbol’s names appear only as empty strings or “no name” in object file readers. The linker supports symbol hiding through the --hide and --unhide options.

The syntax for these options are:

```--hide=' pattern '```

```--unhide=' pattern '```

The `pattern` is a string with optional wildcards ? or *. Use ? to match a single character and use * to match zero or more characters.

The --hide option hides global symbols which have a linkname matching the pattern. It hides the symbols matching the pattern by changing the name to an empty string. A global symbol which is hidden is also localized.

The --unhide option reveals (un-hides) global symbols that match the pattern that are hidden by the --hide option. The --unhide option excludes symbols that match pattern from symbol hiding provided the pattern defined by --unhide is more restrictive than the pattern defined by --hide.

These options have the following properties:

- The --hide and --unhide options can be specified more than once on the command line.
- The order of --hide and --unhide has no significance.
- A symbol is matched by only one pattern defined by either --hide or --unhide.
- A symbol is matched by the most restrictive pattern. Pattern A is considered more restrictive than Pattern B, if Pattern A matches a narrower set than Pattern B.
- It is an error if a symbol matches patterns from --hide and --unhide and if one does not supersede other. Pattern A supersedes pattern B if A can match everything B can, and some more. If Pattern A supersedes Pattern B, then Pattern B is said to more restrictive than Pattern A.
- These options affect final and partial linking.

In map files these symbols are listed under the Hidden Symbols heading.
7.4.14 Alter the Library Search Algorithm (--library Option, --search_path Option, and C6X_C_DIR Environment Variable)

Usually, when you want to specify a file as linker input, you simply enter the filename; the linker looks for the file in the current directory. For example, suppose the current directory contains the library object.lib. Assume that this library defines symbols that are referenced in the file file1.obj. This is how you link the files:

```
cl6x --run_linker file1.obj object.lib
```

If you want to use a file that is not in the current directory, use the --library linker option. The --library option's short form is `-l`. The syntax for this option is:

```
--library=pathname filename
```

The `filename` is the name of an archive, an object file, or link command file. You can specify up to 128 search paths.

The --library option is not required when one or more members of an object library are specified for input to an output section. For more information about allocating archive members, see Section 7.5.4.5.

You can augment the linker's directory search algorithm by using the --search_path linker option or the C6X_C_DIR environment variable. The linker searches for object libraries and command files in the following order:

1. It searches directories named with the --search_path linker option. The --search_path option must appear before the --library option on the command line or in a command file.
2. It searches directories named with C6X_C_DIR.
3. If C6X_C_DIR is not set, it searches directories named with the assembler's C6X_A_DIR environment variable.
4. It searches the current directory.

7.4.14.1 Name an Alternate Library Directory (--search_path Option)

The --search_path option names an alternate directory that contains input files. The --search_path option's short form is `-I`. The syntax for this option is:

```
--search_path=pathname
```

The `pathname` names a directory that contains input files.

When the linker is searching for input files named with the --library option, it searches through directories named with --search_path first. Each --search_path option specifies only one directory, but you can have several --search_path options per invocation. When you use the --search_path option to name an alternate directory, it must precede any --library option used on the command line or in a command file.

For example, assume that there are two archive libraries called r.lib and lib2.lib that reside in ld and ld2 directories. The table below shows the directories that r.lib and lib2.lib reside in, how to set environment variable, and how to use both libraries during a link. Select the row for your operating system:

<table>
<thead>
<tr>
<th>Operating System</th>
<th>Enter</th>
</tr>
</thead>
<tbody>
<tr>
<td>UNIX (Bourne shell)</td>
<td><code>cl6x --run_linker f1.obj f2.obj --search_path=/ld --search_path=/ld2 --library=r.lib --library=lib2.lib</code></td>
</tr>
<tr>
<td>Windows</td>
<td><code>cl6x --run_linker f1.obj f2.obj --search_path=\ld --search_path=\ld2 --library=r.lib --library=lib2.lib</code></td>
</tr>
</tbody>
</table>
7.4.14.2 Name an Alternate Library Directory (C6X_C_DIR Environment Variable)

An environment variable is a system symbol that you define and assign a string to. The linker uses an environment variable named C6X_C_DIR to name alternate directories that contain object libraries. The command syntaxes for assigning the environment variable are:

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

The *pathnames* are directories that contain input files. Use the --library linker option on the command line or in a command file to tell the linker which library or link command file to search for. The pathnames must follow these constraints:

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

In the example below, assume that two archive libraries called r.lib and lib2.lib reside in ld and ld2 directories. The table below shows how to set the environment variable, and how to use both libraries during a link. Select the row for your operating system:

<table>
<thead>
<tr>
<th>Operating System</th>
<th>Invocation Command</th>
</tr>
</thead>
<tbody>
<tr>
<td>UNIX (Bourne shell)</td>
<td>cl6x --run linker f1.obj f2.obj --library=r.lib --library=lib2.lib</td>
</tr>
<tr>
<td>Windows</td>
<td>cl6x --run linker f1.obj f2.obj --library=r.lib --library=lib2.lib</td>
</tr>
</tbody>
</table>

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

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

The assembler uses an environment variable named C6X_A_DIR to name alternate directories that contain copy/include files or macro libraries. If C6X_C_DIR is not set, the linker searches for object libraries in the directories named with C6X_A_DIR. For information about C6X_A_DIR, see Section 3.5.2. For more information about object libraries, see Section 7.6.

7.4.14.3 Exhaustively Read and Search Libraries (--reread_libs and --priority Options)

There are two ways to exhaustively search for unresolved symbols:

- Reread libraries if you cannot resolve a symbol reference (--reread_libs).
- Search libraries in the order that they are specified (--priority).

The linker normally reads input files, including archive libraries, only once when they are encountered on the command line or in the command file. When an archive is read, any members that resolve references to undefined symbols are included in the link. If an input file later references a symbol defined in a previously read archive library, the reference is not resolved.

With the --reread_libs option, you can force the linker to reread all libraries. The linker rereads libraries until no more references can be resolved. Linking using --reread_libs may be slower, so you should use it only as needed. For example, if a.lib contains a reference to a symbol defined in b.lib, and b.lib contains a reference to a symbol defined in a.lib, you can resolve the mutual dependencies by listing one of the libraries twice, as in:

```
c6x --run_linker --library=a.lib --library=b.lib --library=a.lib
```
or you can force the linker to do it for you:

c6x --run_linker --reread_libs --library=a.lib --library=b.lib

The --priority option provides an alternate search mechanism for libraries. Using --priority causes each unresolved reference to be satisfied by the first library that contains a definition for that symbol. For example:

objfile references A
lib1 defines B
lib2 defines A, B; obj defining A refers to B

% c6x --run_linker objfile lib1 lib2

Under the existing model, objfile resolves its reference to A in lib2, pulling in a reference to B, which resolves to the B in lib2.

Under --priority, objfile resolves its reference to A in lib2, pulling in a reference to B, but now B is resolved by searching the libraries in order and resolves B to the first definition it finds, namely the one in lib1.

The --priority option is useful for libraries that provide overriding definitions for related sets of functions in other libraries without having to provide a complete version of the whole library.

For example, suppose you want to override versions of malloc and free defined in the rts6200.lib without providing a full replacement for rts6200.lib. Using --priority and linking your new library before rts6200.lib guarantees that all references to malloc and free resolve to the new library.

The --priority option is intended to support linking programs with DSP/BIOS where situations like the one illustrated above occur.

7.4.15 Change Symbol Localization

Symbol localization changes symbol linkage from global to local (static). This is used to obscure global symbols in a library which should not be visible outside the library, but must be global because they are accessed by several modules in the library. The linker supports symbol localization through the --localize and --globalize linker options.

The syntax for these options are:

--localize='pattern'

--globalize='pattern'

The pattern is a string with optional wild cards ? or *. Use ? to match a single character and use * to match zero or more characters.

The --localize option changes the symbol linkage to local for symbols matching the pattern.

The --globalize option changes the symbol linkage to global for symbols matching the pattern. The --globalize option only affects symbols that are localized by the --localize option. The --globalize option excludes symbols that match the pattern from symbol localization, provided the pattern defined by --globalize is more restrictive than the pattern defined by --localize.

---

Specifying C/C++ Symbols with --localize and --globalize

NOTE: For COFF ABI, the compiler prepends an underscore _ to the beginning of all C/C++ identifiers. That is, for a function named foo2(), foo2() is prefixed with _ and _foo2 becomes the link-time symbol. The --localize and --globalize options accept the link-time symbols. Thus, you specify --localize='foo2' to localize the C function _foo2().

For EABI, the link-time symbol is the same as the HLL name.

These options have the following properties:

• The --localize and --globalize options can be specified more than once on the command line.
• The order of --localize and --globalize options has no significance.
• A symbol is matched by only one pattern defined by either --localize or --globalize.
• A symbol is matched by the most restrictive pattern. Pattern A is considered more restrictive than Pattern B, if Pattern A matches a narrower set than Pattern B.
• It is an error if a symbol matches patterns from --localize and --globalize and if one does not supersede other. Pattern A supersedes pattern B if A can match everything B can, and some more. If Pattern A supersedes Pattern B, then Pattern B is said to more restrictive than Pattern A.

• These options affect final and partial linking.

In map files these symbols are listed under the Localized Symbols heading.

### 7.4.15.1 Make All Global Symbols Static (--make_static Option)

The --make_static option makes all global symbols static. Static symbols are not visible to externally linked modules. By making global symbols static, global symbols are essentially hidden. This allows external symbols with the same name (in different files) to be treated as unique.

The --make_static option effectively nullifies all .global assembler directives. All symbols become local to the module in which they are defined, so no external references are possible. For example, assume file1.obj and file2.obj both define global symbols called EXT. By using the --make_static option, you can link these files without conflict. The symbol EXT defined in file1.obj is treated separately from the symbol EXT defined in file2.obj.

```bash
cl6x --run_linker --make_static file1.obj file2.obj
```

### 7.4.15.2 Make a Symbol Global (--make_global Option)

The --make_static option makes all global symbols static. If you have a symbol that you want to remain global and you use the --make_static option, you can use the --make_global option to declare that symbol to be global. The --make_global option overrides the effect of the --make_static option for the symbol that you specify. The syntax for the --make_global option is:

```bash
--make_global= global_symbol
```

### 7.4.16 Create a Map File (--map_file Option)

The syntax for the --map_file option is:

```bash
--map_file= filename
```

The linker map describes:

• Memory configuration
• Input and output section allocation
• Linker-generated copy tables
• Trampolines
• The addresses of external symbols after they have been relocated
• Hidden and localized symbols

The map file contains the name of the output module and the entry point; it can also contain up to three tables:

• A table showing the new memory configuration if any nondefault memory is specified (memory configuration). The table has the following columns; this information is generated on the basis of the information in the MEMORY directive in the link command file:
  – **Name.** This is the name of the memory range specified with the MEMORY directive.
  – **Origin.** This specifies the starting address of a memory range.
  – **Length.** This specifies the length of a memory range.
  – **Unused.** This specifies the total amount of unused (available) memory in that memory area.
  – **Attributes.** This specifies one to four attributes associated with the named range:

R specifies that the memory can be read.
W specifies that the memory can be written to.
X specifies that the memory can contain executable code.
I specifies that the memory can be initialized.
For more information about the MEMORY directive, see Section 7.5.3.

- A table showing the linked addresses of each output section and the input sections that make up the output sections (section allocation map). This table has the following columns; this information is generated on the basis of the information in the SECTIONS directive in the link command file:
  - **Output section.** This is the name of the output section specified with the SECTIONS directive.
  - **Origin.** The first origin listed for each output section is the starting address of that output section. The indented origin value is the starting address of that portion of the output section.
  - **Length.** The first length listed for each output section is the length of that output section. The indented length value is the length of that portion of the output section.
  - **Attributes/input sections.** This lists the input file or value associated with an output section. If the input section could not be allocated, the map file will indicate this with "FAILED TO ALLOCATE".

For more information about the SECTIONS directive, see Section 7.5.4.

- A table showing each external symbol and its address sorted by symbol name.
- A table showing each external symbol and its address sorted by symbol address.

This following example links file1.obj and file2.obj and creates a map file called map.out:

```
c16x --run_linker file1.obj file2.obj --map_file=map.out
```

Example 7-25 shows an example of a map file.

### 7.4.17 Managing Map File Contents (--mapfile_contents Option)

The --mapfile_contents option assists with managing the content of linker-generated map files. The syntax for the --mapfile_contents option is:

```
--mapfile_contents=filter[, filter]
```

When the --map_file option is specified, the linker produces a map file containing information about memory usage, placement information about sections that were created during a link, details about linker-generated copy tables, and symbol values.

The new --mapfile_contents option provides a mechanism for you to control what information is included in or excluded from a map file. When you specify --mapfile_contents=help from the command line, a help screen listing available filter options is displayed.

The following filter options are available:

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Description</th>
<th>Default State</th>
</tr>
</thead>
<tbody>
<tr>
<td>copytables</td>
<td>Copy tables</td>
<td>On</td>
</tr>
<tr>
<td>entry</td>
<td>Entry point</td>
<td>On</td>
</tr>
<tr>
<td>load_addr</td>
<td>Display load addresses</td>
<td>Off</td>
</tr>
<tr>
<td>memory</td>
<td>Memory ranges</td>
<td>On</td>
</tr>
<tr>
<td>sections</td>
<td>Sections</td>
<td>On</td>
</tr>
<tr>
<td>sym_defs</td>
<td>Defined symbols per file</td>
<td>Off</td>
</tr>
<tr>
<td>sym_name</td>
<td>Symbols sorted by name</td>
<td>On</td>
</tr>
<tr>
<td>sym_runaddr</td>
<td>Symbols sorted by run address</td>
<td>On</td>
</tr>
<tr>
<td>all</td>
<td>Enables all attributes</td>
<td></td>
</tr>
<tr>
<td>none</td>
<td>Disables all attributes</td>
<td></td>
</tr>
</tbody>
</table>

The --mapfile_contents option controls display filter settings by specifying a comma-delimited list of display attributes. When prefixed with the word no, an attribute is disabled instead of enabled. For example:

```
--mapfile_contents=copytables,noentry
--mapfile_contents=all, nocopytables
--mapfile_contents=none, entry
```
By default, those sections that are currently included in the map file when the --map_file option is specified are included. The filters specified in the --mapfile_contents options are processed in the order that they appear in the command line. In the third example above, the first filter, none, clears all map file content. The second filter, entry, then enables information about entry points to be included in the generated map file. That is, when --mapfile_contents=none,entry is specified, the map file contains only information about entry points.

There are two new filters included with the --mapfile_contents option, load_addr and sym_defs. These are both disabled by default. If you turn on the load_addr filter, the map file includes the load address of symbols that are included in the symbol list in addition to the run address (if the load address is different from the run address).

The sym_defs filter can be used to include information about all static and global symbols defined in an application on a file by file basis. You may find it useful to replace the sym_name and sym_runaddr sections of the map file with the sym_defs section by specifying the following --mapfile_contents option:

```
--mapfile_contents=nosym_name,nosym_runaddr,sym_defs
```

### 7.4.18 Disable Name Demangling (--no_demangle)

By default, the linker uses demangled symbol names in diagnostics. For example:

```
undefined symbol
ANewClass::getValue() first referenced in file
```

The --no_demangle option disables the demangling of symbol names in diagnostics. For example:

```
undefined symbol
_ZN9ANewClass8getValueEv first referenced in file
```

### 7.4.19 Disable Merge of Symbolic Debugging Information (--no_sym_merge Option)

By default, the linker eliminates duplicate entries of symbolic debugging information. Such duplicate information is commonly generated when a C program is compiled for debugging. For example:

```
- [ header.h ]-
+ typedef struct
+ {< define some structure members>
+ } XYZ;
- [ f1.c ]-
+ #include "header.h"
+ ...
- [ f2.c ]-
+ #include "header.h"
+ ...
```

When these files are compiled for debugging, both f1.obj and f2.obj have symbolic debugging entries to describe type XYZ. For the final output file, only one set of these entries is necessary. The linker eliminates the duplicate entries automatically.

Use the COFF only --no_sym_merge option if you want the linker to keep such duplicate entries in COFF object files. Using the --no_sym_merge option has the effect of the linker running faster and using less host memory during linking, but the resulting executable file may be very large due to duplicated debug information.
### 7.4.20 Strip Symbolic Information (--no_sym_table Option)

The --no_sym_table option creates a smaller output module by omitting symbol table information and line number entries. The --no_sym_table option is useful for production applications when you do not want to disclose symbolic information to the consumer.

This example links file1.obj and file2.obj and creates an output module, stripped of line numbers and symbol table information, named nosym.out:

```
cl6x --run_linker --output_file=nosym.out --no_sym_table file1.obj file2.obj
```

Using the --no_sym_table option limits later use of a symbolic debugger.

**NOTE:** The --no_sym_table option is deprecated. To remove symbol table information, use the strip6x utility as described in Section 10.4.

### 7.4.21 Name an Output Module (--output_file Option)

The linker creates an output module when no errors are encountered. If you do not specify a filename for the output module, the linker gives it the default name a.out. If you want to write the output module to a different file, use the --output_file option. The syntax for the --output_file option is:

```
--output_file= filename
```

The `filename` is the new output module name.

This example links file1.obj and file2.obj and creates an output module named run.out:

```
cl6x --run_linker --output_file=run.out file1.obj file2.obj
```

### 7.4.22 Prioritizing Function Placement (--preferred_order Option)

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

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

Refer to the *TMS320C6000 Optimizing Compiler v 7.0 User's Guide* for details on the program cache layout tool which is impacted most by --preferred_option.

### 7.4.23 C Language Options (--ram_model and --rom_model Options)

The --ram_model and --rom_model options cause the linker to use linking conventions that are required by the C compiler.

- The --ram_model option tells the linker to initialize variables at load time.
- The --rom_model option tells the linker to autoinitialize variables at run time.

For more information, see Section 7.10, Section 7.10.4, and Section 7.10.5.
7.4.24 Retain Discarded Sections (--retain Option)

When --unused_section_elimination is on, the ELF linker does not include a section in the final link if it is not needed in the executable to resolve references. The --retain option tells the linker to retain a list of sections that would otherwise not be retained. This option accepts the wildcards ‘*’ and ‘?’. When wildcards are used, the argument should be in quotes. The syntax for this option is:

```
--retain=sym_or_scn_spec
```

The --retain option take one of the following forms:

- **--retain= symbol_spec**
  Specifying the symbol format retains sections that define `symbol_spec`. For example, this code retains sections that define symbols that start with `init`:
  ```
  --retain='init*'
  ```
  You cannot specify `--retain='*'.

- **--retain= file_spec[, scn_spec, ...]**
  Specifying the file format retains sections that match one or more `scn_spec` from files matching the `file_spec`. For example, this code retains .initvec sections from all input files:
  ```
  --retain='init*'
  ```
  You can specify `--retain='*(*' to retain all sections from all input files. However, this does not prevent sections from library members from being optimized out.

- **--retain= ar_spec<mem_spec[, scn_spec, ...]>[, scn_spec, ...]**
  Specifying the archive format retains sections matching one or more `scn_spec` from members matching one or more `mem_spec` from archive files matching `ar_spec`. For example, this code retains the .text sections from `printf.obj` in the `rts32eabi.lib` library:
  ```
  --retain=rtseabi.lib<printf.obj>({.text})
  ```
  If the library is specified with the --library option (--library=rtseabi.lib) the library search path is used to search for the library. You cannot specify `'*'(*')'.

7.4.25 Create an Absolute Listing File (--run_abs Option)

The --run_abs option produces an output file for each file that was linked. These files are named with the input filenames and an extension of .abs. Header files, however, do not generate a corresponding .abs file.

7.4.26 Scan All Libraries for Duplicate Symbol Definitions (--scan_libraries)

The --scan_libraries option scans all libraries during a link looking for duplicate symbol definitions to those symbols that are actually included in the link. The scan does not consider absolute symbols or symbols defined in COMDAT sections. The --scan_libraries option helps determine those symbols that were actually chosen by the linker over other existing definitions of the same symbol in a library.

The library scanning feature can be used to check against unintended resolution of a symbol reference to a definition when multiple definitions are available in the libraries.

7.4.27 Define Stack Size (--stack_size Option)

The TMS320C6000 C/C++ compiler uses an uninitialized section, .stack, to allocate space for the run-time stack. You can set the size of this section in bytes at link time with the --stack_size option. The syntax for the --stack_size option is:

```
--stack_size= size
```

The `size` must be a constant and is in bytes. This example defines a 4K byte stack:

```
cl6x --run_linker --stack_size=0x1000 /* defines a 4K heap (.stack section)*/
```

If you specified a different stack size in an input section, the input section stack size is ignored. Any symbols defined in the input section remain valid; only the stack size is different.

When the linker defines the .stack section, it also defines a global symbol, __STACK_SIZE, and assigns it a value equal to the size of the section. The default software stack size is 1K bytes.
7.4.28 **Enforce Strict Compatibility (--strict_compatibility Option)**

The linker performs more conservative and rigorous compatibility checking of input object files when you specify the --strict_compatibility option. Using this option guards against additional potential compatibility issues, but may signal false compatibility errors when linking in object files built with an older toolset, or with object files built with another compiler vendor's toolset. To avoid issues with legacy libraries, the --strict_compatibility option is turned off by default.

7.4.29 **Mapping of Symbols (--symbol_map Option)**

Symbol mapping allows a symbol reference to be resolved by a symbol with a different name. Symbol mapping allows functions to be overridden with alternate definitions. This feature can be used to patch in alternate implementations, which provide patches (bug fixes) or alternate functionality. The syntax for the --symbol_map option is:

```
--symbol_map= refname=defname
```

For example, the following code makes the linker resolve any references to foo by the definition foo_patch:

```
--symbol_map='foo=foo_patch'
```

7.4.30 **Generate Far Call Trampolines (--trampolines Option)**

The TMS320C6000 has PC-relative call and PC-relative branch instructions whose range is smaller than the entire address space. When these instructions are used, the destination address must be near enough to the instruction that the difference between the call and the destination fits in the available encoding bits. If the called function is too far away from the calling function, the linker generates an error.

The alternative to a PC-relative call is an absolute call, which is often implemented as an indirect call: load the called address into a register, and call that register. This is often undesirable because it takes more instructions (speed- and size-wise) and requires an extra register to contain the address.

By default, the compiler generates near calls. The --trampolines option causes the linker to generate a trampoline code section for each call that is linked out-of-range of its called destination. The trampoline code section contains a sequence of instructions that performs a transparent long branch to the original called address. Each calling instruction that is out-of-range from the called function is redirected to the trampoline.

For example, in a section of C code the bar function calls the foo function. The compiler generates this code for the function:

```
bar:
  ...
  call  foo  ; call the function "foo"
  ...
```

If the foo function is placed out-of-range from the call to foo that is inside of bar, then with --trampolines the linker changes the original call to foo into a call to foo_trampoline as shown:

```
bar:
  ...
  call  foo_trampoline  ; call a trampoline for foo
  ...
```

The above code generates a trampoline code section called foo_trampoline, which contains code that executes a long branch to the original called function, foo. For example:

```
foo_trampoline:
  branch_long  foo
```

Trampolines can be shared among calls to the same called function. The only requirement is that all calls to the called function be linked near the called function's trampoline.

The syntax for the option is:

```
--trampoline[=on|off]
```

The default setting is on. For C6000, trampolines are turned on by default.
When the linker produces a map file (the --map_file option) and it has produced one or more trampolines, then the map file will contain statistics about what trampolines were generated to reach which functions. A list of calls for each trampoline is also provided in the map file.

The Linker Assumes B15 Contains the Stack Pointer

**NOTE:** Assembly language programmers must be aware that the linker assumes B15 contains the stack pointer. The linker must save and restore values on the stack in trampoline code that it generates. If you do not use B15 as the stack pointer, you should use the linker option that disables trampolines, --trampolines=off. Otherwise, trampolines could corrupt memory and overwrite register values.

7.4.30.1 Carrying Trampolines From Load Space to Run Space

It is sometimes useful to load code in one location in memory and run it in another. The linker provides the capability to specify separate load and run allocations for a section. The burden of actually copying the code from the load space to the run space is left to you.

A copy function must be executed before the real function can be executed in its run space. To facilitate this copy function, the assembler provides the .label directive, which allows you to define a load-time address. These load-time addresses can then be used to determine the start address and size of the code to be copied. However, this mechanism will not work if the code contains a call that requires a trampoline to reach its called function. This is because the trampoline code is generated at link time, after the load-time addresses associated with the .label directive have been defined. If the linker detects the definition of a .label symbol in an input section that contains a trampoline call, then a warning is generated.

To solve this problem, you can use the START(), END(), and SIZE() operators (see Section 7.5.8.7). These operators allow you to define symbols to represent the load-time start address and size inside the link command file. These symbols can be referenced by the copy code, and their values are not resolved until link time, after the trampoline sections have been allocated.

Here is an example of how you could use the START() and SIZE() operators in association with an output section to copy the trampoline code section along with the code containing the calls that need trampolines:

```
SECTIONS
{ .foo : load = ROM, run = RAM, start(foo_start), size(foo_size)
  x.obj(.text) }
.text: {} > ROM
.far: { -l=rts.lib(.text) } > FAR_MEM
}
```

A function in x.obj contains an run-time-support call. The run-time-support library is placed in far memory and so the call is out-of-range. A trampoline section will be added to the .foo output section by the linker. The copy code can refer to the symbols foo_start and foo_size as parameters for the load start address and size of the entire .foo output section. This allows the copy code to copy the trampoline section along with the original x.obj code in .text from its load space to its run space.

7.4.30.2 Disadvantages of Using Trampolines

An alternative method to creating a trampoline code section for a call that cannot reach its called function is to actually modify the source code for the call. In some cases this can be done without affecting the size of the code. However, in general, this approach is extremely difficult, especially when the size of the code is affected by the transformation.

While generating far call trampolines provides a more straightforward solution, trampolines have the disadvantage that they are somewhat slower than directly calling a function. They require both a call and a branch. Additionally, while inline code could be tailored to the environment of the call, trampolines are generated in a more general manner, and may be slightly less efficient than inline code.
7.4.30.3 Minimizing the Number of Trampolines Required (--minimize_trampolines Option)

The --minimize_trampolines option attempts to place sections so as to minimize the number of far call trampolines required, possibly at the expense of optimal memory packing. The syntax is:

```
--minimize_trampolines[=postorder]
```

The argument selects a heuristic to use. The postorder heuristic attempts to place functions before their callers, so that the PC-relative offset to the callee is known when the caller is placed.

When a call is placed and the callee's address is unknown, the linker must provisionally reserve space for a far call trampoline in case the callee turns out to be too far away. Even if the callee ends up being close enough, the trampoline reservation can interfere with optimal placement for very large code sections. By placing the callee first, its address is known when the caller is placed so the linker can definitively know if a trampoline is required.

7.4.30.4 Making Trampoline Reservations Adjacent (--trampoline_min_spacing Option)

When trampoline reservations are spaced more closely than the specified limit, use the --trampoline_min_spacing option to try to make them adjacent. The syntax is:

```
--trampoline_min_spacing=size
```

A higher value minimizes fragmentation, but may result in more trampolines. A lower value may reduce trampolines, at the expense of fragmentation and linker running time. Specifying 0 for this option disables coalescing. The default is 16K.

7.4.31 Introduce an Unresolved Symbol (--undef_sym Option)

The --undef_sym option introduces the linkname for an unresolved symbol into the linker's symbol table. This forces the linker to search a library and include the member that defines the symbol. The linker must encounter the --undef_sym option before it links in the member that defines the symbol. The syntax for the --undef_sym option is:

```
--undef_sym=symbol
```

For example, suppose a library named rts6200.lib contains a member that defines the symbol symtab; none of the object files being linked reference symtab. However, suppose you plan to relink the output module and you want to include the library member that defines symtab in this link. Using the --undef_sym option as shown below forces the linker to search rts6200.lib for the member that defines symtab and to link in the member.

```
cl6x --run_linker --undef_sym=symtab file1.obj file2.obj rts6200.lib
```

If you do not use --undef_sym, this member is not included, because there is no explicit reference to it in file1.obj or file2.obj.

7.4.32 Do Not Remove Unused Sections (--unused_section_elimination Option)

In order to minimize the footprint, the ELF linker does not include a section that is not needed to resolve any references in the final executable. Use --unused_section_elimination=off to disable this optimization. The syntax for the option is:

```
--unused_section_elimination[=on|off]
```

The linker default behavior is equivalent to --unused_section_elimination=on.
7.4.33 Display a Message When an Undefined Output Section Is Created (--warn_sections Option)

In a link command file, you can set up a SECTIONS directive that describes how input sections are combined into output sections. However, if the linker encounters one or more input sections that do not have a corresponding output section defined in the SECTIONS directive, the linker combines the input sections that have the same name into an output section with that name. By default, the linker does not display a message to tell you that this occurred.

You can use the --warn_sections option to cause the linker to display a message when it creates a new output section.

For more information about the SECTIONS directive, see Section 7.5.4. For more information about the default actions of the linker, see Section 7.7.

7.4.34 Generate XML Link Information File (--xml_link_info Option)

The linker supports the generation of an XML link information file through the --xml_link_info=file option. This option causes the linker to generate a well-formed XML file containing detailed information about the result of a link. The information included in this file includes all of the information that is currently produced in a linker generated map file.

See for specifics on the contents of the generated XML file.

7.4.35 Zero Initialization (--zero_init Option)

In ANSI C, global and static variables that are not explicitly initialized must be set to 0 before program execution. The C/C++ EABI compiler supports preinitialization of uninitialized variables by default. This can be turned off by specifying the linker option --zero_init=off. COFF ABI does not support zero initialization.

The syntax for the --zero_init option is:

--zero_init=[on|off]
7.5 **Linker Command Files**

Linker command files allow you to put linking information in a file; this is useful when you invoke the linker often with the same information. Linker command files are also useful because they allow you to use the MEMORY and SECTIONS directives to customize your application. You must use these directives in a command file; you cannot use them on the command line.

Linker command files are ASCII files that contain one or more of the following:

- Input filenames, which specify object files, archive libraries, or other command files. (If a command file calls another command file as input, this statement must be the last statement in the calling command file. The linker does not return from called command files.)
- Linker options, which can be used in the command file in the same manner that they are used on the command line
- The MEMORY and SECTIONS linker directives. The MEMORY directive defines the target memory configuration (see Section 7.5.3). The SECTIONS directive controls how sections are built and allocated (see Section 7.5.4.)
- Assignment statements, which define and assign values to global symbols

To invoke the linker with a command file, enter the `cl6x --run_linker` command and follow it with the name of the command file:

```
cl6x --run_linker command_filename
```

The linker processes input files in the order that it encounters them. If the linker recognizes a file as an object file, it links the file. Otherwise, it assumes that a file is a command file and begins reading and processing commands from it. Command filenames are case sensitive, regardless of the system used.

*Example 7-1* shows a sample link command file called link.cmd.

**Example 7-1. Linker Command File**

```plaintext
a.obj /* First input filename */
b.obj /* Second input filename */
--output_file=prog.out /* Option to specify output file */
--map_file=prog.map /* Option to specify map file */
```

The sample file in *Example 7-1* contains only filenames and options. (You can place comments in a command file by delimiting them with /* and */.) To invoke the linker with this command file, enter:

```
cl6x --run_linker link.cmd
```

You can place other parameters on the command line when you use a command file:

```
cl6x --run_linker --relocatable link.cmd c.obj d.obj
```

The linker processes the command file as soon as it encounters the filename, so a.obj and b.obj are linked into the output module before c.obj and d.obj.

You can specify multiple command files. If, for example, you have a file called names.lst that contains filenames and another file called dir.cmd that contains linker directives, you could enter:

```
cl6x --run_linker names.lst dir.cmd
```

One command file can call another command file; this type of nesting is limited to 16 levels. If a command file calls another command file as input, this statement must be the last statement in the calling command file.

Blanks and blank lines are insignificant in a command file except as delimiters. This also applies to the format of linker directives in a command file. *Example 7-2* shows a sample command file that contains linker directives.
Example 7-2. Command File With Linker Directives

```
a.obj b.obj c.obj /* Input filenames */
--output_file=prog.out /* Options */
--map_file=prog.map
MEMORY /* MEMORY directive */
{
    FAST_MEM: origin = 0x0100 length = 0x0100
    SLOW_MEM: origin = 0x7000 length = 0x1000
}
SECTIONS /* SECTIONS directive */
{
    .text: > SLOW_MEM
    .data: > SLOW_MEM
    .bss: > FAST_MEM
}
```

For more information, see Section 7.5.3 for the MEMORY directive, and Section 7.5.4 for the SECTIONS directive.

7.5.1 Reserved Names in Linker Command Files

The following names (in lowercase also) are reserved as keywords for linker directives. Do not use them as symbol or section names in a command file.

<table>
<thead>
<tr>
<th>reserved names</th>
</tr>
</thead>
<tbody>
<tr>
<td>ALIGN</td>
</tr>
<tr>
<td>ATTR</td>
</tr>
<tr>
<td>BLOCK</td>
</tr>
<tr>
<td>COMPRESSION</td>
</tr>
<tr>
<td>COPY</td>
</tr>
<tr>
<td>DSECT</td>
</tr>
<tr>
<td>f</td>
</tr>
<tr>
<td>FILL</td>
</tr>
<tr>
<td>GROUP</td>
</tr>
<tr>
<td>HIGH</td>
</tr>
<tr>
<td>i (lowercase l)</td>
</tr>
<tr>
<td>len</td>
</tr>
<tr>
<td>LENGTH</td>
</tr>
<tr>
<td>LOAD</td>
</tr>
<tr>
<td>LOAD_END</td>
</tr>
<tr>
<td>LOAD_SIZE</td>
</tr>
<tr>
<td>LOAD_START</td>
</tr>
<tr>
<td>MEM</td>
</tr>
<tr>
<td>MEMORY</td>
</tr>
<tr>
<td>NOINIT</td>
</tr>
<tr>
<td>NOLOAD</td>
</tr>
<tr>
<td>ORIGIN</td>
</tr>
<tr>
<td>PAGE</td>
</tr>
<tr>
<td>PALIGN</td>
</tr>
<tr>
<td>RUN</td>
</tr>
<tr>
<td>RUN_END</td>
</tr>
<tr>
<td>RUN_SIZE</td>
</tr>
<tr>
<td>RUN_START</td>
</tr>
<tr>
<td>SECTIONS</td>
</tr>
<tr>
<td>TABLE</td>
</tr>
<tr>
<td>TYPE</td>
</tr>
<tr>
<td>UNION</td>
</tr>
<tr>
<td>UNORDERED</td>
</tr>
</tbody>
</table>

7.5.2 Constants in Linker Command Files

You can specify constants with either of two syntax schemes: the scheme used for specifying decimal, octal, or hexadecimal constants used in the assembler (see Section 3.7) or the scheme used for integer constants in C syntax.

Examples:

<table>
<thead>
<tr>
<th>format</th>
<th>decimal</th>
<th>octal</th>
<th>hexadecimal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Assembler format</td>
<td>32</td>
<td>40q</td>
<td>0x20h</td>
</tr>
<tr>
<td>C format</td>
<td>32</td>
<td>040</td>
<td>0x20</td>
</tr>
</tbody>
</table>
7.5.3 The MEMORY Directive

The linker determines where output sections are allocated into memory; it must have a model of target memory to accomplish this. The MEMORY directive allows you to specify a model of target memory so that you can define the types of memory your system contains and the address ranges they occupy. The linker maintains the model as it allocates output sections and uses it to determine which memory locations can be used for object code.

The memory configurations of TMS320C6000 systems differ from application to application. The MEMORY directive allows you to specify a variety of configurations. After you use MEMORY to define a memory model, you can use the SECTIONS directive to allocate output sections into defined memory.

For more information, see Section 2.3 and Section 2.4.

7.5.3.1 Default Memory Model

If you do not use the MEMORY directive, the linker uses a default memory model that is based on the TMS320C6000 architecture. This model assumes that the full 32-bit address space ($2^{32}$ locations) is present in the system and available for use. For more information about the default memory model, see Section 7.7.

7.5.3.2 MEMORY Directive Syntax

The MEMORY directive identifies ranges of memory that are physically present in the target system and can be used by a program. Each range has several characteristics:

- **Name**
- **Starting address**
- **Length**
- **Optional set of attributes**
- **Optional fill specification**

When you use the MEMORY directive, be sure to identify all memory ranges that are available for loading code. Memory defined by the MEMORY directive is configured; any memory that you do not explicitly account for with MEMORY is unconfigured. The linker does not place any part of a program into unconfigured memory. You can represent nonexistent memory spaces by simply not including an address range in a MEMORY directive statement.

The MEMORY directive is specified in a command file by the word MEMORY (uppercase), followed by a list of memory range specifications enclosed in braces. The MEMORY directive in Example 7-3 defines a system that has:

- 4K bytes of fast external memory at address 0x0000 0000
- 2K bytes of slow external memory at address 0x0000 1000
- 4K bytes of slow external memory at address 0x1000 0000

**Example 7-3. The MEMORY Directive**

```c
/****************************************************/
/* Sample command file with MEMORY directive */
/****************************************************/
file1.obj  file2.obj /* Input files */
--output_file=prog.out /* Options */

MEMORY
{
  FAST_MEM (RX): origin = 0x00000000 length = 0x00001000
  SLOW_MEM (RW): origin = 0x00001000 length = 0x00000800
  EXT_MEM (RX): origin = 0x10000000 length = 0x00001000
}
```

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The general syntax for the MEMORY directive is:

```
MEMORY
{
  name 1 [(attr)]: origin = constant, length = constant [, fill = constant]
  
  ...

  name n [(attr)]: origin = constant, length = constant [, fill = constant]
}
```

ame names a memory range. A memory name can be one to 64 characters; valid characters include A-Z, a-z, $, ., and _. The names have no special significance to the linker; they simply identify memory ranges. Memory range names are internal to the linker and are not retained in the output file or in the symbol table. All memory ranges must have unique names and must not overlap.

attr specifies one to four attributes associated with the named range. Attributes are optional; when used, they must be enclosed in parentheses. Attributes restrict the allocation of output sections into certain memory ranges. If you do not use any attributes, you can allocate any output section into any range with no restrictions. Any memory for which no attributes are specified (including all memory in the default model) has all four attributes. Valid attributes are:

- **R** specifies that the memory can be read.
- **W** specifies that the memory can be written to.
- **X** specifies that the memory can contain executable code.
- **I** specifies that the memory can be initialized.

origin specifies the starting address of a memory range; enter as origin, org, or o. The value, specified in bytes, is a 32-bit constant and can be decimal, octal, or hexadecimal.

length specifies the length of a memory range; enter as length, len, or l. The value, specified in bytes, is a 32-bit constant and can be decimal, octal, or hexadecimal.

fill specifies a fill character for the memory range; enter as fill or f. Fills are optional. The value is a integer constant and can be decimal, octal, or hexadecimal. The fill value is used to fill areas of the memory range that are not allocated to a section.

---

**Filling Memory Ranges**

**NOTE:** If you specify fill values for large memory ranges, your output file will be very large because filling a memory range (even with 0s) causes raw data to be generated for all unallocated blocks of memory in the range.

The following example specifies a memory range with the R and W attributes and a fill constant of 0FFFFFFFh:

```
MEMORY
{
  RFILE (RW) : o = 0x00000020, l = 0x00001000, f = 0xFFFFFFFFh
}
```

You normally use the MEMORY directive in conjunction with the SECTIONS directive to control allocation of output sections. After you use MEMORY to specify the target system's memory model, you can use SECTIONS to allocate output sections into specific named memory ranges or into memory that has specific attributes. For example, you could allocate the .text and .data sections into the area named FAST_MEM and allocate the .bss section into the area named SLOW_MEM.
7.5.4 The SECTIONS Directive

The SECTIONS directive controls your sections in the following ways:

- Describes how input sections are combined into output sections
- Defines output sections in the executable program
- Specifies where output sections are placed in memory (in relation to each other and to the entire memory space)
- Permits renaming of output sections

For more information, see Section 2.3, Section 2.4, and Section 2.2.4. Subsections allow you to manipulate sections with greater precision.

If you do not specify a SECTIONS directive, the linker uses a default algorithm for combining and allocating the sections. This describes this algorithm in detail.

7.5.4.1 SECTIONS Directive Syntax

The SECTIONS directive is specified in a command file by the word SECTIONS (uppercase), followed by a list of output section specifications enclosed in braces.

The general syntax for the SECTIONS directive is:

```
SECTIONS
{
  name : [property [, property] [, property] . . . ]
  name : [property [, property] [, property] . . . ]
  name : [property [, property] [, property] . . . ]
}
```

Each section specification, beginning with `name`, defines an output section. (An output section is a section in the output file.) A section name can be a subsection specification. (See Section 7.5.4.4 for information on multi-level subsections.) After the section name is a list of properties that define the section's contents and how the section is allocated. The properties can be separated by optional commas. Possible properties for a section are as follows:

- **Load allocation** defines where in memory the section is to be loaded.
  Syntax: `load = allocation` or `allocation` or `> allocation`

- **Run allocation** defines where in memory the section is to be run.
  Syntax: `run = allocation` or `run > allocation`

- **Input sections** defines the input sections (object files) that constitute the output section.
  Syntax: `{ input_sections }

- **Section type** defines flags for special section types. See Section 7.5.7
  Syntax: `type = COPY` or `type = DSECT` or `type = NOLOAD`

- **Fill value** defines the value used to fill uninitialized holes. See Section 7.5.9.
  Syntax: `fill = value` or `name : [properties = value]`
Example 7-4 shows a SECTIONS directive in a sample link command file.

Example 7-4. The SECTIONS Directive

```c
/***********************/
/* Sample command file with SECTIONS directive */
/***********************/
file1.obj  file2.obj  /* Input files */
--output_file=prog.out  /* Options */
SECTIONS
{
  .text:   load = EXT_MEM, run = 0x00000000
  .const:  load = FAST_MEM
  .bss:    load = SLOW_MEM
  .vectors: load = 0x00000000
  {
    t1.obj(.intvec1)
    t2.obj(.intvec2)
    endvec = .;
  }
  .data:alpha: align = 16
  .data:beta: align = 16
}
```

Figure 7-2 shows the six output sections defined by the SECTIONS directive in Example 7-4 (.vectors, .text, .const, .bss, .data:alpha, and .data:beta) and shows how these sections are allocated in memory.

Figure 7-2. Section Allocation Defined by Example 7-4

- Bound at 0x00000000: The .vectors section is composed of the .intvec1 section from t1.obj and the .intvec2 section from t2.obj.
- Allocated in FAST_MEM: The .const section combines the .const sections from file1.obj and file2.obj.
- Allocated in SLOW_MEM: The .bss section combines the .bss sections from file1.obj and file2.obj.
- Aligned on 16-byte boundary: The .data:alpha subsection combines the .data:alpha subsections from file1.obj and file2.obj. The .data:beta subsection combines the .data:beta subsections from file1.obj and file2.obj. The linker places the subsections anywhere there is space for them (in SLOW_MEM in this illustration) and aligns each on a 16-byte boundary.
- Empty range of memory as defined in above: The .text section combines the .text sections from file1.obj and file2.obj. The linker combines all sections named .text into this section. The application must relocate the section to run at 0x00000800.
7.5.4.2 Allocation

The linker assigns each output section two locations in target memory: the location where the section will be loaded and the location where it will be run. Usually, these are the same, and you can think of each section as having only a single address. The process of locating the output section in the target's memory and assigning its address(es) is called allocation. For more information about using separate load and run allocation, see Section 7.5.5.

If you do not tell the linker how a section is to be allocated, it uses a default algorithm to allocate the section. Generally, the linker puts sections wherever they fit into configured memory. You can override this default allocation for a section by defining it within a SECTIONS directive and providing instructions on how to allocate it.

You control allocation by specifying one or more allocation parameters. Each parameter consists of a keyword, an optional equal sign or greater-than sign, and a value optionally enclosed in parentheses. If load and run allocation are separate, all parameters following the keyword LOAD apply to load allocation, and those following the keyword RUN apply to run allocation. The allocation parameters are:

- **Binding** allocates a section at a specific address.
  \[\text{.text: load = 0x1000}\]

- **Named memory** allocates the section into a range defined in the MEMORY directive with the specified name (like SLOW_MEM) or attributes.
  \[\text{.text: load > SLOW_MEM}\]

- **Alignment** uses the align or palign keyword to specify that the section must start on an address boundary.
  \[\text{.text: align = 0x100}\]

- **Blocking** uses the block keyword to specify that the section must fit between two address boundaries: if the section is too big, it starts on an address boundary.
  \[\text{.text: block(0x100)}\]

For the load (usually the only) allocation, you can simply use a greater-than sign and omit the load keyword:

\[\text{text: > SLOW_MEM .text: {...} > SLOW_MEM}\]
\[\text{text: > 0x4000}\]

If more than one parameter is used, you can string them together as follows:

\[\text{.text: > SLOW_MEM align 16}\]

Or if you prefer, use parentheses for readability:

\[\text{.text: load = (SLOW_MEM align(16))}\]

You can also use an input section specification to identify the sections from input files that are combined to form an output section. See Section 7.5.4.3.

7.5.4.2.1 Binding

You can supply a specific starting address for an output section by following the section name with an address:

\[\text{.text: 0x00001000}\]

This example specifies that the .text section must begin at location 0x1000. The binding address must be a 32-bit constant.

Output sections can be bound anywhere in configured memory (assuming there is enough space), but they cannot overlap. If there is not enough space to bind a section to a specified address, the linker issues an error message.

**Binding is Incompatible With Alignment and Named Memory**

**NOTE:** You cannot bind a section to an address if you use alignment or named memory. If you try to do this, the linker issues an error message.
7.5.4.2.2 Named Memory

You can allocate a section into a memory range that is defined by the MEMORY directive (see Section 7.5.3). This example names ranges and links sections into them:

```
MEMORY
{
  SLOW_MEM (RIX) : origin = 0x00000000, length = 0x00001000
  FAST_MEM (RWIX) : origin = 0x30000000, length = 0x00000300
}
```

```
SECTIONS
{
  .text : > SLOW_MEM
  .data : > FAST_MEM ALIGN(128)
  .bss : > FAST_MEM
}
```

In this example, the linker places .text into the area called SLOW_MEM. The .data and .bss output sections are allocated into FAST_MEM. You can align a section within a named memory range; the .data section is aligned on a 128-byte boundary within the FAST_MEM range.

Similarly, you can link a section into an area of memory that has particular attributes. To do this, specify a set of attributes (enclosed in parentheses) instead of a memory name. Using the same MEMORY directive declaration, you can specify:

```
SECTIONS
{
  .text: > (X) /* .text -- > executable memory */
  .data: > (RI) /* .data -- > read or init memory */
  .bss : > (RW) /* .bss -- > read or write memory */
}
```

In this example, the .text output section can be linked into either the SLOW_MEM or FAST_MEM area because both areas have the X attribute. The .data section can also go into either SLOW_MEM or FAST_MEM because both areas have the R and I attributes. The .bss output section, however, must go into the FAST_MEM area because only FAST_MEM is declared with the W attribute.

You cannot control where in a named memory range a section is allocated, although the linker uses lower memory addresses first and avoids fragmentation when possible. In the preceding examples, assuming no conflicting assignments exist, the .text section starts at address 0. If a section must start on a specific address, use binding instead of named memory.

7.5.4.2.3 Controlling Allocation Using The HIGH Location Specifier

The linker allocates output sections from low to high addresses within a designated memory range by default. Alternatively, you can cause the linker to allocate a section from high to low addresses within a memory range by using the HIGH location specifier in the SECTION directive declaration.

For example, given this MEMORY directive:

```
MEMORY
{
  RAM : origin = 0x0200, length = 0x0800
  FLASH : origin = 0x1100, length = 0xE3E0
  VECTORS : origin = 0x8FEE, length = 0x001E
  RESET : origin = 0xFFFE, length = 0x0002
}
```

and an accompanying SECTIONS directive:

```
SECTIONS
{
  .bss : {} > RAM
  .sysmem : {} > RAM
  .stack : {} > RAM (HIGH)
}
```

The HIGH specifier used on the .stack section allocation causes the linker to attempt to allocate .stack into the higher addresses within the RAM memory range. The .bss and .sysmem sections are allocated into the lower addresses within RAM. Example 7-5 illustrates a portion of a map file that shows where the given sections are allocated within RAM for a typical program.
Example 7-5. Linker Allocation With the HIGH Specifier

<table>
<thead>
<tr>
<th>Section</th>
<th>Offset</th>
<th>Size</th>
<th>Type</th>
<th>Allocation</th>
</tr>
</thead>
<tbody>
<tr>
<td>.bss</td>
<td>0</td>
<td>00000200 00000270</td>
<td>UNINITIALIZED</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>00000200 0000011a</td>
<td>rtsxxx.lib : defs.obj (.bss)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>0000031a 00000088</td>
<td>: trgdrv.obj (.bss)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>000003a2 00000078</td>
<td>: lowlev.obj (.bss)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>0000041a 00000046</td>
<td>: exit.obj (.bss)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>00000460 00000008</td>
<td>: memory.obj (.bss)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>00000468 00000004</td>
<td>: _lock.obj (.bss)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>0000046c 00000002</td>
<td>: fopen.obj (.bss)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>0000046e 00000002</td>
<td>hello.obj (.bss)</td>
<td></td>
</tr>
<tr>
<td>.sysmem</td>
<td>0</td>
<td>00000470 00000120</td>
<td>UNINITIALIZED</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>00000470 00000004</td>
<td>rtsxxx.lib : memory.obj (.sysmem)</td>
<td></td>
</tr>
<tr>
<td>.stack</td>
<td>0</td>
<td>000008c0 00000140</td>
<td>UNINITIALIZED</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>000008c0 00000002</td>
<td>rtsxxx.lib : boot.obj (.stack)</td>
<td></td>
</tr>
</tbody>
</table>

As shown in Example 7-5, the .bss and .sysmem sections are allocated at the lower addresses of RAM (0x0200 - 0x0590) and the .stack section is allocated at address 0x08c0, even though lower addresses are available.

Without using the HIGH specifier, the linker allocation would result in the code shown in Example 7-6.

The HIGH specifier is ignored if it is used with specific address binding or automatic section splitting (>> operator).

Example 7-6. Linker Allocation Without HIGH Specifier

<table>
<thead>
<tr>
<th>Section</th>
<th>Offset</th>
<th>Size</th>
<th>Type</th>
<th>Allocation</th>
</tr>
</thead>
<tbody>
<tr>
<td>.bss</td>
<td>0</td>
<td>00000200 00000270</td>
<td>UNINITIALIZED</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>00000200 0000011a</td>
<td>rtsxxx.lib : defs.obj (.bss)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>0000031a 00000088</td>
<td>: trgdrv.obj (.bss)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>000003a2 00000078</td>
<td>: lowlev.obj (.bss)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>0000041a 00000046</td>
<td>: exit.obj (.bss)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>00000460 00000008</td>
<td>: memory.obj (.bss)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>00000468 00000004</td>
<td>: _lock.obj (.bss)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>0000046c 00000002</td>
<td>: fopen.obj (.bss)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>0000046e 00000002</td>
<td>hello.obj (.bss)</td>
<td></td>
</tr>
<tr>
<td>.sysmem</td>
<td>0</td>
<td>00000470 00000120</td>
<td>UNINITIALIZED</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>00000470 00000004</td>
<td>rtsxxx.lib : memory.obj (.sysmem)</td>
<td></td>
</tr>
<tr>
<td>.stack</td>
<td>0</td>
<td>000008c0 00000140</td>
<td>UNINITIALIZED</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>000008c0 00000002</td>
<td>rtsxxx.lib : boot.obj (.stack)</td>
<td></td>
</tr>
</tbody>
</table>

7.5.4.2.4 Alignment and Blocking

You can tell the linker to place an output section at an address that falls on an n-byte boundary, where n is a power of 2, by using the align keyword. For example, the following code allocates .text so that it falls on a 32-byte boundary:

```
.text: load = align(32)
```

You can specify the same alignment with the palign keyword. In addition, palign ensures the section's size is a multiple of its placement alignment restrictions, padding the section size up to such a boundary, as needed.

Blocking is a weaker form of alignment that allocates a section anywhere within a block of size n. The specified block size must be a power of 2. For example, the following code allocates .bss so that the entire section is contained in a single 128-byte page or begins on that boundary:

```
bss: load = block(0x0080)
```

You can use alignment or blocking alone or in conjunction with a memory area, but alignment and blocking cannot be used together.
7.5.4.2.5 Alignment With Padding

As with align, you can tell the linker to place an output section at an address that falls on an n-byte boundary, where n is a power of 2, by using the `palign` keyword. In addition, `palign` ensures that the size of the section is a multiple of its placement alignment restrictions, padding the section size up to such a boundary, as needed.

For example, the following code lines allocate `.text` on a 2-byte boundary within the PMEM area. The `.text` section size is guaranteed to be a multiple of 2 bytes. Both statements are equivalent:

```
.text: palign(2) {} > PMEM
.text: palign = 2 {} > PMEM
```

If the linker adds padding to an initialized output section then the padding space is also initialized. By default, padding space is filled with a value of 0 (zero). However, if a fill value is specified for the output section then any padding for the section is also filled with that fill value.

For example, consider the following section specification:

```
.mytext: palign(8), fill = 0xffffffff {} > PMEM
```

In this example, the length of the `.mytext` section is 6 bytes before the `palign` operator is applied. The contents of `.mytext` are as follows:

<table>
<thead>
<tr>
<th>addr</th>
<th>content</th>
</tr>
</thead>
<tbody>
<tr>
<td>0000</td>
<td>0x1234</td>
</tr>
<tr>
<td>0002</td>
<td>0x1234</td>
</tr>
<tr>
<td>0004</td>
<td>0x1234</td>
</tr>
</tbody>
</table>

After the `palign` operator is applied, the length of `.mytext` is 8 bytes, and its contents are as follows:

<table>
<thead>
<tr>
<th>addr</th>
<th>content</th>
</tr>
</thead>
<tbody>
<tr>
<td>0000</td>
<td>0x1234</td>
</tr>
<tr>
<td>0002</td>
<td>0x1234</td>
</tr>
<tr>
<td>0004</td>
<td>0x1234</td>
</tr>
<tr>
<td>0006</td>
<td>0xffffffff</td>
</tr>
</tbody>
</table>

The size of `.mytext` has been bumped to a multiple of 8 bytes and the padding created by the linker has been filled with 0xff.

The fill value specified in the linker command file is interpreted as a 16-bit constant, so if you specify this code:

```
.mytext: palign(8), fill = 0xff {} > PMEM
```

The fill value assumed by the linker is 0x00ff, and `.mytext` will then have the following contents:

<table>
<thead>
<tr>
<th>addr</th>
<th>content</th>
</tr>
</thead>
<tbody>
<tr>
<td>0000</td>
<td>0x1234</td>
</tr>
<tr>
<td>0002</td>
<td>0x1234</td>
</tr>
<tr>
<td>0004</td>
<td>0x1234</td>
</tr>
<tr>
<td>0006</td>
<td>0xff</td>
</tr>
<tr>
<td>0008</td>
<td>0x00ff</td>
</tr>
<tr>
<td>000a</td>
<td>0x00ff</td>
</tr>
</tbody>
</table>

If the `palign` operator is applied to an uninitialized section, then the size of the section is bumped to the appropriate boundary, as needed, but any padding created is not initialized.
7.5.4.3 Specifying Input Sections

An input section specification identifies the sections from input files that are combined to form an output section. In general, the linker combines input sections by concatenating them in the order in which they are specified. However, if alignment or blocking is specified for an input section, all of the input sections within the output section are ordered as follows:

- All aligned sections, from largest to smallest
- All blocked sections, from largest to smallest
- All other sections, from largest to smallest

The size of an output section is the sum of the sizes of the input sections that it comprises.

**Example 7-7** shows the most common type of section specification; note that no input sections are listed.

**Example 7-7. The Most Common Method of Specifying Section Contents**

```
SECTIONS
{
 .text:
 .data:
 .bss:
}
```

In **Example 7-7**, the linker takes all the .text sections from the input files and combines them into the .text output section. The linker concatenates the .text input sections in the order that it encounters them in the input files. The linker performs similar operations with the .data and .bss sections. You can use this type of specification for any output section.

You can explicitly specify the input sections that form an output section. Each input section is identified by its filename and section name:

```
SECTIONS
{
 .text : /* Build .text output section */
  { 
   f1.obj(.text) /* Link .text section from f1.obj */
   f2.obj(secl) /* Link sec1 section from f2.obj */
   f3.obj/* Link ALL sections from f3.obj */
   f4.obj(.text,sec2) /* Link .text and sec2 from f4.obj */
  }
}
```

It is not necessary for input sections to have the same name as each other or as the output section they become part of. If a file is listed with no sections, all of its sections are included in the output section. If any additional input sections have the same name as an output section but are not explicitly specified by the SECTIONS directive, they are automatically linked in at the end of the output section. For example, if the linker found more .text sections in the preceding example and these .text sections were not specified anywhere in the SECTIONS directive, the linker would concatenate these extra sections after f4.obj(sec2).

The specifications in **Example 7-7** are actually a shorthand method for the following:

```
SECTIONS
{
 .text: { *(.text) }
 .data: { *(.data) }
 .bss: { *(.bss) }
}
```

The specification *(.text) means the unallocated .text sections from all the input files. This format is useful when:

- You want the output section to contain all input sections that have a specified name, but the output section name is different from the input sections' name.
- You want the linker to allocate the input sections before it processes additional input sections or commands within the braces.
The following example illustrates the two purposes above:

```
SECTIONS {
  .text : {
    abc.obj(xqt)
    *(.text)
  }
  .data : {
    *(.data)
    fil.obj(table)
  }
}
```

In this example, the .text output section contains a named section xqt from file abc.obj, which is followed by all the .text input sections. The .data section contains all the .data input sections, followed by a named section table from the file fil.obj. This method includes all the unallocated sections. For example, if one of the .text input sections was already included in another output section when the linker encountered *((.text)), the linker could not include that first .text input section in the second output section.

### 7.5.4.4 Using Multi-Level Subsections

Subsections can be identified with the base section name and one or more subsection names separated by colons. For example, A:B and A:B:C name subsections of the base section A. In certain places in a link command file specifying a base name, such as A, selects the section A as well as any subsections of A, such as A:B or A:C:D.

A name such as A:B can be used to specify a (sub)section of that name as well as any (multi-level) subsections beginning with that name, such as A:B:C, A:B:OTHER, etc. All the subsections of A:B are also subsections of A. A and A:B are supersections of A:B:C. Among a group of supersections of a subsection, the nearest supersection is the supersection with the longest name. Thus, among {A, A:B} the nearest supersection of A:B:C:D is A:B.

With multiple levels of subsections, the constraints are the following:

1. When specifying input sections within a file (or library unit) the section name selects an input section of the same name and any subsections of that name.
2. Input sections that are not explicitly allocated are allocated in an existing output section of the same name or in the nearest existing supersection of such an output section. An exception to this rule is that during a partial link (specified by the --relocatable linker option) a subsection is allocated only to an existing output section of the same name.
3. If no such output section described in 2) is defined, the input section is put in a newly created output section with the same name as the base name of the input section

Consider linking input sections with the following names:

- europe:north:norway
- europe:central:france
- europe:south:spain
- europe:north:sweden
- europe:central:germany
- europe:south:italy
- europe:north:finland
- europe:central:denmark
- europe:south:malta
- europe:north:iceland

This SECTIONS specification allocates the input sections as indicated in the comments:

```
SECTIONS {
  nordic: {*{europe:north}} /* the nordic countries */
  central: {*{europe:central}} /* france, germany */
  therest: {*{europe}} /* spain, italy, malta */
}
```
This SECTIONS specification allocates the input sections as indicated in the comments:

```
SECTIONS {
  islands: {*(europe:south:malta) /* malta, iceland */
      *(europe:north:iceland)} /* finland */
  europe:north:finland : {} /* norway, sweden */
  europe:north : {} /* germany, denmark */
  europe:central : {} /* france */
  /* (italy, spain) go into a linker-generated output section "europe" */
}
```

### Upward Compatibility of Multi-Level Subsections

**NOTE:** Existing linker commands that use the existing single-level subsection features and which do not contain section names containing multiple colon characters continue to behave as before. However, if section names in a link command file or in the input sections supplied to the linker contain multiple colon characters, some change in behavior could be possible. You should carefully consider the impact of the new rules for multiple levels to see if it affects a particular system link.

### 7.5.4.5 Specifying Library or Archive Members as Input to Output Sections

You can specify one or more members of an object library or archive for input to an output section. Consider this SECTIONS directive:

**Example 7-8. Archive Members to Output Sections**

```
SECTIONS {
  boot > BOOT1
  {
    -l=rtsXX.lib < boot.obj> {.text}
    -l=rtsXX.lib < exit.obj strcpy.obj > (.text)
  }
  .rts > BOOT2
  {
    -l=rtsXX.lib {.text}
  }
  .text > RAM
  {
    * (.text)
  }
}
```

In **Example 7-8**, the .text sections of boot.obj, exit.obj, and strcpy.obj are extracted from the run-time-support library and placed in the .boot output section. The remainder of the run-time-support library object that is referenced is allocated to the .rts output section. Finally, the remainder of all other .text sections are to be placed in section .text.

An archive member or a list of members is specified by surrounding the member name(s) with angle brackets < and > after the library name. Any object files separated by commas or spaces from the specified archive file are legal within the angle brackets.

The --library option (which normally implies a library path search be made for the named file following the option) listed before each library in **Example 7-8** is optional when listing specific archive members inside < >. Using < > implies that you are referring to a library.
To collect a set of the input sections from a library in one place, use the --library option within the
SECTIONS directive. For example, the following collects all the .text sections from rts6200.lib into the
.rtstest section:

```
SECTIONS
{
  .rtstest { -l=rts6200.lib(.text) } > RAM
}
```

### SECTIONS Directive Effect on --priority

**NOTE:** Specifying a library in a SECTIONS directive causes that library to be entered in the list of
libraries that the linker searches to resolve references. If you use the --priority option, the first
library specified in the command file will be searched first.

#### 7.5.4.6 Allocation Using Multiple Memory Ranges

The linker allows you to specify an explicit list of memory ranges into which an output section can be
allocated. Consider the following example:

```
MEMORY
{
  P_MEM1 : origin = 0x02000, length = 0x01000
  P_MEM2 : origin = 0x04000, length = 0x01000
  P_MEM3 : origin = 0x06000, length = 0x01000
  P_MEM4 : origin = 0x08000, length = 0x01000
}
SECTIONS
{
  .text : { } > P_MEM1 | P_MEM2 | P_MEM4
}
```

The | operator is used to specify the multiple memory ranges. The .text output section is allocated as a
whole into the first memory range in which it fits. The memory ranges are accessed in the order specified.
In this example, the linker first tries to allocate the section in P_MEM1. If that attempt fails, the linker tries
to place the section into P_MEM2, and so on. If the output section is not successfully allocated in any of
the named memory ranges, the linker issues an error message.

With this type of SECTIONS directive specification, the linker can seamlessly handle an output section
that grows beyond the available space of the memory range in which it is originally allocated. Instead of
modifying the link command file, you can let the linker move the section into one of the other areas.

#### 7.5.4.7 Automatic Splitting of Output Sections Among Non-Contiguous Memory Ranges

The linker can split output sections among multiple memory ranges to achieve an efficient allocation. Use
the >> operator to indicate that an output section can be split, if necessary, into the specified memory
ranges. For example:

```
MEMORY
{
  P_MEM1 : origin = 0x2000, length = 0x1000
  P_MEM2 : origin = 0x4000, length = 0x1000
  P_MEM3 : origin = 0x6000, length = 0x1000
  P_MEM4 : origin = 0x8000, length = 0x1000
}
SECTIONS
{
  .text: { *(.text) } >> P_MEM1 | P_MEM2 | P_MEM3 | P_MEM4
}
```

In this example, the >> operator indicates that the .text output section can be split among any of the listed
memory areas. If the .text section grows beyond the available memory in P_MEM1, it is split on an input
section boundary, and the remainder of the output section is allocated to P_MEM2 | P_MEM3 | P_MEM4.
The | operator is used to specify the list of multiple memory ranges.
You can also use the >> operator to indicate that an output section can be split within a single memory range. This functionality is useful when several output sections must be allocated into the same memory range, but the restrictions of one output section cause the memory range to be partitioned. Consider the following example:

```
MEMORY
{
    RAM : origin = 0x1000, length = 0x8000
}
SECTIONS
{
    .special: { f1.obj(.text) } = 0x4000
    .text: { *(.text) } >> RAM
}
```

The .special output section is allocated near the middle of the RAM memory range. This leaves two unused areas in RAM: from 0x1000 to 0x4000, and from the end of f1.obj(.text) to 0x8000. The specification for the .text section allows the linker to split the .text section around the .special section and use the available space in RAM on either side of .special.

The >> operator can also be used to split an output section among all memory ranges that match a specified attribute combination. For example:

```
MEMORY
{
    P_MEM1 (RWX) : origin = 0x1000, length = 0x2000
    P_MEM2 (RWI) : origin = 0x4000, length = 0x1000
}
SECTIONS
{
    .text: { *(.text) } >> (RW)
}
```

The linker attempts to allocate all or part of the output section into any memory range whose attributes match the attributes specified in the SECTIONS directive.

This SECTIONS directive has the same effect as:

```
SECTIONS
{
    .text: { *(.text) } >> P_MEM1 | P_MEM2
}
```

Certain sections should not be split:

- Certain sections created by the compiler, including
  - The .cinit section, which contains the autoinitialization table for C/C++ programs
  - The .pinit section, which contains the list of global constructors for C++ programs
  - The .bss section, which defines global variables
- An output section with an input section specification that includes an expression to be evaluated. The expression may define a symbol that is used in the program to manage the output section at run time.
- An output section that has a START(), END(), OR SIZE() operator applied to it. These operators provide information about a section's load or run address, and size. Splitting the section may compromise the integrity of the operation.
- The run allocation of a UNION. (Splitting the load allocation of a UNION is allowed.)

If you use the >> operator on any of these sections, the linker issues a warning and ignores the operator.
7.5.5 Specifying a Section's Run-Time Address

At times, you may want to load code into one area of memory and run it in another. For example, you may have performance-critical code in slow external memory. The code must be loaded into slow external memory, but it would run faster in fast external memory.

The linker provides a simple way to accomplish this. You can use the SECTIONS directive to direct the linker to allocate a section twice: once to set its load address and again to set its run address. For example:

```
.fir: load = SLOW_MEM, run = FAST_MEM
```

Use the `load` keyword for the load address and the `run` keyword for the run address.

See Section 2.5 for an overview on run-time relocation.

7.5.5.1 Specifying Load and Run Addresses

The load address determines where a loader places the raw data for the section. Any references to the section (such as labels in it) refer to its run address. The application must copy the section from its load address to its run address; this does not happen automatically when you specify a separate run address.

If you provide only one allocation (either load or run) for a section, the section is allocated only once and loads and runs at the same address. If you provide both allocations, the section is allocated as if it were two sections of the same size. This means that both allocations occupy space in the memory map and cannot overlay each other or other sections. (The UNION directive provides a way to overlay sections; see Section 7.5.6.1.)

If either the load or run address has additional parameters, such as alignment or blocking, list them after the appropriate keyword. Everything related to allocation after the keyword `load` affects the load address until the keyword `run` is seen, after which, everything affects the run address. The load and run allocations are completely independent, so any qualification of one (such as alignment) has no effect on the other. You can also specify run first, then load. Use parentheses to improve readability.

The examples below specify load and run addresses:

- `.data: load = SLOW_MEM, align = 32, run = FAST_MEM`
  (align applies only to load)
- `.data: load = (SLOW_MEM align 32), run = FAST_MEM`
  (identical to previous example)
- `.data: run = FAST_MEM, align 32, load = align 16`
  (align 32 in FAST_MEM for run; align 16 anywhere for load)

7.5.5.2 Uninitialized Sections

Uninitialized sections (such as .bss) are not loaded, so their only significant address is the run address. The linker allocates uninitialized sections only once: if you specify both run and load addresses, the linker warns you and ignores the load address. Otherwise, if you specify only one address, the linker treats it as a run address, regardless of whether you call it load or run. This example specifies load and run addresses for an uninitialized section:

```
.bss: load = 0x1000, run = FAST_MEM
```

A warning is issued, load is ignored, and space is allocated in FAST_MEM. All of the following examples have the same effect. The .bss section is allocated in FAST_MEM.

- `.bss: load = FAST_MEM`
- `.bss: run = FAST_MEM`
- `.bss: > FAST_MEM`
7.5.5.3 Referring to the Load Address by Using the .label Directive

Normally, any reference to a symbol in a section refers to its run-time address. However, it may be necessary at run time to refer to a load-time address. Specifically, the code that copies a section from its load address to its run address must have access to the load address. The .label directive defines a special symbol that refers to the section's load address. Thus, whereas normal symbols are relocated with respect to the run address, .label symbols are relocated with respect to the load address. See Create a Load-Time Address Label for more information on the .label directive.

Example 7-9 and Example 7-10 show the use of the .label directive to copy a section from its load address in SLOW_MEM to its run address in FAST_MEM. Figure 7-3 illustrates the run-time execution of Example 7-9.

Example 7-9. Copying Section Assembly Language File

```
.sect "fir"
.align 4
.label fir_src

fir
    ; insert code here

.label fir_end

.text
MVKL fir_src, A4
MVKH fir_src, A4
MVKL fir_end, A5
MVKH fir_end, A5
MVKL fir, A6
MVKH fir, A6
SUB A5, A4, A1

loop:
    [!A1] B done
LDW *A4+, B3
NOP 4
    ; branch occurs
STW B3, *A6+
SUB A1, 4, A1
B loop
NOP 5
    ; branch occurs

done:
    B fir
NOP 5
    ; call occurs
```

Example 7-10. Linker Command File for Example 7-9

```
/************************************************************
/* PARTIAL LINKER COMMAND FILE FOR FIR EXAMPLE */
/************************************************************/

MEMORY
{
  FAST_MEM : origin = 0x00001000, length = 0x00001000
  SLOW_MEM : origin = 0x10000000, length = 0x00001000
}

SECTIONS
{
  .text: load = FAST_MEM
  .fir: load = SLOW_MEM, run FAST_MEM
}
```
7.5.6 Using UNION and GROUP Statements

Two SECTIONS statements allow you to conserve memory: GROUP and UNION. Unioning sections causes the linker to allocate them to the same run address. Grouping sections causes the linker to allocate them contiguously in memory. Section names can refer to sections, subsections, or archive library members.

7.5.6.1 Overlaying Sections With the UNION Statement

For some applications, you may want to allocate more than one section to run at the same address. For example, you may have several routines you want in fast external memory at various stages of execution. Or you may want several data objects that are not active at the same time to share a block of memory. The UNION statement within the SECTIONS directive provides a way to allocate several sections at the same run-time address.

In Example 7-11, the .bss sections from file1.obj and file2.obj are allocated at the same address in FAST_MEM. In the memory map, the union occupies as much space as its largest component. The components of a union remain independent sections; they are simply allocated together as a unit.

Example 7-11. The UNION Statement

```plaintext
SECTIONS
{
  .text: load = SLOW_MEM
  UNION: run = FAST_MEM
  {
    .bss:part1: { file1.obj(.bss) }
    .bss:part2: { file2.obj(.bss) }
  }
  .bss:part3: run = FAST_MEM { globals.obj(.bss) }
}
```

Allocation of a section as part of a union affects only its run address. Under no circumstances can sections be overlaid for loading. If an initialized section is a union member (an initialized section, such as .text, has raw data), its load allocation must be separately specified. See Example 7-12.
Example 7-12. Separate Load Addresses for UNION Sections

UNION run = FAST_MEM
{
    .text:part1: load = SLOW_MEM, { file1.obj(.text) }
    .text:part2: load = SLOW_MEM, { file2.obj(.text) }
}

Figure 7-4. Memory Allocation Shown in Example 7-11 and Example 7-12

Since the .text sections contain data, they cannot load as a union, although they can be run as a union. Therefore, each requires its own load address. If you fail to provide a load allocation for an initialized section within a UNION, the linker issues a warning and allocates load space anywhere it can in configured memory.

Uninitialized sections are not loaded and do not require load addresses.

The UNION statement applies only to allocation of run addresses, so it is meaningless to specify a load address for the union itself. For purposes of allocation, the union is treated as an uninitialized section: any one allocation specified is considered a run address, and if both run and load addresses are specified, the linker issues a warning and ignores the load address.
7.5.6.2 Grouping Output Sections Together

The SECTIONS directive’s GROUP option forces several output sections to be allocated contiguously. For example, assume that a section named term_rec contains a termination record for a table in the .data section. You can force the linker to allocate .data and term_rec together:

Example 7-13. Allocate Sections Together

```
SECTIONS
{
  .text /* Normal output section */
  .bss /* Normal output section */
  GROUP 0x00001000 : /* Specify a group of sections */
  { /* First section in the group */
    .data /* Allocated immediately after .data */
    term_rec /* Allocated immediately after .data */
  }
}
```

You can use binding, alignment, or named memory to allocate a GROUP in the same manner as a single output section. In the preceding example, the GROUP is bound to address 0x1000. This means that .data is allocated at 0x1000, and term_rec follows it in memory.

You Cannot Specify Addresses for Sections Within a GROUP

NOTE: When you use the GROUP option, binding, alignment, or allocation into named memory can be specified for the group only. You cannot use binding, named memory, or alignment for sections within a group.

7.5.6.3 Nesting UNIONs and GROUPs

The linker allows arbitrary nesting of GROUP and UNION statements with the SECTIONS directive. By nesting GROUP and UNION statements, you can express hierarchical overlays and groupings of sections. Example 7-14 shows how two overlays can be grouped together.

Example 7-14. Nesting GROUP and UNION Statements

```
SECTIONS
{
  GROUP 0x1000 : run = FAST_MEM
  {
    UNION:
    { /*  */
      mysect1: load = SLOW_MEM
      mysect2: load = SLOW_MEM
    }
    UNION:
    { /*  */
      mysect3: load = SLOW_MEM
      mysect4: load = SLOW_MEM
    }
  }
}
```

For this example, the linker performs the following allocations:

- The four sections (mysect1, mysect2, mysect3, mysect4) are assigned unique, non-overlapping load addresses. The name you defined is used in the SLOW_MEM memory region. This assignment is determined by the particular load allocations given for each section.
- Sections mysect1 and mysect2 are assigned the same run address in FAST_MEM.
- Sections mysect3 and mysect4 are assigned the same run address in FAST_MEM.
• The run addresses of mysect1/mysect2 and mysect3/mysect4 are allocated contiguously, as directed by the GROUP statement (subject to alignment and blocking restrictions).

To refer to groups and unions, linker diagnostic messages use the notation:

```
GROUP_n UNION_n
```

In this notation, \( n \) is a sequential number (beginning at 1) that represents the lexical ordering of the group or union in the linker control file, without regard to nesting. Groups and unions each have their own counter.

### 7.5.6.4 Checking the Consistency of Allocators

The linker checks the consistency of load and run allocations specified for unions, groups, and sections. The following rules are used:

• Run allocations are only allowed for top-level sections, groups, or unions (sections, groups, or unions that are not nested under any other groups or unions). The linker uses the run address of the top-level structure to compute the run addresses of the components within groups and unions.

• The linker does not accept a load allocation for UNIONs.

• The linker does not accept a load allocation for uninitialized sections.

• In most cases, you must provide a load allocation for an initialized section. However, the linker does not accept a load allocation for an initialized section that is located within a group that already defines a load allocator.

• If a union contains sections that are initialized, the union must have a load allocation for each initialized section nested within the group.

• The load allocator given for the group does not uniquely specify the load allocation for the elements within the union: .text2 and .text3. In this case, the linker issues a diagnostic message to request that these load allocations be specified explicitly.
7.5.6.5 Naming UNIONs and GROUPs

You can give a name to a UNION or GROUP by entering the name in parentheses after the declaration. For example:

```c
GROUP (BSS_SYSMEM_STACK_GROUP)
{
  .bss :{}
  .sysmem :{}
  .stack :{}
} load=D_MEM, run=D_MEM
```

The name you defined is used in diagnostics for easy identification of the problem LCF area. For example:

```plaintext
warning: LOAD placement ignored for "BSS_SYSMEM_STACK_GROUP": object is uninitialized
```

```c
UNION (TEXT_CINIT_UNION)
{
  .const :{} load=D_MEM, table(table1)
  .pinit :{} load=D_MEM, table(table1)
} run=P_MEM
```

```plaintext
warning: table(table1) operator ignored: table(table1) has already been applied to a section in the "UNION(TEXT_CINIT_UNION)" in which ".pinit" is a descendant
```

7.5.7 Special Section Types (DSECT, COPY, NOLOAD, and NOINIT)

You can assign three special types to output sections: DSECT, COPY, and NOLOAD. These types affect the way that the program is treated when it is linked and loaded. You can assign a type to a section by placing the type after the section definition. For example:

```c
SECTIONS
{
sec1: load = 0x00002000, type = DSECT {f1.obj}
sec2: load = 0x00004000, type = COPY {f2.obj}
sec3: load = 0x00006000, type = NOLOAD {f3.obj}
sec4: load = 0x00008000, type = NOINIT {f4.obj}
}
```

- The DSECT type creates a dummy section with the following characteristics:
  - It is not included in the output section memory allocation. It takes up no memory and is not included in the memory map listing.
  - It can overlay other output sections, other DSECTs, and unconfigured memory.
  - Global symbols defined in a dummy section are relocated normally. They appear in the output module's symbol table with the same value they would have if the DSECT had actually been loaded. These symbols can be referenced by other input sections.
  - Undefined external symbols found in a DSECT cause specified archive libraries to be searched.
  - The section's contents, relocation information, and line number information are not placed in the output module.

In the preceding example, none of the sections from f1.obj are allocated, but all the symbols are relocated as though the sections were linked at address 0x2000. The other sections can refer to any of the global symbols in sec1.

- A COPY section is similar to a DSECT section, except that its contents and associated information are written to the output module. The .cinit section that contains initialization tables for the TMS320C6000 C/C++ compiler has this attribute under the run-time initialization model.

- A NOLOAD section differs from a normal output section in one respect: the section's contents, relocation information, and line number information are not placed in the output module. The linker allocates space for the section, and it appears in the memory map listing.

- A NOINIT section is not C auto-initialized by the linker. It is your responsibility to initialize this section as needed.
7.5.8 Assigning Symbols at Link Time

Linker assignment statements allow you to define external (global) symbols and assign values to them at link time. You can use this feature to initialize a variable or pointer to an allocation-dependent value.

7.5.8.1 Syntax of Assignment Statements

The syntax of assignment statements in the linker is similar to that of assignment statements in the C language:

- `symbol = expression;` assigns the value of expression to symbol
- `symbol += expression;` adds the value of expression to symbol
- `symbol -= expression;` subtracts the value of expression from symbol
- `symbol *= expression;` multiplies symbol by expression
- `symbol /= expression;` divides symbol by expression

The symbol should be defined externally. If it is not, the linker defines a new symbol and enters it into the symbol table. The expression must follow the rules defined in Section 7.5.8.3. Assignment statements must terminate with a semicolon.

The linker processes assignment statements after it allocates all the output sections. Therefore, if an expression contains a symbol, the address used for that symbol reflects the symbol's address in the executable output file.

For example, suppose a program reads data from one of two tables identified by two external symbols, Table1 and Table2. The program uses the symbol cur_tab as the address of the current table. The cur_tab symbol must point to either Table1 or Table2. You could accomplish this in the assembly code, but you would need to reassemble the program to change tables. Instead, you can use a linker assignment statement to assign cur_tab at link time:

```
prog.obj /* Input file */
cur_tab = Table1; /* Assign cur_tab to one of the tables */
```

7.5.8.2 Assigning the SPC to a Symbol

A special symbol, denoted by a dot (.), represents the current value of the section program counter (SPC) during allocation. The SPC keeps track of the current location within a section. The linker's . symbol is analogous to the assembler's $ symbol. The . symbol can be used only in assignment statements within a SECTIONS directive because . is meaningful only during allocation and SECTIONS controls the allocation process. (See Section 7.5.4.)

The . symbol refers to the current run address, not the current load address, of the section.

For example, suppose a program needs to know the address of the beginning of the .data section. By using the .global directive (see Identify Global Symbols), you can create an external undefined variable called Dstart in the program. Then, assign the value of . to Dstart:

```
SECTIONS
{
    .text: {}
    .data: {Dstart = .;}
    .bss : {}
}
```

This defines Dstart to be the first linked address of the .data section. (Dstart is assigned before .data is allocated.) The linker relocates all references to Dstart.

A special type of assignment assigns a value to the . symbol. This adjusts the SPC within an output section and creates a hole between two input sections. Any value assigned to . to create a hole is relative to the beginning of the section, not to the address actually represented by the . symbol. Holes and assignments to . are described in Section 7.5.9.
7.5.8.3 Assignment Expressions

These rules apply to linker expressions:

- Expressions can contain global symbols, constants, and the C language operators listed in Table 7-10.
- All numbers are treated as long (32-bit) integers.
- Constants are identified by the linker in the same way as by the assembler. That is, numbers are recognized as decimal unless they have a suffix (H or h for hexadecimal and Q or q for octal). C language prefixes are also recognized (0 for octal and 0x for hex). Hexadecimal constants must begin with a digit. No binary constants are allowed.
- Symbols within an expression have only the value of the symbol's address. No type-checking is performed.
- Linker expressions can be absolute or relocatable. If an expression contains any relocatable symbols (and 0 or more constants or absolute symbols), it is relocatable. Otherwise, the expression is absolute. If a symbol is assigned the value of a relocatable expression, it is relocatable; if it is assigned the value of an absolute expression, it is absolute.

The linker supports the C language operators listed in Table 7-10 in order of precedence. Operators in the same group have the same precedence. Besides the operators listed in Table 7-10, the linker also has an align operator that allows a symbol to be aligned on an n-byte boundary within an output section (n is a power of 2). For example, the following expression aligns the SPC within the current section on the next 16-byte boundary. Because the align operator is a function of the current SPC, it can be used only in the same context as .—that is, within a SECTIONS directive.

```
. = align(16);
```

### Table 7-10. Groups of Operators Used in Expressions (Precedence)

<table>
<thead>
<tr>
<th>Group 1 (Highest Precedence)</th>
<th>Group 6</th>
<th>Group 2</th>
<th>Group 7</th>
<th>Group 3</th>
<th>Group 8</th>
<th>Group 4</th>
<th>Group 9</th>
<th>Group 5</th>
<th>Group 10 (Lowest Precedence)</th>
</tr>
</thead>
<tbody>
<tr>
<td>! Logical NOT</td>
<td></td>
<td>*</td>
<td>Multiplication</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>= Assignment</td>
</tr>
<tr>
<td>~ Bitwise NOT</td>
<td></td>
<td>/</td>
<td>Division</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>+ = A + = B * A = A + B</td>
</tr>
<tr>
<td>- Negation</td>
<td></td>
<td>%</td>
<td>Modulus</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>- = A - = B * A = A - B</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>* = A * = B * A = A * B</td>
</tr>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>= = A / = B * A = A / B</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>&gt; = Greater than or equal to</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>&gt;= Greater than or equal to</td>
</tr>
</tbody>
</table>

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7.5.8.4 Symbols Defined by the Linker

The linker automatically defines several symbols based on which sections are used in your assembly source. A program can use these symbols at run time to determine where a section is linked. Since these symbols are external, they appear in the linker map. Each symbol can be accessed in any assembly language module if it is declared with a .global directive (see Identify Global Symbols). You must have used the corresponding section in a source module for the symbol to be created. Values are assigned to these symbols as follows:

- `.text` is assigned the first address of the .text output section. (It marks the beginning of executable code.)
- `etext` is assigned the first address following the .text output section. (It marks the end of executable code.)
- `.data` is assigned the first address of the .data output section. (It marks the beginning of initialized data tables.)
- `edata` is assigned the first address following the .data output section. (It marks the end of initialized data tables.)
- `.bss` is assigned the first address of the .bss output section. (It marks the beginning of uninitialized data.)
- `end` is assigned the first address following the .bss output section. (It marks the end of uninitialized data.)

The following symbols are defined only for C/C++ support when the --ram_model or --rom_model option is used.

- `__TI_STACK_END` is assigned the end of the .stack size for ELF.
- `__TI_STACK_SIZE` is assigned the size of the .stack section for ELF.
- `__STACK_END` is assigned the end of the .stack size for COFF.
- `__STACK_SIZE` is assigned the size of the .stack section for COFF.
- `__SYSMEM_SIZE` is assigned the size of the .sysmem section for COFF.
- `__TI_SYSMEM_SIZE` is assigned the size of the .sysmem section for ELF.

7.5.8.5 Assigning Exact Start, End, and Size Values of a Section to a Symbol

The code generation tools currently support the ability to load program code in one area of (slow) memory and run it in another (faster) area. This is done by specifying separate load and run addresses for an output section or group in the link command file. Then execute a sequence of instructions (the copying code in Example 7-9) that moves the program code from its load area to its run area before it is needed.

There are several responsibilities that a programmer must take on when setting up a system with this feature. One of these responsibilities is to determine the size and run-time address of the program code to be moved. The current mechanisms to do this involve use of the .label directives in the copying code. A simple example is illustrated Example 7-9.

This method of specifying the size and load address of the program code has limitations. While it works fine for an individual input section that is contained entirely within one source file, this method becomes more complicated if the program code is spread over several source files or if the programmer wants to copy an entire output section from load space to run space.

Another problem with this method is that it does not account for the possibility that the section being moved may have an associated far call trampoline section that needs to be moved with it.
7.5.8.6 Why the Dot Operator Does Not Always Work

The dot operator (.) is used to define symbols at link-time with a particular address inside of an output section. It is interpreted like a PC. Whatever the current offset within the current section is, that is the value associated with the dot. Consider an output section specification within a SECTIONS directive:

```c
outsect:
{
  s1.obj(.text)
  end_of_s1 = .;
  start_of_s2 = .;
  s2.obj(.text)
  end_of_s2 = .;
}
```

This statement creates three symbols:

- `end_of_s1` — the end address of .text in s1.obj
- `start_of_s2` — the start address of .text in s2.obj
- `end_of_s2` — the end address of .text in s2.obj

Suppose there is padding between s1.obj and s2.obj that is created as a result of alignment. Then `start_of_s2` is not really the start address of the .text section in s2.obj, but it is the address before the padding needed to align the .text section in s2.obj. This is due to the linker's interpretation of the dot operator as the current PC. It is also due to the fact that the dot operator is evaluated independently of the input sections around it.

Another potential problem in the above example is that `end_of_s2` may not account for any padding that was required at the end of the output section. You cannot reliably use `end_of_s2` as the end address of the output section. One way to get around this problem is to create a dummy section immediately after the output section in question. For example:

```c
GROUP
{
  outsect:
  {
    start_of_outsect = .;
    ...
  }
  dummy: { size_of_outsect = . - start_of_outsect; }
}
```

7.5.8.7 Address and Dimension Operators

Six new operators have been added to the link command file syntax:

- **LOAD_START(sym)**: Defines `sym` with the load-time start address of related allocation unit
- **START(sym)**: Defines `sym` with the load-time end address of related allocation unit
- **LOAD_END(sym)**: Defines `sym` with the load-time size of related allocation unit
- **END(sym)**: Defines `sym` with the run-time start address of related allocation unit
- **LOAD_SIZE(sym)**: Defines `sym` with the run-time end address of related allocation unit
- **RUN_SIZE(sym)**: Defines `sym` with the run-time size of related allocation unit

**Linker Command File Operator Equivalencies**

**NOTE:** `LOAD_START()` and `START()` are equivalent, as are `LOAD_END()`/`END()` and `LOAD_SIZE()`/`SIZE()`. The LOAD names are recommended for clarity.

The new address and dimension operators can be associated with several different kinds of allocation units, including input items, output sections, GROUPs, and UNIONs. The following sections provide some examples of how the operators can be used in each case.
7.5.8.7.1 Input Items

Consider an output section specification within a SECTIONS directive:

```c
outsect:
{
    s1.obj(.text)
    end_of_s1 = .;
    start_of_s2 = .;
    s2.obj(.text)
    end_of_s2 = .;
}
```

This can be rewritten using the START and END operators as follows:

```c
outsect:
{
    s1.obj(.text) { END(end_of_s1) }
    s2.obj(.text) { START(start_of_s2), END(end_of_s2) }
}
```

The values of end_of_s1 and end_of_s2 will be the same as if you had used the dot operator in the original example, but start_of_s2 would be defined after any necessary padding that needs to be added between the two .text sections. Remember that the dot operator would cause start_of_s2 to be defined before any necessary padding is inserted between the two input sections.

The syntax for using these operators in association with input sections calls for braces {} to enclose the operator list. The operators in the list are applied to the input item that occurs immediately before the list.

7.5.8.7.2 Output Section

The START, END, and SIZE operators can also be associated with an output section. Here is an example:

```c
outsect: START(start_of_outsect), SIZE(size_of_outsect)
{
    <list of input items>
}
```

In this case, the SIZE operator defines size_of_outsect to incorporate any padding that is required in the output section to conform to any alignment requirements that are imposed.

The syntax for specifying the operators with an output section do not require braces to enclose the operator list. The operator list is simply included as part of the allocation specification for an output section.

7.5.8.7.3 GROUPs

Here is another use of the START and SIZE operators in the context of a GROUP specification:

```c
GROUP
{
    outsect1: { ... }
    outsect2: { ... }
} load = ROM, run = RAM, START(group_start), SIZE(group_size);
```

This can be useful if the whole GROUP is to be loaded in one location and run in another. The copying code can use group_start and group_size as parameters for where to copy from and how much is to be copied. This makes the use of .label in the source code unnecessary.
7.5.8.7.4 UNIONS

The RUN_SIZE and LOAD_SIZE operators provide a mechanism to distinguish between the size of a UNION's load space and the size of the space where its constituents are going to be copied before they are run. Here is an example:

UNION: run = RAM, LOAD_START(union_load_addr), LOAD_SIZE(union_id_sz), RUN_SIZE(union_run_sz)

{  
  .text1: load = ROM, SIZE(text1_size) { f1.obj(.text) }
  .text2: load = ROM, SIZE(text2_size) { f2.obj(.text) }
}

Here union_id_sz is going to be equal to the sum of the sizes of all output sections placed in the union. The union_run_sz value is equivalent to the largest output section in the union. Both of these symbols incorporate any padding due to blocking or alignment requirements.

7.5.9 Creating and Filling Holes

The linker provides you with the ability to create areas within output sections that have nothing linked into them. These areas are called holes. In special cases, uninitialized sections can also be treated as holes. This section describes how the linker handles holes and how you can fill holes (and uninitialized sections) with values.

7.5.9.1 Initialized and Uninitialized Sections

There are two rules to remember about the contents of output sections. An output section contains either:

- Raw data for the entire section
- No raw data

A section that has raw data is referred to as initialized. This means that the object file contains the actual memory image contents of the section. When the section is loaded, this image is loaded into memory at the section's specified starting address. The .text and .data sections always have raw data if anything was assembled into them. Named sections defined with the .sect assembler directive also have raw data.

By default, the .bss section (see Reserve Space in the .bss Section) and sections defined with the .usect directive (see Reserve Uninitialized Space) have no raw data (they are uninitialized). They occupy space in the memory map but have no actual contents. Uninitialized sections typically reserve space in fast external memory for variables. In the object file, an uninitialized section has a normal section header and can have symbols defined in it; no memory image, however, is stored in the section.

7.5.9.2 Creating Holes

You can create a hole in an initialized output section. A hole is created when you force the linker to leave extra space between input sections within an output section. When such a hole is created, the linker must supply raw data for the hole.

Holes can be created only within output sections. Space can exist between output sections, but such space is not a hole. To fill the space between output sections, see Section 7.5.3.2.

To create a hole in an output section, you must use a special type of linker assignment statement within an output section definition. The assignment statement modifies the SPC (denoted by .) by adding to it, assigning a greater value to it, or aligning it on an address boundary. The operators, expressions, and syntaxes of assignment statements are described in Section 7.5.8.
The following example uses assignment statements to create holes in output sections:

```c
SECTIONS
{
    outsect:
    {
        file1.obj(.text)
        . += 0x0100 /* Create a hole with size 0x0100 */
        file2.obj(.text)
        . = align(16); /* Create a hole to align the SPC */
        file3.obj(.text)
    }
}
```

The output section `outsect` is built as follows:

1. The `.text` section from `file1.obj` is linked in.
2. The linker creates a 256-byte hole.
3. The `.text` section from `file2.obj` is linked in after the hole.
4. The linker creates another hole by aligning the SPC on a 16-byte boundary.
5. Finally, the `.text` section from `file3.obj` is linked in.

All values assigned to the `. `symbol within a section refer to the relative address within the section. The linker handles assignments to the `. `symbol as if the section started at address 0 (even if you have specified a binding address). Consider the statement `. = align(16)` in the example. This statement effectively aligns the `file3.obj .text` section to start on a 16-byte boundary within `outsect`. If `outsect` is ultimately allocated to start on an address that is not aligned, the `file3.obj .text` section will not be aligned either.

The `. `symbol refers to the current run address, not the current load address, of the section.

Expressions that decrement the `. `symbol are illegal. For example, it is invalid to use the `-=` operator in an assignment to the `. `symbol. The most common operators used in assignments to the `. `symbol are `+=` and `align`.

If an output section contains all input sections of a certain type (such as `.text`), you can use the following statements to create a hole at the beginning or end of the output section.

```c
.text: { .+= 0x0100; } /* Hole at the beginning */
.data: { *(.data)
        . += 0x0100; } /* Hole at the end */
```

Another way to create a hole in an output section is to combine an uninitialized section with an initialized section to form a single output section. In this case, the linker treats the uninitialized section as a hole and supplies data for it. The following example illustrates this method:

```c
SECTIONS
{
    outsect:
    {
        file1.obj(.text)
        file1.obj(.bss) /* This becomes a hole */
    }
}
```

Because the `.text` section has raw data, all of `outsect` must also contain raw data. Therefore, the uninitialized `.bss` section becomes a hole.

Uninitialized sections become holes only when they are combined with initialized sections. If several uninitialized sections are linked together, the resulting output section is also uninitialized.
7.5.9.3 Filling Holes

When a hole exists in an initialized output section, the linker must supply raw data to fill it. The linker fills holes with a 32-bit fill value that is replicated through memory until it fills the hole. The linker determines the fill value as follows:

1. If the hole is formed by combining an uninitialized section with an initialized section, you can specify a fill value for the uninitialized section. Follow the section name with an = sign and a 32-bit constant. For example:

```c
SECTIONS
{ outsect:
  {  
    file1.obj(.text)
    file2.obj(.bss)= 0xFF00FF00 /* Fill this hole with 0xFF00FF00 */ 
  }
}
```

2. You can also specify a fill value for all the holes in an output section by supplying the fill value after the section definition:

```c
SECTIONS
{ outsect:fill = 0xFF00FF00 /* Fills holes with 0xFF00FF00 */
  {  
    file1.obj(.text)
    file1.obj(.bss) /* This creates a hole */
  }
}
```

3. If you do not specify an initialization value for a hole, the linker fills the hole with the value specified with the --fill_value option (see Section 7.4.10). For example, suppose the command file link.cmd contains the following SECTIONS directive:

```c
SECTIONS { .text: { .= 0x0100; } /* Create a 100 word hole */ }
```

Now invoke the linker with the --fill_value option:

```
c16x --run_linker --fill_value=0xFFFFFFFF link.cmd
```

This fills the hole with 0xFFFFFFFF.

4. If you do not invoke the linker with the --fill_value option or otherwise specify a fill value, the linker fills holes with 0s.

Whenever a hole is created and filled in an initialized output section, the hole is identified in the link map along with the value the linker uses to fill it.

7.5.9.4 Explicit Initialization of Uninitialized Sections

You can force the linker to initialize an uninitialized section by specifying an explicit fill value for it in the SECTIONS directive. This causes the entire section to have raw data (the fill value). For example:

```c
SECTIONS
{  
  .bss: fill = 0x12341234 /* Fills .bss with 0x12341234 */
}
```

---

**NOTE:** Because filling a section (even with 0s) causes raw data to be generated for the entire section in the output file, your output file will be very large if you specify fill values for large sections or holes.
7.6 Object Libraries

An object library is a partitioned archive file that contains object files as members. Usually, a group of
related modules are grouped together into a library. When you specify an object library as linker input, the
linker includes any members of the library that define existing unresolved symbol references. You can use
the archiver to build and maintain libraries. Section 6.1 contains more information about the archiver.

Using object libraries can reduce link time and the size of the executable module. Normally, if an object
file that contains a function is specified at link time, the file is linked whether the function is used or not;
however, if that same function is placed in an archive library, the file is included only if the function is
referenced.

The order in which libraries are specified is important, because the linker includes only those members
that resolve symbols that are undefined at the time the library is searched. The same library can be
specified as often as necessary; it is searched each time it is included. Alternatively, you can use the
--reread_libs option to reread libraries until no more references can be resolved (see Section 7.4.14.3). A
library has a table that lists all external symbols defined in the library; the linker searches through the table
until it determines that it cannot use the library to resolve any more references.

The following examples link several files and libraries, using these assumptions:

- Input files f1.obj and f2.obj both reference an external function named clrscr.
- Input file f1.obj references the symbol origin.
- Input file f2.obj references the symbol fillclr.
- Member 0 of library libc.lib contains a definition of origin.
- Member 3 of library liba.lib contains a definition of fillclr.
- Member 1 of both libraries defines clrscr.

If you enter:

```sh
cl6x --run_linker f1.obj f2.obj liba.lib libc.lib
```

then:

- Member 1 of liba.lib satisfies the f1.obj and f2.obj references to clrscr because the library is searched
  and the definition of clrscr is found.
- Member 0 of libc.lib satisfies the reference to origin.
- Member 3 of liba.lib satisfies the reference to fillclr.

If, however, you enter:

```sh
cl6x --run_linker f1.obj f2.obj libc.lib liba.lib
```

then the references to clrscr are satisfied by member 1 of libc.lib.

If none of the linked files reference symbols defined in a library, you can use the --undef_sym option to
force the linker to include a library member. (See Section 7.4.31.) The next example creates an undefined
symbol rout1 in the linker's global symbol table:

```sh
cl6x --run_linker --undef_sym=rout1 libc.lib
```

If any member of libc.lib defines rout1, the linker includes that member.

Library members are allocated according to the SECTIONS directive default allocation algorithm; see
Section 7.5.4.

Section 7.4.14 describes methods for specifying directories that contain object libraries.
## 7.7 Default Allocation Algorithm

The MEMORY and SECTIONS directives provide flexible methods for building, combining, and allocating sections. However, any memory locations or sections that you choose *not* to specify must still be handled by the linker. The linker uses default algorithms to build and allocate sections within the specifications you supply.

If you do not use the MEMORY and SECTIONS directives, the linker allocates output sections as though the definitions in Example 7-15 were specified.

### Example 7-15. Default Allocation for TMS320C6000 Devices

```
MEMORY
{
    RAM : origin = 0x00000001, length = 0xFFFFFFFF
}
SECTIONS
{
    .text : ALIGN(32) {} > RAM
    .const : ALIGN(8) {} > RAM
    .data : ALIGN(8) {} > RAM
    .bss : ALIGN(8) {} > RAM
    .cinit : ALIGN(4) {} > RAM ; cflag option only
    .pinit : ALIGN(4) {} > RAM ; cflag option only
    .stack : ALIGN(8) {} > RAM ; cflag option only
    .sysmem: ALIGN(8) {} > RAM ; cflag option only
    .switch: ALIGN(4) {} > RAM ; cflag option only
    .cio : ALIGN(4) {} > RAM ; cflag option only
}
```

All .text input sections are concatenated to form a .text output section in the executable output file, and all .data input sections are combined to form a .data output section.

If you use a SECTIONS directive, the linker performs *no part* of the default allocation. Allocation is performed according to the rules specified by the SECTIONS directive and the general algorithm described next in Section 7.7.1.

### 7.7.1 How the Allocation Algorithm Creates Output Sections

An output section can be formed in one of two ways:

**Method 1** As the result of a SECTIONS directive definition

**Method 2** By combining input sections with the same name into an output section that is not defined in a SECTIONS directive

If an output section is formed as a result of a SECTIONS directive, this definition completely determines the section's contents. (See Section 7.5.4 for examples of how to define an output section's content.)

If an output section is formed by combining input sections not specified by a SECTIONS directive, the linker combines all such input sections that have the same name into an output section with that name. For example, suppose the files f1.obj and f2.obj both contain named sections called Vectors and that the SECTIONS directive does not define an output section for them. The linker combines the two Vectors sections from the input files into a single output section named Vectors, allocates it into memory, and includes it in the output file.

By default, the linker does not display a message when it creates an output section that is not defined in the SECTIONS directive. You can use the --warn_sections linker option (see Section 7.4.33) to cause the linker to display a message when it creates a new output section.
After the linker determines the composition of all output sections, it must allocate them into configured memory. The MEMORY directive specifies which portions of memory are configured. If there is no MEMORY directive, the linker uses the default configuration as shown in Example 7-15. (See Section 7.5.3 for more information on configuring memory.)

### 7.7.2 Reducing Memory Fragmentation

The linker's allocation algorithm attempts to minimize memory fragmentation. This allows memory to be used more efficiently and increases the probability that your program will fit into memory. The algorithm comprises these steps:

1. Each output section for which you have supplied a specific binding address is placed in memory at that address.
2. Each output section that is included in a specific, named memory range or that has memory attribute restrictions is allocated. Each output section is placed into the first available space within the named area, considering alignment where necessary.
3. Any remaining sections are allocated in the order in which they are defined. Sections not defined in a SECTIONS directive are allocated in the order in which they are encountered. Each output section is placed into the first available memory space, considering alignment where necessary.

### 7.8 Linker-Generated Copy Tables

The linker supports extensions to the link command file syntax that enable the following:

- Make it easier for you to copy objects from load-space to run-space at boot time
- Make it easier for you to manage memory overlays at run time
- Allow you to split GROUPs and output sections that have separate load and run addresses

#### 7.8.1 A Current Boot-Loaded Application Development Process

In some embedded applications, there is a need to copy or download code and/or data from one location to another at boot time before the application actually begins its main execution thread. For example, an application may have its code and/or data in FLASH memory and need to copy it into on-chip memory before the application begins execution.

One way you can develop an application like this is to create a copy table in assembly code that contains three elements for each block of code or data that needs to be moved from FLASH into on-chip memory at boot time:

- The load address
- The run address
- The size

The process you follow to develop such an application might look like this:

1. Build the application to produce a .map file that contains the load and run addresses of each section that has a separate load and run placement.
2. Edit the copy table (used by the boot loader) to correct the load and run addresses as well as the size of each block of code or data that needs to be moved at boot time.
3. Build the application again, incorporating the updated copy table.
4. Run the application.

This process puts a heavy burden on you to maintain the copy table (by hand, no less). Each time a piece of code or data is added or removed from the application, you must repeat the process in order to keep the contents of the copy table up to date.
7.8.2 An Alternative Approach

You can avoid some of this maintenance burden by using the LOAD_START(), RUN_START(), and SIZE() operators that are already part of the link command file syntax. For example, instead of building the application to generate a .map file, the link command file can be annotated:

```plaintext
SECTIONS

  .flashcode: { app_tasks.obj(.text) }
  load = FLASH, run = PMEM,
  LOAD_START(_flash_code_ld_start),
  RUN_START(_flash_code_rn_start),
  SIZE(_flash_code_size)

...
```

In this example, the LOAD_START(), RUN_START(), and SIZE() operators instruct the linker to create three symbols:

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>_flash_code_ld_start</td>
<td>Load address of .flashcode section</td>
</tr>
<tr>
<td>_flash_code_rn_start</td>
<td>Run address of .flashcode section</td>
</tr>
<tr>
<td>_flash_code_size</td>
<td>Size of .flashcode section</td>
</tr>
</tbody>
</table>

These symbols can then be referenced from the copy table. The actual data in the copy table will be updated automatically each time the application is linked. This approach removes step 1 of the process described in Section 7.8.1.

While maintenance of the copy table is reduced markedly, you must still carry the burden of keeping the copy table contents in sync with the symbols that are defined in the link command file. Ideally, the linker would generate the boot copy table automatically. This would avoid having to build the application twice and free you from having to explicitly manage the contents of the boot copy table.

For more information on the LOAD_START(), RUN_START(), and SIZE() operators, see Section 7.5.8.7.
7.8.3 Overlay Management Example

Consider an application which contains a memory overlay that must be managed at run time. The memory overlay is defined using a UNION in the link command file as illustrated in Example 7-16:

Example 7-16. Using a UNION for Memory Overlay

```
SECTIONS
{
    ...
    UNION
    {
        GROUP
        {
            .task1: { task1.obj(.text) }
            .task2: { task2.obj(.text) }
        } load = ROM, LOAD_START(_task12_load_start), SIZE(_task12_size)
        GROUP
        {
            .task3: { task3.obj(.text) }
            .task4: { task4.obj(.text) }
        } load = ROM, LOAD_START(_task34_load_start), SIZE(_task34_size)
    } run = RAM, RUN_START(_task_run_start)
    ...
}
```

The application must manage the contents of the memory overlay at run time. That is, whenever any services from .task1 or .task2 are needed, the application must first ensure that .task1 and .task2 are resident in the memory overlay. Similarly for .task3 and .task4.

To affect a copy of .task1 and .task2 from ROM to RAM at run time, the application must first gain access to the load address of the tasks (_task12_load_start), the run address (_task_run_start), and the size (_task12_size). Then this information is used to perform the actual code copy.

7.8.4 Generating Copy Tables Automatically With the Linker

The linker supports extensions to the link command file syntax that enable you to do the following:

- Identify any object components that may need to be copied from load space to run space at some point during the run of an application
- Instruct the linker to automatically generate a copy table that contains (at least) the load address, run address, and size of the component that needs to be copied
- Instruct the linker to generate a symbol specified by you that provides the address of a linker-generated copy table. For instance, Example 7-16 can be written as shown in Example 7-17:
Example 7-17. Produce Address for Linker Generated Copy Table

```c
SECTIONS
{
    ...

    UNION
    {
        GROUP
        {
            .task1: { task1.obj(.text) }
            .task2: { task2.obj(.text) }
        } load = ROM, table(_task12_copy_table)

        GROUP
        {
            .task3: { task3.obj(.text) }
            .task4: { task4.obj(.text) }
        } load = ROM, table(_task34_copy_table)

        } run = RAM

    }

    ...

}
```

Using the SECTIONS directive from Example 7-17 in the link command file, the linker generates two copy tables named: _task12_copy_table and _task34_copy_table. Each copy table provides the load address, run address, and size of the GROUP that is associated with the copy table. This information is accessible from application source code using the linker-generated symbols, _task12_copy_table and _task34_copy_table, which provide the addresses of the two copy tables, respectively.

Using this method, you do not have to worry about the creation or maintenance of a copy table. You can reference the address of any copy table generated by the linker in C/C++ or assembly source code, passing that value to a general purpose copy routine which will process the copy table and affect the actual copy.

### 7.8.5 The table() Operator

You can use the table() operator to instruct the linker to produce a copy table. A table() operator can be applied to an output section, a GROUP, or a UNION member. The copy table generated for a particular table() specification can be accessed through a symbol specified by you that is provided as an argument to the table() operator. The linker creates a symbol with this name and assigns it the address of the copy table as the value of the symbol. The copy table can then be accessed from the application using the linker-generated symbol.

Each table() specification you apply to members of a given UNION must contain a unique name. If a table() operator is applied to a GROUP, then none of that GROUP’s members may be marked with a table() specification. The linker detects violations of these rules and reports them as warnings, ignoring each offending use of the table() specification. The linker does not generate a copy table for erroneous table() operator specifications.
7.8.6 Boot-Time Copy Tables

The linker supports a special copy table name, BINIT (or binit), that you can use to create a boot-time copy table. For example, the link command file for the boot-loaded application described in Section 7.8.2 can be rewritten as follows:

```c
SECTIONS
{
    .flashcode: { app_tasks.obj(.text) }
    load = FLASH, run = PMEM,
    table(BINIT)
    ...
}
```

For this example, the linker creates a copy table that can be accessed through a special linker-generated symbol, ___binit__, which contains the list of all object components that need to be copied from their load location to their run location at boot-time. If a link command file does not contain any uses of table(BINIT), then the ___binit__ symbol is given a value of -1 to indicate that a boot-time copy table does not exist for a particular application.

You can apply the table(BINIT) specification to an output section, GROUP, or UNION member. If used in the context of a UNION, only one member of the UNION can be designated with table(BINIT). If applied to a GROUP, then none of that GROUP's members may be marked with table(BINIT). The linker detects violations of these rules and reports them as warnings, ignoring each offending use of the table(BINIT) specification.

7.8.7 Using the table() Operator to Manage Object Components

If you have several pieces of code that need to be managed together, then you can apply the same table() operator to several different object components. In addition, if you want to manage a particular object component in multiple ways, you can apply more than one table() operator to it. Consider the link command file excerpt in Example 7-18:

```c
Example 7-18. Linker Command File to Manage Object Components

SECTIONS
{
    UNION
    {
        .first: { a1.obj(.text), b1.obj(.text), c1.obj(.text) }
        load = EMEM, run = PMEM, table(BINIT), table(_first_ctbl)

        .second: { a2.obj(.text), b2.obj(.text) }
        load = EMEM, run = PMEM, table(_second_ctbl)
    }

    .extra: load = EMEM, run = PMEM, table(BINIT)
    ...
}
```

In this example, the output sections .first and .extra are copied from external memory (EMEM) into program memory (PMEM) at boot time while processing the BINIT copy table. After the application has started executing its main thread, it can then manage the contents of the overlay using the two overlay copy tables named: _first_ctbl and _second_ctbl.
7.8.8 Compression Support

When automatically generating copy tables, the linker provides a way to compress the load-space data. This can reduce the read-only memory footprint. This compressed data can be decompressed while copying the data from load space to run space.

You can specify compression in two ways:

- The linker command line option --copy_compression=compression_kind can be used to apply the specified compression to any output section that has a table() operator applied to it.
- The table() operator now accepts a compression parameter. The syntax is:

  ```
  table ( name , compression= compression_kind )
  ```

  The `compression_kind` can be one of the following types:
  - `off`. Don't compress the data.
  - `rle`. Compress data using Run Length Encoding.

  A table() operator without the compression keyword uses the compression kind specified using the command line option --copy_compression.

When you choose compression, it is not guaranteed that the linker will compress the load data. The linker compresses load data only when such compression reduces the overall size of the load space. In some cases even if the compression results in smaller load section size the linker does not compress the data if the decompression routine offsets for the savings.

For example, assume RLE compression reduces the size of section1 by 30 bytes. Also assume the RLE decompression routine takes up 40 bytes in load space. By choosing to compress section1 the load space is increased by 10 bytes. Therefore, the linker will not compress section1. On the other hand, if there is another section (say section2) that can benefit by more than 10 bytes from applying the same compression then both sections can be compressed and the overall load space is reduced. In such cases the linker compresses both the sections.

You cannot force the linker to compress the data when doing so does not result in savings.

7.8.8.1 Compressed Copy Table Format

The copy table format is the same irrespective of the compression. The size field of the copy record is overloaded to support compression. Figure 7-5 illustrates the compressed copy table layout.

**Figure 7-5. Compressed Copy Table**

<table>
<thead>
<tr>
<th>Rec size</th>
<th>Rec cnt</th>
<th>Load address</th>
<th>Run address</th>
<th>Size (0 if load data is compressed)</th>
</tr>
</thead>
</table>

In Figure 7-5, if the size in the copy record is non-zero it represents the size of the data to be copied, and also means that the size of the load data is the same as the run data. When the size is 0, it means that the load data is compressed.
7.8.8.2 Compressed Section Representation in the Object File

When the load data is not compressed, the object file can have only one section with a different load and run address.

Consider the following table() operation in the linker command file.

```plaintext
SECTIONS
{
    .task1: load = ROM, run = RAM, table(_task1_table)
}
```

The output object file has one output section named .task1 which has a different load and run addresses. This is possible because the load space and run space have identical data when the section is not compressed.

Alternatively, consider the following:

```plaintext
SECTIONS
{
    .task1: load = ROM, run = RAM, table(_task1_table, compression=rle)
}
```

If the linker compresses the .task1 section then the load space data and the run space data are different. The linker creates the following two sections:

- **.task1**: This section is uninitialized. This output section represents the run space image of section task1.
- **.task1.load**: This section is initialized. This output section represents the load space image of the section task1. This section usually is considerably smaller in size than .task1 output section.

7.8.8.3 Compressed Data Layout

The compressed load data has the following layout:

<table>
<thead>
<tr>
<th>8-bit index</th>
<th>Compressed data</th>
</tr>
</thead>
</table>

The first eight bits of the load data are the handler index. This handler index is used to index into a handler table to get the address of a handler function that knows how to decode the data that follows. The handler table is a list of 32-bit function pointers as shown in Figure 7-6.

**Figure 7-6. Handler Table**

```
_TI_Handler_Table_Base:

<table>
<thead>
<tr>
<th>32-bit handler address 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>:</td>
</tr>
<tr>
<td>:</td>
</tr>
</tbody>
</table>

_TI_Handler_Table_Limit:

<table>
<thead>
<tr>
<th>32-bit handler address N</th>
</tr>
</thead>
</table>
```

The linker creates a separate output section for the load and run space. For example, if .task1.load is compressed using RLE, the handler index points to an entry in the handler table that has the address of the run-time-support routine __TI_decompress_rle().
7.8.8.4 Run-Time Decompression

During run time you call the run-time-support routine copy_in() to copy the data from load space to run space. The address of the copy table is passed to this routine. First the routine reads the record count. Then it repeats the following steps for each record:

1. Read load address, run address and size from record.
2. If size is zero go to step 5.
3. Call memcpy passing the run address, load address and size.
4. Go to step 1 if there are more records to read.
5. Read the first byte from load address. Call this index.
6. Read the handler address from (&__TI_Handler_Base)[index].
7. Call the handler and pass load address + 1 and run address.
8. Go to step 1 if there are more records to read.

The routines to handle the decompression of load data are provided in the run-time-support library.

7.8.8.5 Compression Algorithms

Run Length Encoding (RLE):

| 8-bit index | Initialization data compressed using run length encoding |

The data following the 8-bit index is compressed using run length encoded (RLE) format. C6000 uses a simple run length encoding that can be decompressed using the following algorithm:

1. Read the first byte, Delimiter (D).
2. Read the next byte (B).
3. If B != D copy B to the output buffer and go to step 2.
4. Read the next byte (L).
5. If L > 0 and L < 4 copy D to the output buffer L times. Go to step 2.
6. If L = 4 read the next byte (B’). Copy B’ to the output buffer L times. Go to step 2.
7. Read the next 16 bits (LL).
8. Read the next byte (C).
9. If C != 0 copy C to the output buffer L times. Go to step 2.
10. End of processing.

The C6000 run-time support library has a routine __TI_decompress_rle() to decompress data compressed using RLE. The first argument to this function is the address pointing to the byte after the 8-bit index. The second argument is the run address from the C auto initialization record.

Lempel-Ziv Storer and Szymanski Compression (LZSS):

| 8-bit index | Data compressed using LZSS |

The data following the 8-bit index is compressed using LZSS compression. The C6000 run-time-support library has the routine __TI_decompress_lzss() to decompress the data compressed using LZSS. The first argument to this function is the address pointing to the byte after the 8-bit Index, and the second argument is the run address from the C auto initialization record.
7.8.9 Copy Table Contents

In order to use a copy table that is generated by the linker, you must be aware of the contents of the copy table. This information is included in a new run-time-support library header file, cpy_tbl.h, which contains a C source representation of the copy table data structure that is automatically generated by the linker.

Example 7-19 shows the TMS320C6000 copy table header file.

Example 7-19. TMS320C6000 cpy_tbl.h File

```c
/****************************************************************************/
/* cpy_tbl.h */
/* */
/* Copyright (c) 2003 Texas Instruments Incorporated */
/* */
/* Specification of copy table data structures which can be automatically */
/* generated by the linker (using the table() operator in the LCF). */
/* */
/****************************************************************************/

/**************************************************************/
/* Copy Record Data Structure */
/**************************************************************/
typedef struct copy_record
{
    unsigned int load_addr;
    unsigned int run_addr;
    unsigned int size;
} COPY_RECORD;

/**************************************************************/
/* Copy Table Data Structure */
/**************************************************************/
typedef struct copy_table
{
    unsigned short rec_size;
    unsigned short num_recs;
    COPY_RECORD recs[1];
} COPY_TABLE;

/**************************************************************/
/* Prototype for general purpose copy routine. */
/**************************************************************/
extern void copy_in(COPY_TABLE *tp);
#endif /* !_CPY_TBL */
#endif /* __cplusplus */
#endif /* !_CPP_STYLE_HEADER */
#endif /* __cplusplus */

For each object component that is marked for a copy, the linker creates a COPY_RECORD object for it. Each COPY_RECORD contains at least the following information for the object component:

- The load address
- The run address
- The size
The linker collects all COPY_RECORDs that are associated with the same copy table into a COPY_TABLE object. The COPY_TABLE object contains the size of a given COPY_RECORD, the number of COPY_RECORDs in the table, and the array of COPY_RECORDs in the table. For instance, in the BINIT example in Section 7.8.6, the .first and .extra output sections will each have their own COPY_RECORD entries in the BINIT copy table. The BINIT copy table will then look like this:

```c
COPY_TABLE __binit__ = { 12, 2,
{ <load address of .first>,
 <run address of .first>,
 <size of .first> },
{ <load address of .extra>,
 <run address of .extra>,
 <size of .extra> });
```

### 7.8.10 General Purpose Copy Routine

The cpy_tbl.h file in Example 7-19 also contains a prototype for a general-purpose copy routine, copy_in(), which is provided as part of the run-time-support library. The copy_in() routine takes a single argument: the address of a linker-generated copy table. The routine then processes the copy table data object and performs the copy of each object component specified in the copy table.

The copy_in() function definition is provided in the cpy_tbl.c run-time-support source file shown in Example 7-20.

#### Example 7-20. Run-Time-Support cpy_tbl.c File

```c
/****************************************************************************/
/* cpy_tbl.c */
/* */
/* Copyright (c) 2003 Texas Instruments Incorporated */
/* */
/* General purpose copy routine. Given the address of a link-generated */
/* COPY_TABLE data structure, effect the copy of all object components */
/* that are designated for copy via the corresponding LCF table() operator. */
/* */
/****************************************************************************/
#include <cpy_tbl.h>
#include <string.h>

typedef void (*handler_fptr)(const unsigned char *in, unsigned char *out);

/****************************************************************************/
/* COPY_IN() */
/****************************************************************************/
void copy_in(COPY_TABLE *tp)
{
 unsigned short I;
 for (I = 0; I < tp->num_recs; I++)
 {
 COPY_RECORD crp = tp->recs[i];
 unsigned char *ld_addr = (unsigned char *)crp.load_addr;
 unsigned char *rn_addr = (unsigned char *)crp.run_addr;
 if (crp.size)
 
 /*-----------------------------------------------*/
 /* Copy record has a non-zero size so the data is not compressed. */
 /* Just copy the data. */
 /*-----------------------------------------------*/
 memcpy(rn_addr, ld_addr, crp.size);
 }
}```
7.8.11  **Linker-Generated Copy Table Sections and Symbols**

The linker creates and allocates a separate input section for each copy table that it generates. Each copy table symbol is defined with the address value of the input section that contains the corresponding copy table.

The linker generates a unique name for each overlay copy table input section. For example, `table(_first_ctbl)` would place the copy table for the `.first` section into an input section called `.ovly:_first_ctbl`. The linker creates a single input section, `.binit`, to contain the entire boot-time copy table.

**Example 7-21** illustrates how you can control the placement of the linker-generated copy table sections using the input section names in the link command file.

### Example 7-21. Controlling the Placement of the Linker-Generated Copy Table Sections

```c
SECTIONS
{
  UNION
  {
    .first: { a1.obj(.text), b1.obj(.text), c1.obj(.text) }
      load = EMEM, run = PMEM, table(BINIT), table(_first_ctbl)
    .second: { a2.obj(.text), b2.obj(.text) }
      load = EMEM, run = PMEM, table(_second_ctbl)
  }
  .extra: load = EMEM, run = PMEM, table(BINIT)
  ...
  .ovly: { } > BMEM
  .binit: { } > BMEM
}
```

For the link command file in **Example 7-21**, the boot-time copy table is generated into a `.binit` input section, which is collected into the `.binit` output section, which is mapped to an address in the BMEM memory area. The `_first_ctbl` is generated into the `.ovly:_first_ctbl` input section and the `_second_ctbl` is generated into the `.ovly:_second_ctbl` input section. Since the base names of these input sections match the name of the `.ovly` output section, the input sections are collected into the `.ovly` output section, which is then mapped to an address in the BMEM memory area.

If you do not provide explicit placement instructions for the linker-generated copy table sections, they are allocated according to the linker's default placement algorithm.

The linker does not allow other types of input sections to be combined with a copy table input section in the same output section. The linker does not allow a copy table section that was created from a partial link session to be used as input to a succeeding link session.
7.8.12 Splitting Object Components and Overlay Management

In previous versions of the linker, splitting sections that have separate load and run placement instructions was not permitted. This restriction was because there was no effective mechanism for you, the developer, to gain access to the load address or run address of each one of the pieces of the split object component. Therefore, there was no effective way to write a copy routine that could move the split section from its load location to its run location.

However, the linker can access both the load address and run address of every piece of a split object component. Using the table() operator, you can tell the linker to generate this information into a copy table. The linker gives each piece of the split object component a COPY_RECORD entry in the copy table object.

For example, consider an application which has seven tasks. Tasks 1 through 3 are overlaid with tasks 4 through 7 (using a UNION directive). The load placement of all of the tasks is split among four different memory areas (LMEM1, LMEM2, LMEM3, and LMEM4). The overlay is defined as part of memory area PMEM. You must move each set of tasks into the overlay at run time before any services from the set are used.

You can use table() operators in combination with splitting operators, >>, to create copy tables that have all the information needed to move either group of tasks into the memory overlay as shown in Example 7-22. Example 7-23 illustrates a possible driver for such an application.

Example 7-22. Creating a Copy Table to Access a Split Object Component

```
SECTIONS
{
    UNION
    {
        .task1to3: { *(.task1), *(.task2), *(.task3) }
        load >> LMEM1 | LMEM2 | LMEM4, table(_task13_ctbl)
    }
    GROUP
    {
        .task4: { *(.task4) }
        .task5: { *(.task5) }
        .task6: { *(.task6) }
        .task7: { *(.task7) }
    }
    load >> LMEM1 | LMEM3 | LMEM4, table(_task47_ctbl)
}
run = PMEM
...
.ovly: > LMEM4
}
```
You must declare a COPY_TABLE object as `far` to allow the overlay copy table section placement to be independent from the other sections containing data objects (such as `.bss`).

The contents of the `.task1to3` section are split in the section's load space and contiguous in its run space. The linker-generated copy table, `_task13_ctbl`, contains a separate COPY_RECORD for each piece of the split section `.task1to3`. When the address of `_task13_ctbl` is passed to `copy_in()`, each piece of `.task1to3` is copied from its load location into the run location.

The contents of the GROUP containing tasks 4 through 7 are also split in load space. The linker performs the GROUP split by applying the split operator to each member of the GROUP in order. The copy table for the GROUP then contains a COPY_RECORD entry for every piece of every member of the GROUP. These pieces are copied into the memory overlay when the `_task47_ctbl` is processed by `copy_in()`.

The split operator can be applied to an output section, GROUP, or the load placement of a UNION or UNION member. The linker does not permit a split operator to be applied to the run placement of either a UNION or of a UNION member. The linker detects such violations, emits a warning, and ignores the offending split operator usage.
Partial (Incremental) Linking

An output file that has been linked can be linked again with additional modules. This is known as *partial linking* or *incremental linking*. Partial linking allows you to partition large applications, link each part separately, and then link all the parts together to create the final executable program.

Follow these guidelines for producing a file that you will relink:

- The intermediate files produced by the linker *must* have relocation information. Use the `--relocatable` option when you link the file the first time. (See Section 7.4.2.2.)
- Intermediate files *must* have symbolic information. By default, the linker retains symbolic information in its output. Do not use the `--no_sym_table` option if you plan to relink a file, because `--no_sym_table` strips symbolic information from the output module. (See Section 7.4.20.)
- Intermediate linkers should be concerned only with the formation of output sections and not with allocation. All allocation, binding, and MEMORY directives should be performed in the final linker. When the ELF object file format is used, input sections are not combined into output sections during a partial link unless a matching SECTIONS directive is specified in the link step command file.
- If the intermediate files have global symbols that have the same name as global symbols in other files and you want them to be treated as static (visible only within the intermediate file), you must link the files with the `--make_static` option (see Section 7.4.15.1).
- If you are linking C code, do not use `--ram_model` or `--rom_model` until the final linker. Every time you invoke the linker with the `--ram_model` or `--rom_model` option, the linker attempts to create an entry point. (See Section 7.4.23.)

The following example shows how you can use partial linking:

**Step 1:** Link the file file1.com; use the `--relocatable` option to retain relocation information in the output file tempout1.out.
```
c16x --run_linker --relocatable --output_file=tempout1 file1.com
```
file1.com contains:
```
SECTIONS { ss1: { f1.obj f2.obj . . . fn.obj } }
```

**Step 2:** Link the file file2.com; use the `--relocatable` option to retain relocation information in the output file tempout2.out.
```
c16x --run_linker --relocatable --output_file=tempout2 file2.com
```
file2.com contains:
```
SECTIONS { ss2: { g1.obj g2.obj . . . gn.obj } }
```

**Step 3:** Link tempout1.out and tempout2.out.
```
c16x --run_linker --map_file=final.map --output_file=final.out tempout1.out tempout2.out
```
7.10 Linking C/C++ Code

The C/C++ compiler produces assembly language source code that can be assembled and linked. For example, a C program consisting of modules prog1, prog2, etc., can be assembled and then linked to produce an executable file called prog.out:

```
cl6x --run_linker --rom_model --output_file prog.out prog1.obj prog2.obj ... rts6200.lib
```

The --rom_model option tells the linker to use special conventions that are defined by the C/C++ environment.

The archive libraries shipped by TI contain C/C++ run-time-support functions.

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.

For more information about the TMS320C6000 C/C++ language, including the run-time environment and run-time-support functions, see the TMS320C6000 Optimizing Compiler User's Guide.

7.10.1 Run-Time Initialization

All C/C++ programs must be linked with code to initialize and execute the program, called a bootstrap routine, also known as the boot.obj object module. The symbol _c_int00 is defined as the program entry point and is the start of the C boot routine in boot.obj; referencing _c_int00 ensures that boot.obj is automatically linked in from the run-time-support library. When a program begins running, it executes boot.obj first. The boot.obj symbol contains code and data for initializing the run-time environment and performs the following tasks:

- Sets up the system stack and configuration registers
- Processes the run-time .cinit initialization table and autoinitializes global variables (when the linker is invoked with the --rom_model option)
- Disables interrupts and calls _main

The run-time-support object libraries contain boot.obj. You can:

- Use the archiver to extract boot.obj from the library and then link the module in directly.
- Include the appropriate run-time-support library as an input file (the linker automatically extracts boot.obj when you use the --ram_model or --rom_model option).

7.10.2 Object Libraries and Run-Time Support

The TMS320C6000 Optimizing Compiler User's Guide describes additional run-time-support functions that are included in rts.src. If your program uses any of these functions, you must link the appropriate run-time-support library with your object files.

You can also create your own object libraries and link them. The linker includes and links only those library members that resolve undefined references.

7.10.3 Setting the Size of the Stack and Heap Sections

The C/C++ language uses two uninitialized sections called .sysmem and .stack for the memory pool used by the malloc() functions and the run-time stacks, respectively. You can set the size of these by using the --heap_size or --stack_size option and specifying the size of the section as a 4-byte constant immediately after the option. If the options are not used, the default size of the heap is 1K bytes and the default size of the stack is 1K bytes.

See Section 7.4.12 for setting heap sizes and Section 7.4.27 for setting stack sizes.
7.10.4 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. 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 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 slow external memory and copied to fast external memory each time the program starts.

Figure 7-7 illustrates autoinitialization at run time. Use this method in any system where your application runs from code burned into slow external memory.

![Figure 7-7. Autoinitialization at Run Time](image)

7.10.5 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 linker 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 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 7-8 illustrates the initialization of variables at load time.
7.10.6 The --rom_model and --ram_model Linker Options

The following list outlines what happens when you invoke the linker with the --ram_model or --rom_model option.

- The symbol `_c_int00` is defined as the program entry point. The `_c_int00` symbol is the start of the C boot routine in boot.obj; referencing `_c_int00` ensures that boot.obj is automatically linked in from the appropriate run-time-support library.

- The `.cinit` output section is padded with a termination record to designate to the boot routine (autoinitialize at run time) or the loader (initialize at load time) when to stop reading the initialization tables.

- When you initialize at load time (--ram_model option):
  - The linker sets cinit to -1. This indicates that the initialization tables are not in memory, so no initialization is performed at run time.
  
  - The STYP_COPY flag (0010h) is set in the .cinit section header. STYP_COPY is the special attribute that tells the loader to perform initialization directly and not to load the .cinit section into memory. The linker does not allocate space in memory for the .cinit section.

- When you autoinitialize at run time (--rom_model option), the linker defines cinit as the starting address of the .cinit section. The C boot routine uses this symbol as the starting point for autoinitialization.
7.11   Linker Example

This example links three object files named demo.obj, ctrl.obj, and tables.obj and creates a program called demo.out.

Assume that target memory has the following program memory configuration:

<table>
<thead>
<tr>
<th>Address Range</th>
<th>Contents</th>
</tr>
</thead>
<tbody>
<tr>
<td>0x00000000 to 0x00001000</td>
<td>SLOW_MEM</td>
</tr>
<tr>
<td>0x00001000 to 0x00002000</td>
<td>FAST_MEM</td>
</tr>
<tr>
<td>0x08000000 to 0x08000400</td>
<td>EEPROM</td>
</tr>
</tbody>
</table>

The output sections are constructed in the following manner:

- Executable code, contained in the .text sections of demo.obj, fft.obj, and tables.obj, is linked into program memory ROM.
- Variables, contained in the var_defs section of demo.obj, are linked into data memory in block FAST_MEM_2.
- Tables of coefficients in the .data sections of demo.obj, tables.obj, and fft.obj are linked into FAST_MEM_1. A hole is created with a length of 100 and a fill value of 0x07A1C.
- The xy section form demo.obj, which contains buffers and variables, is linked by default into page 1 of the block STACK, since it is not explicitly linked.
- Executable code, contained in the .text sections of demo.obj, ctrl.obj, and tables.obj, must be linked into FAST_MEM.
- A set of interrupt vectors, contained in the .intvecs section of tables.obj, must be linked at address 0x00000000.
- A table of coefficients, contained in the .data section of tables.obj, must be linked into EEPROM. The remainder of block EEPROM must be initialized to the value 0xFF00FF00.
- A set of variables, contained in the .bss section of ctrl.obj, must be linked into SLOW_MEM and preinitialized to 0x00000100.
- The .bss sections of demo.obj and tables.obj must be linked into SLOW_MEM.

Example 7-24 shows the link command file for this example. Example 7-25 shows the map file.
Example 7-24. Linker Command File, demo.cmd

```c
/******************************************************************************
/*** Specify Linker Options  ***
*******************************************************************************/
--entry_point SETUP /* Define the program entry point */
--output_file=demo.out /* Name the output file */
--map_file=demo.map /* Create an output map file */
/*******************************************************************************/
/*** Specify the Input Files  ***
*******************************************************************************/
demo.obj
ctrl.obj
tables.obj
/*******************************************************************************/
/*** Specify the Memory Configurations  ***
*******************************************************************************/
MEMORY
{
   FAST_MEM : org = 0x00000000 len = 0x00001000
   SLOW_MEM : org = 0x00001000 len = 0x00001000
   EEPROM  : org = 0x08000000 len = 0x00000400
}
/*******************************************************************************/
/*** Specify the Output Sections  ***
*******************************************************************************/
SECTIONS
{
   .text : {} > FAST_MEM /* Link all .text sections into ROM */
   .intvecs : {} > 0x0 /* Link interrupt vectors at 0x0 */
   .data : /* Link .data sections */
   { tables.obj(.data)
      . = 0x400; /* Create hole at end of block */
   } = 0xFF00FF00 > EEPROM /* Fill and link into EEPROM */
   ctrl_vars: /* Create new ctrl variables section */
   { ctrl.obj(.bss)
      } = 0x00000100 > SLOW_MEM /* Fill with 0x100 and link into RAM */
   .bss : {} > SLOW_MEM /* Link remaining .bss sections into RAM */
}
/*******************************************************************************/
/*** End of Command File  ***
*******************************************************************************/
```

Invoke the linker by entering the following command:

c6x --run_linker demo.cmd

This creates the map file shown in Example 7-25 and an output file called demo.out that can be run on a TMS320C6000.
Example 7-25. Output Map File, demo.map

OUTPUT FILE NAME: <demo.out>
ENTRY POINT SYMBOL: 0

MEMORY CONFIGURATION

<table>
<thead>
<tr>
<th>name</th>
<th>origin</th>
<th>length</th>
<th>used</th>
<th>attributes</th>
<th>fill</th>
</tr>
</thead>
<tbody>
<tr>
<td>FAST_MEM</td>
<td>00000000</td>
<td>00001000</td>
<td>0000078</td>
<td>RWIX</td>
<td></td>
</tr>
<tr>
<td>SLOW_MEM</td>
<td>00001000</td>
<td>00001000</td>
<td>0000502</td>
<td>RWIX</td>
<td></td>
</tr>
<tr>
<td>EEPROM</td>
<td>08000000</td>
<td>0000400</td>
<td>0000400</td>
<td>RWIX</td>
<td></td>
</tr>
</tbody>
</table>

SECTION ALLOCATION MAP

<table>
<thead>
<tr>
<th>output</th>
<th>section</th>
<th>page</th>
<th>origin</th>
<th>length</th>
<th>attributes</th>
<th>input sections</th>
</tr>
</thead>
<tbody>
<tr>
<td>.text</td>
<td>0</td>
<td>0</td>
<td>00000000</td>
<td>0000064</td>
<td>demo.obj (.text)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>00000000</td>
<td>000030</td>
<td>tables.obj (.text)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>00000030</td>
<td>000000</td>
<td>--HOLE-- [fill = 00000000]</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>00000000</td>
<td>000024</td>
<td>ctrl.obj (.text)</td>
<td></td>
</tr>
<tr>
<td>.intvecs</td>
<td>0</td>
<td>0</td>
<td>00000000</td>
<td>000014</td>
<td>tables.obj (.intvecs)</td>
<td></td>
</tr>
<tr>
<td>.data</td>
<td>0</td>
<td>0</td>
<td>08000000</td>
<td>0000400</td>
<td>demo.obj (.data)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>08000000</td>
<td>00000004</td>
<td>tables.obj (.data)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>08000004</td>
<td>00003fc</td>
<td>--HOLE-- [fill = ff00ff00]</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>08000400</td>
<td>00000000</td>
<td>ctrl.obj (.data)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>08000400</td>
<td>00000000</td>
<td>demo.obj (.data)</td>
<td></td>
</tr>
<tr>
<td>ctrl_vars</td>
<td>0</td>
<td>0</td>
<td>00001000</td>
<td>0000500</td>
<td>ctrl.obj (.bss) [fill = 0000100]</td>
<td></td>
</tr>
<tr>
<td>.bss</td>
<td>0</td>
<td>0</td>
<td>00001500</td>
<td>000002</td>
<td>UNINITIALIZED</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>00001500</td>
<td>00000002</td>
<td>demo.obj (.bss)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>00001502</td>
<td>00000000</td>
<td>tables.obj (.bss)</td>
<td></td>
</tr>
</tbody>
</table>

GLOBAL SYMBOLS

<table>
<thead>
<tr>
<th>address</th>
<th>name</th>
<th>address</th>
<th>name</th>
</tr>
</thead>
<tbody>
<tr>
<td>00001500</td>
<td>$bss</td>
<td>00000000</td>
<td>.text</td>
</tr>
<tr>
<td>00001500</td>
<td>.bss</td>
<td>00000000</td>
<td>__x42</td>
</tr>
<tr>
<td>08000000</td>
<td>.data</td>
<td>00000018</td>
<td>__SETUP</td>
</tr>
<tr>
<td>0000000</td>
<td>.text</td>
<td>00000040</td>
<td>_fill_tab</td>
</tr>
<tr>
<td>00000018</td>
<td>__SETUP</td>
<td>00000064</td>
<td>etext</td>
</tr>
<tr>
<td>00000040</td>
<td>_fill_tab</td>
<td>00001500</td>
<td>$bss</td>
</tr>
<tr>
<td>00000000</td>
<td>__x42</td>
<td>00001500</td>
<td>.bss</td>
</tr>
<tr>
<td>08000400</td>
<td>edata</td>
<td>00001502</td>
<td>end</td>
</tr>
<tr>
<td>00001502</td>
<td>end</td>
<td>08000000</td>
<td>gvar</td>
</tr>
<tr>
<td>00000064</td>
<td>etext</td>
<td>08000000</td>
<td>.data</td>
</tr>
<tr>
<td>08000000</td>
<td>gvar</td>
<td>08000400</td>
<td>edata</td>
</tr>
<tr>
<td>[11 symbols]</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
The TMS320C6000™ absolute lister is a debugging tool that accepts linked object files as input and creates .abs files as output. These .abs files can be assembled to produce a listing that shows the absolute addresses of object code. Manually, this could be a tedious process requiring many operations; however, the absolute lister utility performs these operations automatically.

**Absolute Listing Is Not Supported for C6400+ and C6740**

**NOTE:** The absolute listing capability is not supported for C6400+ and C6740. You can use the disassembler (dis6x) or the --map_file linker option instead.

<table>
<thead>
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<th>Page</th>
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<tr>
<td>8.3 Absolute Lister Example</td>
<td>236</td>
</tr>
</tbody>
</table>
8.1 Producing an Absolute Listing

Figure 8-1 illustrates the steps required to produce an absolute listing.

Figure 8-1. Absolute Lister Development Flow

Step 1: First, assemble a source file.

Step 2: Link the resulting object file.

Step 3: Invoke the absolute lister; use the linked object file as input. This creates a file with an .abs extension.

Step 4: Finally, assemble the .abs file; you must invoke the assembler with the compiler --absolute_listing option.

This produces a listing file that contains absolute addresses.
8.2 Invoking the Absolute Lister

The syntax for invoking the absolute lister is:

```
abs6x [-options] input file
```

`abs6x` is the command that invokes the absolute lister.

`options` identifies the absolute lister options that you want to use. Options are not case sensitive and can appear anywhere on the command line following the command. Precede each option with a hyphen (-). The absolute lister options are as follows:

- **-e** enables you to change the default naming conventions for filename extensions on assembly files, C source files, and C header files. The valid options are:
  - `ea [.]asmext` for assembly files (default is .asm)
  - `ec [.]cext` for C source files (default is .c)
  - `eh [.]hext` for C header files (default is .h)
  - `ep [.]pext` for CPP source files (default is cpp)
  The . in the extensions and the space between the option and the extension are optional.

- **-q** (quiet) suppresses the banner and all progress information.

`input file` names the linked object file. If you do not supply an extension, the absolute lister assumes that the input file has the default extension .out. If you do not supply an input filename when you invoke the absolute lister, the absolute lister prompts you for one.

The absolute lister produces an output file for each file that was linked. These files are named with the input filenames and an extension of .abs. Header files, however, do not generate a corresponding .abs file.

Assemble these files with the --absolute_listing assembler option as follows to create the absolute listing:

```
cl6x --absolute_listing filename .abs
```

The -e options affect both the interpretation of filenames on the command line and the names of the output files. They should always precede any filename on the command line.

The -e options are useful when the linked object file was created from C files compiled with the debugging option (--symdebug:dwarf compiler option). When the debugging option is set, the resulting linked object file contains the name of the source files used to build it. In this case, the absolute lister does not generate a corresponding .abs file for the C header files. Also, the .abs file corresponding to a C source file uses the assembly file generated from the C source file rather than the C source file itself.

For example, suppose the C source file hello.csr is compiled with the debugging option set; the debugging option generates the assembly file hello.s. The hello.csr file includes hello.hsr. Assuming the executable file created is called hello.out, the following command generates the proper .abs file:

```
abs6x -ea s -ec csr -eh hsr hello.out
```

An .abs file is not created for hello.hsr (the header file), and hello.abs includes the assembly file hello.s, not the C source file hello.csr.
8.3 Absolute Lister Example

This example uses three source files. The files module1.asm and module2.asm both include the file globals.def.

module1.asm

.text
.align 4
.bss array, 100
.bss dflag, 4
.copy globals.def

MVKL offset, A0
MVKH offset, A0
LDW *b14(dflag), A2
nop 4

module2.asm

.bss offset, 2
.copy globals.def

mvkl offset, a0
mvkh offset, a0
mvkl array, a3
mvkh array, a3

globals.def

.global dflag
.global array
.global offset

The following steps create absolute listings for the files module1.asm and module2.asm:

Step 1: First, assemble module1.asm and module2.asm:
  cl6x module1
  cl6x module2
  This creates two object files called module1.obj and module2.obj.

Step 2: Next, link module1.obj and module2.obj using the following linker command file, called bttest.cmd:

```
--output_file=bttest.out
--map_file=bttest.map
module1.obj
module2.obj
MEMORY
{
  PMEM: origin=00000000h length=00010000h
  DMEM: origin=80000000h length=00010000h
}
SECTIONS
{
  .data: >DMEM
  .text: >PMEM
  .bss: >DMEM
}
```

Invoke the linker:
  cl6x --run_linker bttest.cmd
  This command creates an executable object file called bttest.out; use this new file as input for the absolute lister.
Step 3: Now, invoke the absolute lister:
  
  ```
  abs6x bttest.out
  ```

  This command creates two files called `module1.abs` and `module2.abs`:

  **module1.abs:**
  ```
  .nolist
  array .setsym 080000000h
dflag .setsym 080000064h
offset .setsym 080000068h
.data .setsym 080000000h
__data__ .setsym 080000000h
edata .setsym 080000000h
__edata__ .setsym 080000000h
.text .setsym 000000000h
__text__ .setsym 000000000h
etext .setsym 000000040h
__etext__ .setsym 000000040h
.bss .setsym 080000000h
__bss__ .setsym 080000000h
end .setsym 08000006ah
__end__ .setsym 08000006ah
$bs .setsym 080000000h
.setsect ".text",000000020h
.setsect ".data",080000000h
.setsect ",.bss",080000000h
.list
.text
.copy "module1.asm"
  ```

  **module2.abs:**
  ```
  .nolist
  array .setsym 080000000h
dflag .setsym 080000064h
offset .setsym 080000068h
.data .setsym 080000000h
__data__ .setsym 080000000h
edata .setsym 080000000h
__edata__ .setsym 080000000h
.text .setsym 000000000h
__text__ .setsym 000000000h
etext .setsym 000000040h
__etext__ .setsym 000000040h
.bss .setsym 080000000h
__bss__ .setsym 080000000h
end .setsym 08000006ah
__end__ .setsym 08000006ah
$bs .setsym 080000000h
.setsect ".text",000000000h
.setsect ".data",080000000h
.setsect ",.bss",080000000h
.list
.text
.copy "module2.asm"
  ```

These files contain the following information that the assembler needs for Step 4:

- They contain `.setsym` directives, which equate values to global symbols. Both files contain global equates for the symbol `dflag`. The symbol `dflag` was defined in the file `globals.def`, which was included in `module1.asm` and `module2.asm`.
- They contain `.setsect` directives, which define the absolute addresses for sections.
- They contain `.copy` directives, which defines the assembly language source file to include.

The `.setsym` and `.setsect` directives are useful only for creating absolute listings, not normal assembly.

Step 4: Finally, assemble the .abs files created by the absolute lister (remember that you must use the --absolute_listing option when you invoke the assembler):

```
cl6x --absolute_listing module1.abs
cl6x --absolute_listing module2.abs
```

This command sequence creates two listing files called module1.lst and module2.lst; no object code is produced. These listing files are similar to normal listing files; however, the addresses shown are absolute addresses.

The absolute listing files created are module1.lst (see Example 8-1) and module2.lst (see Example 8-2).

**Example 8-1. module1.lst**

<table>
<thead>
<tr>
<th>module1.abs</th>
<th>PAGE 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>22 00000020</td>
<td>.text</td>
</tr>
<tr>
<td>23 .copy &quot;module1.asm&quot;</td>
<td></td>
</tr>
<tr>
<td>A 1 00000020</td>
<td>.text</td>
</tr>
<tr>
<td>A 2 .align 4</td>
<td></td>
</tr>
<tr>
<td>A 3 80000000</td>
<td>.bss array, 100</td>
</tr>
<tr>
<td>A 4 80000064</td>
<td>.bss dflag, 4</td>
</tr>
<tr>
<td>A 5 .copy globals.def</td>
<td></td>
</tr>
<tr>
<td>B 1 .global dflag</td>
<td></td>
</tr>
<tr>
<td>B 2 .global array</td>
<td></td>
</tr>
<tr>
<td>B 3 .global offset</td>
<td></td>
</tr>
<tr>
<td>A 6</td>
<td></td>
</tr>
<tr>
<td>A 7 00000020 00003428! MVKL offset, A0</td>
<td></td>
</tr>
<tr>
<td>A 8 00000024 00400068! MVKH offset, A0</td>
<td></td>
</tr>
<tr>
<td>A 9 00000028 0100196C- LDW *+b14(dflag), A2</td>
<td></td>
</tr>
<tr>
<td>A 10 0000002c 00006000 nop 4</td>
<td></td>
</tr>
<tr>
<td>No Errors, No Warnings</td>
<td></td>
</tr>
</tbody>
</table>

**Example 8-2. module2.lst**

<table>
<thead>
<tr>
<th>module2.abs</th>
<th>PAGE 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>22 00000000</td>
<td>.text</td>
</tr>
<tr>
<td>23 .copy &quot;module2.asm&quot;</td>
<td></td>
</tr>
<tr>
<td>A 1 80000068</td>
<td>.bss offset,2</td>
</tr>
<tr>
<td>A 2 .copy globals.def</td>
<td></td>
</tr>
<tr>
<td>B 1 .global dflag</td>
<td></td>
</tr>
<tr>
<td>B 2 .global array</td>
<td></td>
</tr>
<tr>
<td>B 3 .global offset</td>
<td></td>
</tr>
<tr>
<td>A 3</td>
<td></td>
</tr>
<tr>
<td>A 4 00000000 00003428- mvkl offset, a0</td>
<td></td>
</tr>
<tr>
<td>A 5 00000004 00400068- mvkh offset, a0</td>
<td></td>
</tr>
<tr>
<td>A 6 00000008 01800028- mvkl array,a3</td>
<td></td>
</tr>
<tr>
<td>A 7 0000000c 01C00068! mvkh array,a3</td>
<td></td>
</tr>
<tr>
<td>No Errors, No Warnings</td>
<td></td>
</tr>
</tbody>
</table>
The TMS320C6000™ cross-reference lister is a debugging tool. This utility accepts linked object files as input and produces a cross-reference listing as output. This listing shows symbols, their definitions, and their references in the linked source files.

### Cross-Reference Listing Not Supported for C6400+ and C6740

**NOTE:** The cross-reference listing capability is not supported for C6400+ and C6740. You can use the disassembler, the -m linker option or the object file utility (ofd6x) to obtain similar information.

---

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<tr>
<td>9.2 Invoking the Cross-Reference Lister</td>
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</tr>
<tr>
<td>9.3 Cross-Reference Listing Example</td>
<td>242</td>
</tr>
</tbody>
</table>
9.1 Producing a Cross-Reference Listing

Figure 9-1 illustrates the steps required to produce a cross-reference listing.

**Figure 9-1. The Cross-Reference Lister Development Flow**

Step 1:
- **Assembler source file**
  - **Assembler**
  - **Object file**

  First, invoke the assembler with the compiler `--cross_reference` option. This produces a cross-reference table in the listing file and adds to the object file cross-reference information. By default, only global symbols are cross-referenced. If you use the compiler `--output_all_syms` option, local symbols are cross-referenced as well.

Step 2:
- **Link step**
  - **Linked object file**

  Link the object file (.obj) to obtain an executable object file (.out).

Step 3:
- **Cross-reference lister**
  - **Cross-reference listing**

  Invoke the cross-reference lister. The following section provides the command syntax for invoking the cross-reference lister utility.
9.2 Invoking the Cross-Reference Lister

To use the cross-reference utility, the file must be assembled with the correct options and then linked into an executable file. Assemble the assembly language files with the --cross_reference option. This option creates a cross-reference listing and adds cross-reference information to the object file. By default, the assembler cross-references only global symbols, but if the assembler is invoked with the --output_all_syms option, local symbols are also added. Link the object files to obtain an executable file.

To invoke the cross-reference lister, enter the following:

```
xref6x [options] [input filename [output filename]]
```

- `xref6x` is the command that invokes the cross-reference utility.
- `options` identifies the cross-reference lister options you want to use. Options are not case sensitive and can appear anywhere on the command line following the command.
  - `-l` (lowercase L) specifies the number of lines per page for the output file. The format of the -l option is `-lmnum`, where num is a decimal constant. For example, `-l30` sets the number of lines per page in the output file to 30. The space between the option and the decimal constant is optional. The default is 60 lines per page.
  - `-q` suppresses the banner and all progress information (run quiet).
- `input filename` is a linked object file. If you omit the input filename, the utility prompts for a filename.
- `output filename` is the name of the cross-reference listing file. If you omit the output filename, the default filename is the input filename with an .xrf extension.
### Example 9-1. Cross-Reference Listing

<table>
<thead>
<tr>
<th>Symbol: _SETUP</th>
<th>Filename</th>
<th>RTYP</th>
<th>AsmVal</th>
<th>LnkVal</th>
<th>DefLn</th>
<th>RefLn</th>
<th>RefLn</th>
</tr>
</thead>
<tbody>
<tr>
<td>demo.asm</td>
<td>EDEF</td>
<td>'00000018</td>
<td>00000018</td>
<td>18</td>
<td>13</td>
<td>20</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Symbol: _fill_tab</th>
<th>Filename</th>
<th>RTYP</th>
<th>AsmVal</th>
<th>LnkVal</th>
<th>DefLn</th>
<th>RefLn</th>
<th>RefLn</th>
</tr>
</thead>
<tbody>
<tr>
<td>ctrl.asm</td>
<td>EDEF</td>
<td>'00000000</td>
<td>00000040</td>
<td>10</td>
<td>5</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Symbol: _x42</th>
<th>Filename</th>
<th>RTYP</th>
<th>AsmVal</th>
<th>LnkVal</th>
<th>DefLn</th>
<th>RefLn</th>
<th>RefLn</th>
</tr>
</thead>
<tbody>
<tr>
<td>demo.asm</td>
<td>EDEF</td>
<td>'00000000</td>
<td>00000000</td>
<td>7</td>
<td>4</td>
<td>18</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Symbol: gvar</th>
<th>Filename</th>
<th>RTYP</th>
<th>AsmVal</th>
<th>LnkVal</th>
<th>DefLn</th>
<th>RefLn</th>
<th>RefLn</th>
</tr>
</thead>
<tbody>
<tr>
<td>tables.asm</td>
<td>EDEF</td>
<td>&quot;00000000&quot;</td>
<td>08000000</td>
<td>11</td>
<td>10</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The terms defined below appear in the preceding cross-reference listing:

- **Symbol**: Name of the symbol listed
- **Filename**: Name of the file where the symbol appears
- **RTYP**: The symbol's reference type in this file. The possible reference types are:
  - **STAT**: The symbol is defined in this file and is not declared as global.
  - **EDEF**: The symbol is defined in this file and is declared as global.
  - **EREF**: The symbol is not defined in this file but is referenced as global.
  - **UNDF**: The symbol is not defined in this file and is not declared as global.

- **AsmVal**: This hexadecimal number is the value assigned to the symbol at assembly time. A value may also be preceded by a character that describes the symbol's attributes. Table 9-1 lists these characters and names.

- **LnkVal**: This hexadecimal number is the value assigned to the symbol after linking.

- **DefLn**: The statement number where the symbol is defined.

- **RefLn**: The line number where the symbol is referenced. If the line number is followed by an asterisk (*), then that reference can modify the contents of the object. A blank in this column indicates that the symbol was never used.

### Table 9-1. Symbol Attributes in Cross-Reference Listing

<table>
<thead>
<tr>
<th>Character</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>'</td>
<td>Symbol defined in a .text section</td>
</tr>
<tr>
<td>&quot;</td>
<td>Symbol defined in a .data section</td>
</tr>
<tr>
<td>+</td>
<td>Symbol defined in a .sect section</td>
</tr>
<tr>
<td>-</td>
<td>Symbol defined in a .bss or .usect section</td>
</tr>
</tbody>
</table>
This chapter describes how to invoke the following miscellaneous utilities:

- **The object file display utility** prints the contents of object files, executable files, and/or archive libraries in both text and XML formats.
- **The disassembler** accepts object files and executable files as input and produces an assembly listing as output. This listing shows assembly instructions, their opcodes, and the section program counter values.
- **The name utility** prints a list of names defined and referenced in an object file, executable files, and/or archive libraries.
- **The strip utility** removes symbol table and debugging information from object and executable files.

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10.1 Invoking the Object File Display Utility

The object file display utility, `ofd6x`, prints the contents of object files (.obj), executable files (.out), and/or archive libraries (.lib) in both text and XML formats. Hidden symbols are listed as *no name*, while localized symbols are listed like any other local symbol.

To invoke the object file display utility, enter the following:

```bash
ofd6x [options] input filename [input filename]
```

- `ofd6x` is the command that invokes the object file display utility.
- `input filename` names the object file (.obj), executable file (.out), or archive library (.lib) source file. The filename must contain an extension.
- `options` identify the object file display utility options that you want to use. Options are not case sensitive and can appear anywhere on the command line following the command. Precede each option with a hyphen.
  - **--dwarf_display=attributes** controls the DWARF display filter settings by specifying a comma-delimited list of attributes. When prefixed with `no`, an attribute is disabled instead of enabled.
    - **Examples:**
      - `--dwarf_display=nodabbrev,nodline`
      - `--dwarf_display=all,nodabbrev`
      - `--dwarf_display=none,dinfo,types`
    - The ordering of attributes is important (see **--obj_display**). The list of available display attributes can be obtained by invoking `ofd6x --dwarf_display=help`.
  - `-g` appends DWARF debug information to program output.
  - `-h` displays help
  - `-o=filename` sends program output to `filename` rather than to the screen.
  - **--obj_display attributes** controls the object file display filter settings by specifying a comma-delimited list of attributes. When prefixed with `no`, an attribute is disabled instead of enabled.
    - **Examples:**
      - `--obj_display=rawdata,nostrings`
      - `--obj_display=all,norawdata`
      - `--obj_display=none,header`
    - The ordering of attributes is important. For instance, in "--obj_display=none,header", `ofd6x` disables all output, then re-enables file header information. If the attributes are specified in the reverse order, (header,none), the file header is enabled, the all output is disabled, including the file header. Thus, nothing is printed to the screen for the given files. The list of available display attributes can be obtained by invoking `ofd6x --obj_display=help`.
  - `-v` prints verbose text output.
  - `-x` displays output in XML format.
  - **--xml_indent=num** sets the number of spaces to indent nested XML tags.

If an archive file is given as input to the object file display utility, each object file member of the archive is processed as if it was passed on the command line. The object file members are processed in the order in which they appear in the archive file.

If the object file display utility is invoked without any options, it displays information about the contents of the input files on the console screen.
10.2 Invoking the Disassembler

The disassembler, `dis6x`, examines the output of the assembler or linker. This utility accepts an object file or executable file as input and writes the disassembled object code to standard output or a specified file.

To invoke the disassembler, enter the following:

```
dis6x [options] input filename[.] [output filename]
```

- **dis6x** is the command that invokes the disassembler.
- `-a` disables the printing of branch destination addresses along with labels.
- `-b` displays data as bytes instead of words.
- `-c` dumps the object file information.
- `-d` disables display of data sections.
- `-h` shows the current help screen.
- `-i` disassembles `.data` sections as instructions.
- `-I` disassembles data sections as text.
- `-n` suppresses FP header information for Joule Compact FPs.
- `-o##` disassembles single word `##` or `0x##` then exits.
- `-q` (quiet mode) suppresses the banner and all progress information.
- `-qq` (super quiet mode) suppresses all headers.
- `-s` suppresses printing of address and data words.
- `-t` suppresses the display of text sections in the listing.
- `-v` displays family of the target.

`input filename[.ext]` is the name of the input file. If the optional extension is not specified, the file is searched for in this order:

1. `infile`
2. `infile.out`, an executable file
3. `infile.obj`, an object file

`output filename` is the name of the optional output file to which the disassembly will be written. If an output filename is not specified, the disassembly is written to standard output.

10.3 Invoking the Name Utility

The name utility, `nm6x`, prints the list of names defined and referenced in an object file, executable file, or archive library. It also prints the symbol value and an indication of the kind of symbol. Hidden symbols are listed as "*".

To invoke the name utility, enter the following:

```
rm6x [-options] [input filenames]
```
10.4 Invoking the Strip Utility

The strip utility, strip6x, removes symbol table and debugging information from object and executable files. To invoke the strip utility, enter the following:

```
strip6x [-p] input filename [input filename]
```

strip6x is the command that invokes the strip utility.
input filename is an object file (.obj) or an executable file (.out).
options identifies the strip utility options you want to use. Options are not case sensitive and can appear anywhere on the command line following the invocation. Precede each option with a hyphen (-). The strip utility option is as follows:
-o filename writes the stripped output to filename.
-p removes all information not required for execution. This option causes more information to be removed than the default behavior, but the object file is left in a state that cannot be linked. This option should be used only with executable (.out) files.

When the strip utility is invoked without the -o option, the input object files are replaced with the stripped version.
The TMS320C6000™ assembler and linker create object files which are in binary formats that encourage modular programming and provide powerful and flexible methods for managing code segments and target system memory.

Most EPROM programmers do not accept object files as input. The hex conversion utility converts an object file into one of several standard ASCII hexadecimal formats, suitable for loading into an EPROM programmer. The utility is also useful in other applications requiring hexadecimal conversion of an object file (for example, when using debuggers and loaders).

The hex conversion utility can produce these output file formats:
- ASCII-Hex, supporting 32-bit addresses
- Extended Tektronix (Tektronix)
- Intel MCS-86 (Intel)
- Motorola Exorciser (Motorola-S), supporting 16-bit addresses
- Texas Instruments SDSMAC (TI-Tagged), supporting 16-bit addresses
- Texas Instruments TI-TXT format, supporting 16-bit addresses

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</table>
11.1 The Hex Conversion Utility’s Role in the Software Development Flow

The Hex Conversion Utility’s Role in the Software Development Flow

Figure 11-1 highlights the role of the hex conversion utility in the software development process.

Figure 11-1. The Hex Conversion Utility in the TMS320C6000 Software Development Flow
11.2 Invoking the Hex Conversion Utility

There are two basic methods for invoking the hex conversion utility:

- **Specify the options and filenames on the command line.** The following example converts the file firmware.out into TI-Tagged format, producing two output files, firm.lsb and firm.msb.

  ```
  hex6x -t firmware -o firm.lsb -o firm.msb
  hex6x --ti_tagged firmware --outfile=firm.lsb --outfile=firm.msb
  ```

- **Specify the options and filenames in a command file.** You can create a file that stores command line options and filenames for invoking the hex conversion utility. The following example invokes the utility using a command file called hexutil.cmd:

  ```
  hex6x hexutil.cmd
  ```

In addition to regular command line information, you can use the hex conversion utility ROMS and SECTIONS directives in a command file.

### 11.2.1 Invoking the Hex Conversion Utility From the Command Line

To invoke the hex conversion utility, enter:

```
hex6x [options] filename
```

- **hex6x** is the command that invokes the hex conversion utility.
- **options** supplies additional information that controls the hex conversion process. You can use options on the command line or in a command file. Table 11-1 lists the basic options.
  - All options are preceded by a hyphen and are not case sensitive.
  - Several options have an additional parameter that must be separated from the option by at least one space.
  - Options with multi-character names must be spelled exactly as shown in this document; no abbreviations are allowed.
  - Options are not affected by the order in which they are used. The exception to this rule is the --quiet option, which must be used before any other options.
- **filename** names an object file or a command file (for more information, see Section 11.2.2).

### Table 11-1. Basic Hex Conversion Utility Options

<table>
<thead>
<tr>
<th>Option</th>
<th>Alias</th>
<th>Description</th>
<th>See</th>
</tr>
</thead>
<tbody>
<tr>
<td>--byte</td>
<td>-byte</td>
<td>Number output locations by bytes rather than by target addressing</td>
<td>--</td>
</tr>
<tr>
<td>--entry_point=addr</td>
<td>-e</td>
<td>Specify the entry point address or global symbol at which to begin execution after boot loading</td>
<td>Section 11.10.3.3</td>
</tr>
<tr>
<td>--exclude=(fname(sname))</td>
<td>-exclude</td>
<td>If the filename (fname) is omitted, all sections matching sname will be excluded.</td>
<td>Section 11.7</td>
</tr>
<tr>
<td>--fill=value</td>
<td>-fill</td>
<td>Fill holes with value</td>
<td>Section 11.9.2</td>
</tr>
<tr>
<td>--help</td>
<td>-options, -h</td>
<td>Display the syntax for invoking the utility and list available options. If the option is followed by another option or phrase, detailed information about that option or phrase is displayed. For example, to see information about options associated with generating a boot table, use -help boot.</td>
<td>Section 11.2.2</td>
</tr>
<tr>
<td>--image</td>
<td>-image</td>
<td>Select image mode</td>
<td>Section 11.9.1</td>
</tr>
<tr>
<td>--linkerfill</td>
<td>-linkerfill</td>
<td>Include linker fill sections in images</td>
<td>--</td>
</tr>
<tr>
<td>--map=filename</td>
<td>-map</td>
<td>Generate a map file</td>
<td>Section 11.4.2</td>
</tr>
<tr>
<td>--memwidth=value</td>
<td>-memwidth</td>
<td>Define the system memory word width (default 32 bits)</td>
<td>Section 11.3.2</td>
</tr>
<tr>
<td>--olength=value</td>
<td>-olength</td>
<td>Specify maximum number of data items per line of output</td>
<td>--</td>
</tr>
<tr>
<td>--order=(L</td>
<td>M)</td>
<td>-order</td>
<td>Specify data ordering (endianess)</td>
</tr>
</tbody>
</table>
### Table 11-1. Basic Hex Conversion Utility Options (continued)

<table>
<thead>
<tr>
<th>Option</th>
<th>Alias</th>
<th>Description</th>
<th>See</th>
</tr>
</thead>
<tbody>
<tr>
<td>--outfile=filename</td>
<td>-o</td>
<td>Specify an output filename</td>
<td>Section 11.8</td>
</tr>
<tr>
<td>--quiet</td>
<td>-q</td>
<td>Run quietly (when used, it must appear before other options)</td>
<td>Section 11.2.2</td>
</tr>
<tr>
<td>--romwidth=value</td>
<td>-romwidth</td>
<td>Specify the ROM device width (default depends on format used)</td>
<td>Section 11.3.3</td>
</tr>
<tr>
<td>--zero</td>
<td>-zero, -z</td>
<td>Reset the address origin to 0 in image mode</td>
<td>Section 11.9.3</td>
</tr>
</tbody>
</table>

### Diagnostic Options

<table>
<thead>
<tr>
<th>Option</th>
<th>Alias</th>
<th>Description</th>
<th>See</th>
</tr>
</thead>
<tbody>
<tr>
<td>--diag_error=id</td>
<td></td>
<td>Categorizes the diagnostic identified by id as an error</td>
<td>Section 11.12</td>
</tr>
<tr>
<td>--diag_remark=id</td>
<td></td>
<td>Categorizes the diagnostic identified by id as a remark</td>
<td>Section 11.12</td>
</tr>
<tr>
<td>--diag_suppress=id</td>
<td></td>
<td>Suppresses the diagnostic identified by id</td>
<td>Section 11.12</td>
</tr>
<tr>
<td>--diag_warning=id</td>
<td></td>
<td>Categorizes the diagnostic identified by id as a warning</td>
<td>Section 11.12</td>
</tr>
<tr>
<td>--display_error_number</td>
<td></td>
<td>Displays a diagnostic's identifiers along with its text</td>
<td>Section 11.12</td>
</tr>
<tr>
<td>--issue_remarks</td>
<td></td>
<td>Issues remarks (nonserious warnings)</td>
<td>Section 11.12</td>
</tr>
<tr>
<td>--no_warnings</td>
<td></td>
<td>Suppresses warning diagnostics (errors are still issued)</td>
<td>Section 11.12</td>
</tr>
<tr>
<td>--set_error_limit=count</td>
<td></td>
<td>Sets the error limit to count. The linker abandons linking after this number of errors. (The default is 100.)</td>
<td>Section 11.12</td>
</tr>
</tbody>
</table>

### Boot Table Options

<table>
<thead>
<tr>
<th>Option</th>
<th>Alias</th>
<th>Description</th>
<th>See</th>
</tr>
</thead>
<tbody>
<tr>
<td>--boot</td>
<td>-boot</td>
<td>Convert all initialized sections into bootable form (use instead of a SECTIONS directive)</td>
<td>Section 11.10.3.1</td>
</tr>
<tr>
<td>--bootorg=addr</td>
<td>-bootorg</td>
<td>Specify origin address of the boot loader table</td>
<td>Section 11.10.3.1</td>
</tr>
<tr>
<td>--bootsection=section</td>
<td>-bootsection</td>
<td>Specify which section contains the boot routine and where it should be placed</td>
<td>Section 11.10.3.1</td>
</tr>
</tbody>
</table>

### Output Options

<table>
<thead>
<tr>
<th>Option</th>
<th>Alias</th>
<th>Description</th>
<th>See</th>
</tr>
</thead>
<tbody>
<tr>
<td>--ascii</td>
<td>-a</td>
<td>Select ASCII-Hex</td>
<td>Section 11.13.1</td>
</tr>
<tr>
<td>--intel</td>
<td>-i</td>
<td>Select Intel</td>
<td>Section 11.13.2</td>
</tr>
<tr>
<td>--motorola=1</td>
<td>-m1</td>
<td>Select Motorola-S1</td>
<td>Section 11.13.3</td>
</tr>
<tr>
<td>--motorola=2</td>
<td>-m2</td>
<td>Select Motorola-S2</td>
<td>Section 11.13.3</td>
</tr>
<tr>
<td>--motorola=3</td>
<td>-m3</td>
<td>Select Motorola-S3 (default -m option)</td>
<td>Section 11.13.3</td>
</tr>
<tr>
<td>--tektronix</td>
<td>-x</td>
<td>Select Tektronix (default format when no output option is specified)</td>
<td>Section 11.13.4</td>
</tr>
<tr>
<td>--ti_tagged</td>
<td>-t</td>
<td>Select TI-Tagged</td>
<td>Section 11.13.5</td>
</tr>
<tr>
<td>--ti_txt</td>
<td></td>
<td>Select TI-Txt</td>
<td>Section 11.13.6</td>
</tr>
</tbody>
</table>

### Load Image Options

<table>
<thead>
<tr>
<th>Option</th>
<th>Description</th>
<th>See</th>
</tr>
</thead>
<tbody>
<tr>
<td>--load_image</td>
<td>Select load image</td>
<td>Section 11.6</td>
</tr>
<tr>
<td>--section_name_prefix=string</td>
<td>Specify the section name prefix for load image object files</td>
<td>Section 11.6</td>
</tr>
</tbody>
</table>
11.2.2 Invoking the Hex Conversion Utility With a Command File

A command file is useful if you plan to invoke the utility more than once with the same input files and options. It is also useful if you want to use the ROMS and SECTIONS hex conversion utility directives to customize the conversion process.

Command files are ASCII files that contain one or more of the following:

- **Options and filenames.** These are specified in a command file in exactly the same manner as on the command line.
- **ROMS directive.** The ROMS directive defines the physical memory configuration of your system as a list of address-range parameters. (See Section 11.4.)
- **SECTIONS directive.** The hex conversion utility SECTIONS directive specifies which sections from the object file are selected. (See Section 11.5.)
- **Comments.** You can add comments to your command file by using the /* and */ delimiters. For example:

```
/* This is a comment. */
```

To invoke the utility and use the options you defined in a command file, enter:

```
hex6x command_filename
```

You can also specify other options and files on the command line. For example, you could invoke the utility by using both a command file and command line options:

```
hex6x firmware.cmd --map=firmware.mxp
```

The order in which these options and filenames appear is not important. The utility reads all input from the command line and all information from the command file before starting the conversion process. However, if you are using the -q option, it must appear as the first option on the command line or in a command file.

The --help option 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 options associated with generating a boot table use --help boot.

The --quiet option suppresses the hex conversion utility's normal banner and progress information.

- **Assume that a command file named firmware.cmd contains these lines:**

  ```
  firmware.out /* input file */
  --ti_tagged /* TI-Tagged */
  --outfile=firm.lsb /* output file */
  --outfile=firm.msb /* output file */
  ```

  You can invoke the hex conversion utility by entering:

  ```
  hex6x firmware.cmd
  ```

- **This example shows how to convert a file called appl.out into eight hex files in Intel format. Each output file is one byte wide and 4K bytes long.**

  ```
  appl.out /* input file */
  --intel /* Intel format */
  --map=appl.mxp /* map file */
  ```

  ROMS

  ```
  { 
  ROW1: origin=0x00000000 len=0x4000 romwidth=8 
  files={ appl.u0 appl.u1 appl.u2 appl.u3 }
  ROW2: origin=0x00004000 len=0x4000 romwidth=8 
  files={ appl.u4 appl.u5 appl.u6 appl.u7 }
  }
  ```

  SECTIONS

  ```
  { .text, .data, .cinit, .sectl, .vectors, .const: }
  ```

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11.3 Understanding Memory Widths

The hex conversion utility makes your memory architecture more flexible by allowing you to specify memory and ROM widths. To use the hex conversion utility, you must understand how the utility treats word widths. Three widths are important in the conversion process:

- Target width
- Memory width
- ROM width

The terms target word, memory word, and ROM word refer to a word of such a width.

Figure 11-2 illustrates the separate and distinct phases of the hex conversion utility's process flow.

**Figure 11-2. Hex Conversion Utility Process Flow**

Raw data in object files is represented in the target’s addressable units. For the C6000, this is 32 bits.

### 11.3.1 Target Width

Target width is the unit size (in bits) of the target processor’s word. The unit size corresponds to the data bus size on the target processor. The width is fixed for each target and cannot be changed. The TMS320C6000 targets have a width of 32 bits.
### 11.3.2 Specifying the Memory Width

Memory width is the physical width (in bits) of the memory system. Usually, the memory system is physically the same width as the target processor width: a 32-bit processor has a 32-bit memory architecture. However, some applications require target words to be broken into multiple, consecutive, and narrower memory words.

By default, the hex conversion utility sets memory width to the target width (in this case, 32 bits).

You can change the memory width (except for TI-TXT format) by:

- Using the `--memwidth` option. This changes the memory width value for the entire file.
- Setting the `memwidth` parameter of the ROMS directive. This changes the memory width value for the address range specified in the ROMS directive and overrides the `--memwidth` option for that range.

See Section 11.4.

For both methods, use a value that is a power of 2 greater than or equal to 8.

You should change the memory width default value of 32 only when you need to break single target words into consecutive, narrower memory words.

---

**TI-TXT Format is 8 Bits Wide**

**NOTE:** You cannot change the memory width of the TI-TXT format. The TI-TXT hex format supports an 8-bit memory width only.

**Figure 11-3** demonstrates how the memory width is related to object file data.

**Figure 11-3. Object File Data and Memory Widths**

<table>
<thead>
<tr>
<th>Source file</th>
<th>Object file data (assumed to be in little-endian format)</th>
<th>Memory widths (variable)</th>
</tr>
</thead>
<tbody>
<tr>
<td>.word 0 AABBCCDDh</td>
<td>AA BB CC DD 11 22 33 44</td>
<td>--memwidth=32 (default) --memwidth=16 --memwidth=8</td>
</tr>
<tr>
<td>.word 0 1 1 2 2 3 3 4 4 h</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

---

For both methods, use a value that is a power of 2 greater than or equal to 8.

You should change the memory width default value of 32 only when you need to break single target words into consecutive, narrower memory words.
11.3.3 Partitioning Data Into Output Files

ROM width specifies the physical width (in bits) of each ROM device and corresponding output file (usually one byte or eight bits). The ROM width determines how the hex conversion utility partitions the data into output files. After the object file data is mapped to the memory words, the memory words are broken into one or more output files. The number of output files is determined by the following formulas:

- If memory width ≥ ROM width:
  number of files = memory width ÷ ROM width
- If memory width < ROM width:
  number of files = 1

For example, for a memory width of 32, you could specify a ROM width value of 32 and get a single output file containing 32-bit words. Or you can use a ROM width value of 16 to get two files, each containing 16 bits of each word.

The default ROM width that the hex conversion utility uses depends on the output format:

- All hex formats except TI-Tagged are configured as lists of 8-bit bytes; the default ROM width for these formats is 8 bits.
- TI-Tagged is a 16-bit format; the default ROM width for TI-Tagged is 16 bits.

The TI-Tagged Format is 16 Bits Wide

NOTE: You cannot change the ROM width of the TI-Tagged format. The TI-Tagged format supports a 16-bit ROM width only.

TI-TXT Format is 8 Bits Wide

NOTE: You cannot change the ROM width of the TI-TXT format. The TI-TXT hex format supports only an 8-bit ROM width.

You can change ROM width (except for TI-Tagged and TI-TXT formats) by:

- Using the --romwidth option. This option changes the ROM width value for the entire object file.
- Setting the romwidth parameter of the ROMS directive. This parameter changes the ROM width value for a specific ROM address range and overrides the --romwidth option for that range. See Section 11.4.

For both methods, use a value that is a power of 2 greater than or equal to 8.

If you select a ROM width that is wider than the natural size of the output format (16 bits for TI-Tagged or 8 bits for all others), the utility simply writes multibyte fields into the file.

Figure 11-4 illustrates how the object file data, memory, and ROM widths are related to one another.

Memory width and ROM width are used only for grouping the object file data; they do not represent values. Thus, the byte ordering of the object file data is maintained throughout the conversion process. To refer to the partitions within a memory word, the bits of the memory word are always numbered from right to left as follows:

```
--memwidth=32

<table>
<thead>
<tr>
<th>A A B B C C D D 1 1 2 2 3 3 4 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>31</td>
</tr>
<tr>
<td>0</td>
</tr>
</tbody>
</table>
```
Figure 11-4. Data, Memory, and ROM Widths

Source file

```
.word 0 AABBCDDA
.word 0 1 2 3 4 4 4
```* *

Object file data (assumed to be in little-endian format)

```
AA BB CC DD
11 22 33 44
```* *

Memory widths (variable)

```
--memwidth=32
AABBCDDD
12223344

--memwidth=16
CCDD AABBB
3344 1122

--memwidth=8
DD CC BB AA
44 33 22 11
```* *

Output files

```
--romwidth=8
--outfile=file.b0
DD 44
--outfile=file.b1
CC 33
--outfile=file.b2
BB 22
--outfile=file.b3
AA 11

--romwidth=16
--outfile=file.wrd
CCDDAABB33441122
--outfile=file.b0
DD BB 44 22
--outfile=file.b1
CC AA 33 11
--romwidth=8
--outfile=file.byf
DDCCBBAA44332211
```* *

---

Understanding Memory Widths

Figure 11-4. Data, Memory, and ROM Widths

Source file

```
.word 0 AABBCDDA
.word 0 1 2 3 4 4 4
```* *

Object file data (assumed to be in little-endian format)

```
AA BB CC DD
11 22 33 44
```* *

Memory widths (variable)

```
--memwidth=32
AABBCDDD
12223344

--memwidth=16
CCDD AABBB
3344 1122

--memwidth=8
DD CC BB AA
44 33 22 11
```* *

Output files

```
--romwidth=8
--outfile=file.b0
DD 44
--outfile=file.b1
CC 33
--outfile=file.b2
BB 22
--outfile=file.b3
AA 11

--romwidth=16
--outfile=file.wrd
CCDDAABB33441122
--outfile=file.b0
DD BB 44 22
--outfile=file.b1
CC AA 33 11
--romwidth=8
--outfile=file.byf
DDCCBBAA44332211
```* *
11.3.4 Specifying Word Order for Output Words

There are two ways to split a wide word into consecutive memory locations in the same hex conversion utility output file:

- `--order=M` specifies big-endian ordering, in which the most significant part of the wide word occupies the first of the consecutive locations.
- `--order=L` specifies little-endian ordering, in which the least significant part of the wide word occupies the first of the consecutive locations.

By default, the utility uses little-endian format. Unless your boot loader program expects big-endian format, avoid using `--order=M`.

When the `--order` Option Applies

**NOTE:**

- This option applies only when you use a memory width with a value of 32 (`--memwidth32`). Otherwise, the hex utility does not have access to the entire 32-bit word and cannot perform the byte swapping necessary to change the endianness; `--order` is ignored.
- This option does not affect the way memory words are split into output files. Think of the files as a set: the set contains a least significant file and a most significant file, but there is no ordering over the set. When you list filenames for a set of files, you always list the least significant first, regardless of the `--order` option.

11.4 The ROMS Directive

The ROMS directive specifies the physical memory configuration of your system as a list of address-range parameters.

Each address range produces one set of files containing the hex conversion utility output data that corresponds to that address range. Each file can be used to program one single ROM device.

The ROMS directive is similar to the MEMORY directive of the TMS320C6000 linker: both define the memory map of the target address space. Each line entry in the ROMS directive defines a specific address range. The general syntax is:

```
ROMS
{
  romname : [origin=value,] [length=value,] [romwidth=value,]
            [memwidth=value,] [fill=value]
            [files={ filename1, filename2, ...}]
  romname : [origin=value,] [length=value,] [romwidth=value,]
            [memwidth=value,] [fill=value]
            [files={ filename1, filename2, ...}]

  ...
}
```

**ROMS** begins the directive definition.

**romname** identifies a memory range. The name of the memory range can be one to eight characters in length. The name has no significance to the program; it simply identifies the range, except when the output is for a load image in which case it denotes the section name. (Duplicate memory range names are allowed.)

**origin** specifies the starting address of a memory range. It can be entered as origin, org, or o. The associated value must be a decimal, octal, or hexadecimal constant. If you omit the origin value, the origin defaults to 0. The following table summarizes the notation you can use to specify a decimal, octal, or hexadecimal constant:
length specifies the length of a memory range as the physical length of the ROM device. It can be entered as length, len, or l. The value must be a decimal, octal, or hexadecimal constant. If you omit the length value, it defaults to the length of the entire address space.

romwidth specifies the physical ROM width of the range in bits (see Section 11.3.3). Any value you specify here overrides the --romwidth option. The value must be a decimal, octal, or hexadecimal constant that is a power of 2 greater than or equal to 8.

memwidth specifies the memory width of the range in bits (see Section 11.3.2). Any value you specify here overrides the --memwidth option. The value must be a decimal, octal, or hexadecimal constant that is a power of 2 greater than or equal to 8. When using the memwidth parameter, you must also specify the paddr parameter for each section in the SECTIONS directive. (See Section 11.5.)

fill specifies a fill value to use for the range. In image mode, the hex conversion utility uses this value to fill any holes between sections in a range. A hole is an area between the input sections that comprises an output section that contains no actual code or data. The fill value must be a decimal, octal, or hexadecimal constant with a width equal to the target width. Any value you specify here overrides the --fill option. When using fill, you must also use the --image command line option. (See Section 11.9.2.)

files identifies the names of the output files that correspond to this range. Enclose the list of names in curly braces and order them from least significant to most significant output file, where the bits of the memory word are numbered from right to left. The number of file names must equal the number of output files that the range generates. To calculate the number of output files, see Section 11.3.3. The utility warns you if you list too many or too few filenames.

Unless you are using the --image option, all of the parameters that define a range are optional; the commas and equal signs are also optional. A range with no origin or length defines the entire address space. In image mode, an origin and length are required for all ranges.

Ranges must not overlap and must be listed in order of ascending address.

### 11.4.1 When to Use the ROMS Directive

If you do not use a ROMS directive, the utility defines a single default range that includes the entire address space. This is equivalent to a ROMS directive with a single range without origin or length.

Use the ROMS directive when you want to:

- **Program large amounts of data into fixed-size ROMs.** When you specify memory ranges corresponding to the length of your ROMs, the utility automatically breaks the output into blocks that fit into the ROMs.

- **Restrict output to certain segments.** You can also use the ROMS directive to restrict the conversion to a certain segment or segments of the target address space. The utility does not convert the data that falls outside of the ranges defined by the ROMS directive. Sections can span range boundaries; the utility splits them at the boundary into multiple ranges. If a section falls completely outside any of the ranges you define, the utility does not convert that section and issues no messages or warnings. Thus, you can exclude sections without listing them by name with the SECTIONS directive. However, if a section falls partially in a range and partially in unconfigured memory, the utility issues a warning and converts only the part within the range.
• **Use image mode.** When you use the --image option, you must use a ROMS directive. Each range is filled completely so that each output file in a range contains data for the whole range. Holes before, between, or after sections are filled with the fill value from the ROMS directive, with the value specified with the --fill option, or with the default value of 0.

### 11.4.2 An Example of the ROMS Directive

The ROMS directive in Example 11-1 shows how 16K bytes of 16-bit memory could be partitioned for two 8K-byte 8-bit EPROMs. Figure 11-5 illustrates the input and output files.

**Example 11-1. A ROMS Directive Example**

```plaintext
infile.out
  --image
  --memwidth 16

ROMS
{
  EPROM1: org = 0x00004000, len = 0x2000, romwidth = 8
    files = { rom4000.b0, rom4000.b1}
  EPROM2: org = 0x00006000, len = 0x2000, romwidth = 8,
    fill = 0xFF00FF00,
    files = { rom6000.b0, rom6000.b1}
}
```

**Figure 11-5. The infile.out File Partitioned Into Four Output Files**

The map file (specified with the --map option) is advantageous when you use the ROMS directive with multiple ranges. The map file shows each range, its parameters, names of associated output files, and a list of contents (section names and fill values) broken down by address. Example 11-2 is a segment of the map file resulting from the example in Example 11-1.
Example 11-2. Map File Output From Example 11-1 Showing Memory Ranges

```
00004000..00005fff Page=0 Width=8 "EPROM1"
```

OUTPUT FILES: rom4000.b0  [b0..b7]
              rom4000.b1  [b8..b15]

CONTENTS: 00004000..0000487f .text
           00004880..00005b7f FILL = 00000000
           00005b80..00005fff .data

```
00006000..00007fff Page=0 Width=8 "EPROM2"
```

OUTPUT FILES: rom6000.b0  [b0..b7]
              rom6000.b1  [b8..b15]

CONTENTS: 00006000..0000633f .data
           00006340..000066ff FILL = ff00ff00
           00006700..00007c7f .table
           00007c80..00007fff FILL = ff00ff00

EPROM1 defines the address range from 0x00004000 through 0x00005FFF with the following sections:

<table>
<thead>
<tr>
<th>This section ...</th>
<th>Has this range ...</th>
</tr>
</thead>
<tbody>
<tr>
<td>.text</td>
<td>0x00004000 through 0x0000487F</td>
</tr>
<tr>
<td>.data</td>
<td>0x00005B80 through 0x00005FFF</td>
</tr>
</tbody>
</table>

The rest of the range is filled with 0h (the default fill value), converted into two output files:
- rom4000.b0 contains bits 0 through 7
- rom4000.b1 contains bits 8 through 15

EPROM2 defines the address range from 0x00006000 through 0x00007FFF with the following sections:

<table>
<thead>
<tr>
<th>This section ...</th>
<th>Has this range ...</th>
</tr>
</thead>
<tbody>
<tr>
<td>.data</td>
<td>0x00006000 through 0x0000633F</td>
</tr>
<tr>
<td>.table</td>
<td>0x00006700 through 0x00007C7F</td>
</tr>
</tbody>
</table>

The rest of the range is filled with 0xFF00FF00 (from the specified fill value). The data from this range is converted into two output files:
- rom6000.b0 contains bits 0 through 7
- rom6000.b1 contains bits 8 through 15
11.5 The SECTIONS Directive

You can convert specific sections of the object file by name with the hex conversion utility SECTIONS directive. You can also specify those sections that you want to locate in ROM at a different address than the load address specified in the linker command file. If you:

- Use a SECTIONS directive, the utility converts only the sections that you list in the directive and ignores all other sections in the object file.
- Do not use a SECTIONS directive, the utility converts all initialized sections that fall within the configured memory.

Uninitialized sections are never converted, whether or not you specify them in a SECTIONS directive.

Sections Generated by the C/C++ Compiler

**NOTE:** The TMS320C6000 C/C++ compiler automatically generates these sections:

- **Initialized sections:** .text, .const, .cinit, and .switch
- **Uninitialized sections:** .bss, .stack, and .sysmem

Use the SECTIONS directive in a command file. (See Section 11.2.2.) The general syntax for the SECTIONS directive is:

```
SECTIONS
{
 oname(sname)[:] [paddr=value]
 oname(sname)[:] [paddr= boot]
 oname(sname)[:] [boot]
...
}
```

- **SECTIONS** begins the directive definition.
- **oname** identifies the object filename the section is located within. The filename is optional when only a single input file is given, but required otherwise.
- **sname** identifies a section in the input file. If you specify a section that does not exist, the utility issues a warning and ignores the name.
- **paddr=value** specifies the physical ROM address at which this section should be located. This value overrides the section load address given by the linker. This value must be a decimal, octal, or hexadecimal constant. It can also be the word boot (to indicate a boot table section for use with a boot loader). If your file contains multiple sections, and if one section uses a paddr parameter, then all sections must use a paddr parameter.
- **boot** configures a section for loading by a boot loader. This is equivalent to using paddr=boot. Boot sections have a physical address determined by the location of the boot table. The origin of the boot table is specified with the --bootorg option.

For more similarity with the linker’s SECTIONS directive, you can use colons after the section names (in place of the equal sign on the boot keyboard). For example, the following statements are equivalent:

```
SECTIONS { .text: .data: boot }
SECTIONS { .text: .data = boot }
```

In the example below, the object file contains six initialized sections: .text, .data, .const, .vectors, .coeff, and .tables. Suppose you want only .text and .data to be converted. Use a SECTIONS directive to specify this:

```
SECTIONS { .text: .data: }
```

To configure both of these sections for boot loading, add the boot keyword:

```
SECTIONS { .text = boot .data = boot }
```
11.6 The Load Image Format (--load_image Option)

A load image is an object file which contains the load addresses and initialized sections of one or more executable files. The load image object file can be used for ROM masking or can be relinked in a subsequent link step.

11.6.1 Load Image Section Formation

The load image sections are formed by collecting the initialized sections from the input executables. There are two ways the load image sections are formed:

- **Using the ROMS Directive.** Each memory range that is given in the ROMS directive denotes a load image section. The romname is the section name. The origin and length parameters are required. The memwidth, romwidth, and files parameters are invalid and are ignored.
  
  When using the ROMS directive and the load_image option, the --image option is required.

- **Default Load Image Section Formation.** If no ROMS directive is given, the load image sections are formed by combining contiguous initialized sections in the input executables. Sections with gaps smaller than the target word size are considered contiguous.
  The default section names are image_1, image_2, ... If another prefix is desired, the --section_name_prefix=prefix option can be used.

11.6.2 Load Image Characteristics

All load image sections are initialized data sections. In the absence of a ROMS directive, the load/run address of the load image section is the load address of the first input section in the load image section. If the SECTIONS directive was used and a different load address was given using the paddr parameter, this address will be used.

The load image format always creates a single load image object file. The format of the load image object file is determined based on the input files. The file is not marked executable and does not contain an entry point. The default load image object file name is ti_load_image.obj. This can be changed using the --outfile option. Only one --outfile option is valid when creating a load image, all other occurrences are ignored.

Concerning Load Image Format

**NOTE:** These options are invalid when creating a load image:

- --memwidth
- --romwidth
- --order
- --zero
- --byte

If a boot table is being created, either using the SECTIONS directive or the --boot option, the ROMS directive must be used.

11.7 Excluding a Specified Section

The --exclude section_name option can be used to inform the hex utility to ignore the specified section. If a SECTIONS directive is used, it overrides the --exclude option.

For example, if a SECTIONS directive containing the section name mysect is used and an --exclude mysect is specified, the SECTIONS directive takes precedence and mysect is not excluded.
The --exclude option has a limited wildcard capability. The * character can be placed at the beginning or end of the name specifier to indicate a suffix or prefix, respectively. For example, --exclude sect* disqualifies all sections that begin with the characters sect.

If you specify the --exclude option on the command line with the * wildcard, enter quotes around the section name and wildcard. For example, --exclude "sect*". Using quotes prevents the * from being interpreted by the hex conversion utility. If --exclude is in a command file, then the quotes should not be specified.

If multiple object files are given, the object file in which the section to be excluded can be given in the form oname(sname). If the object filename is not provided, all sections matching the section name are excluded. Wildcards cannot be used for the filename, but can appear within the parentheses.

11.8 Assigning Output Filenames

When the hex conversion utility translates your object file into a data format, it partitions the data into one or more output files. When multiple files are formed by splitting memory words into ROM words, filenames are always assigned in order from least to most significant, where bits in the memory words are numbered from right to left. This is true, regardless of target or endian ordering.

The hex conversion utility follows this sequence when assigning output filenames:

1. **It looks for the ROMS directive.** If a file is associated with a range in the ROMS directive and you have included a list of files (files = {...}) on that range, the utility takes the filename from the list. For example, assume that the target data is 32-bit words being converted to four files, each eight bits wide. To name the output files using the ROMS directive, you could specify:

   ```
   ROMS
   {   RANGE1: romwidth=8, files={ xyz.b0 xyz.b1 xyz.b2 xyz.b3 } }
   ```

   The utility creates the output files by writing the least significant bits to xyz.b0 and the most significant bits to xyz.b3.

2. **It looks for the --outfile options.** You can specify names for the output files by using the --outfile option. If no filenames are listed in the ROMS directive and you use --outfile options, the utility takes the filename from the list of --outfile options. The following line has the same effect as the example above using the ROMS directive:

   ```
   --outfile=xyz.b0 --outfile=xyz.b1 --outfile=xyz.b2 --outfile=xyz.b3
   ```

   If both the ROMS directive and --outfile options are used together, the ROMS directive overrides the --outfile options.

3. **It assigns a default filename.** If you specify no filenames or fewer names than output files, the utility assigns a default filename. A default filename consists of the base name from the input file plus a 2- to 3-character extension. The extension has three parts:

   (a) A format character, based on the output format (see Section 11.13):

   a for ASCII-Hex
   i for Intel
   m for Motorola-S
   t for TI-Tagged
   x for Tektronix

   (b) The range number in the ROMS directive. Ranges are numbered starting with 0. If there is no ROMS directive, or only one range, the utility omits this character.

   (c) The file number in the set of files for the range, starting with 0 for the least significant file.

   For example, assume a.out is for a 32-bit target processor and you are creating Intel format output. With no output filenames specified, the utility produces four output files named a.i0, a.i1, a.i2, a.i3. If you include the following ROMS directive when you invoke the hex conversion utility, you would have eight output files:

   ```
   ROMS
   ```
11.9 Image Mode and the --fill Option

This section points out the advantages of operating in image mode and describes how to produce output files with a precise, continuous image of a target memory range.

11.9.1 Generating a Memory Image

With the --image option, the utility generates a memory image by completely filling all of the mapped ranges specified in the ROMS directive.

An object file consists of blocks of memory (sections) with assigned memory locations. Typically, all sections are not adjacent: there are holes between sections in the address space for which there is no data. When such a file is converted without the use of image mode, the hex conversion utility bridges these holes by using the address records in the output file to skip ahead to the start of the next section. In other words, there may be discontinuities in the output file addresses. Some EPROM programmers do not support address discontinuities.

In image mode, there are no discontinuities. Each output file contains a continuous stream of data that corresponds exactly to an address range in target memory. Any holes before, between, or after sections are filled with a fill value that you supply.

An output file converted by using image mode still has address records, because many of the hexadecimal formats require an address on each line. However, in image mode, these addresses are always contiguous.

<table>
<thead>
<tr>
<th>These output files ...</th>
<th>Contain data in these locations ...</th>
</tr>
</thead>
<tbody>
<tr>
<td>a.i00, a.i01, a.i02, a.i03</td>
<td>0x00001000 through 0x0001FFF</td>
</tr>
<tr>
<td>a.i10, a.i11, a.i12, a.i13</td>
<td>0x00002000 through 0x0002FFF</td>
</tr>
</tbody>
</table>

11.9.2 Specifying a Fill Value

The --fill option specifies a value for filling the holes between sections. The fill value must be specified as an integer constant following the --fill option. The width of the constant is assumed to be that of a word on the target processor. For example, specifying --fill=0x0FFF. The constant value is not sign extended.

The hex conversion utility uses a default fill value of 0 if you do not specify a value with the fill option. The --fill option is valid only when you use --image; otherwise, it is ignored.

11.9.3 Steps to Follow in Using Image Mode

Step 1: Define the ranges of target memory with a ROMS directive. See Section 11.4.

Step 2: Invoke the hex conversion utility with the --image option. You can optionally use the --zero option to reset the address origin to 0 for each output file. If you do not specify a fill value with the ROMS directive and you want a value other than the default of 0, use the --fill option.
11.10 Building a Table for an On-Chip Boot Loader

On the C621x, C671x, and C64x devices, a ROM boot process is supported where the EDMA copies 1K bytes from the beginning of CE1 (EMIFB CE1 on C64x) to address 0, using default ROM timings. After the transfer, the CPU begins executing from address 0. In this mode a second level boot load typically occurs, due to the limited amount of memory copied at boot.

The hex conversion utility supports the second level boot loader by automatically building the boot table.

11.10.1 Description of the Boot Table

The input for a boot loader is the boot table. The boot table contains records that instruct the boot loader to copy blocks of data contained in the table to specified destination addresses. The hex conversion utility automatically builds the boot table for the boot loader. Using the utility, you specify the sections you want the boot loader to initialize through the boot table, the table location, and the name of the section containing the boot loader and where it should be located. The hex conversion utility builds a complete image of the table and converts it into hexadecimal in the output files. Then, you can burn the table into ROM.

11.10.2 The Boot Table Format

The boot table format is simple. There is a header record containing a 4-byte field that indicates where the boot loader should branch after it has completed copying data. After the header, each section that is to be included in the boot table will have the following:

1. 4-byte field containing the size of the section
2. 4-byte field containing the destination address for the copy
3. The actual data to be copied

Multiple sections can be entered; a termination block containing a 4-byte field of zeros follows the last section.

```
<table>
<thead>
<tr>
<th>Section 1 Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Section 1 Dest</td>
</tr>
<tr>
<td>Section 1 Data</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Section 2 Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Section 2 Dest</td>
</tr>
<tr>
<td>Section 2 Data</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Section N Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Section N Dest</td>
</tr>
<tr>
<td>Section N Data</td>
</tr>
</tbody>
</table>

0x00000000
```
11.10.3 How to Build the Boot Table

Table 11-2 summarizes the hex conversion utility options available for the boot loader.

Table 11-2. Boot-Loader Options

<table>
<thead>
<tr>
<th>Option</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>--boot</td>
<td>Convert all sections into bootable form (use instead of a SECTIONS directive).</td>
</tr>
<tr>
<td>--bootorg=value</td>
<td>Specify the source address of the boot loader table.</td>
</tr>
<tr>
<td>--bootsection=section value</td>
<td>Specify the section name containing the boot loader routine. The value argument tells the hex utility where to place the boot loader routine.</td>
</tr>
<tr>
<td>--entry_point=value</td>
<td>Specify the entry point at which to begin execution after boot loading. The value can be an address or a global symbol.</td>
</tr>
</tbody>
</table>

11.10.3.1 Building the Boot Table

To build the boot table, follow these steps:

**Step 1:** Link the file. Each block of the boot table data corresponds to an initialized section in the object file. Uninitialized sections are not converted by the hex conversion utility (see Section 11.5). You must link into your application a boot loader routine that will read the boot table and perform the copy operations. It should be linked to its eventual run-time address.

When you select a section for placement in a boot-loader table, the hex conversion utility places the section's load address in the destination address field for the block in the boot table. The section content is then treated as raw data for that block. The hex conversion utility does not use the section run address. When linking, you need not worry about the ROM address or the construction of the boot table; the hex conversion utility handles this.

**Step 2:** Identify the bootable sections. You can use the --boot option to tell the hex conversion utility to configure all sections for boot loading. Or, you can use a SECTIONS directive to select specific sections to be configured (see Section 11.5). If you use a SECTIONS directive, the --boot option is ignored.

**Step 3:** Set the ROM address of the boot table. Use the --bootorg option to set the source address of the complete table. For example, if you are using the C6711 and booting from memory location 0x90000400, specify --bootorg=0x90000400. The address field for the boot table in the hex conversion utility output file will then start at 0x90000400.

If you do not use the --bootorg option at all, the utility places the table at the origin of the first memory range in a ROMS directive. If you do not use a ROMS directive, the table will start at the first section load address.

**Step 4:** Set boot-loader-specific options. Set entry point. If --entry_point is not used to set the entry point, then it will default to the entry point indicated in the object file.

**Step 5:** Describe the boot routine. If the boot option is used, then you should use the --bootsection option to indicate to the hex utility which section contains the boot routine. This option will prevent the boot routine from being in the boot table. The --bootsection option also indicates to the hex utility where the routine should be placed in ROM. For the C621x, C671x, and C64x devices, this address would typically be the beginning of CE1 (EMIFB CE1 on C64x). This option is ignored if --boot is not used.

When the SECTIONS directive is used to explicitly identify which sections should exits in the boot table, use the PADDR section option to indicate where the boot routine section will exist.

**Step 6:** Describe your system memory configuration. See Section 11.3 and Section 11.4.
11.10.3.2 Leaving Room for the Boot Table

The complete boot table is similar to a single section containing all of the header records and data for the boot loader. The address of this section is the boot table origin. As part of the normal conversion process, the hex conversion utility converts the boot table to hexadecimal format and maps it into the output files like any other section.

Be sure to leave room in your system memory for the boot table, especially when you are using the ROMS directive. The boot table cannot overlap other nonboot sections or unconfigured memory. Usually, this is not a problem; typically, a portion of memory in your system is reserved for the boot table. Simply configure this memory as one or more ranges in the ROMS directive, and use the --bootorg option to specify the starting address.

11.10.3.3 Setting the Entry Point for the Boot Table

After the boot routine finishes copying data, it branches to the entry point defined the object file. By using the --entry_point option with the hex conversion utility, you can set the entry point to a different address.

For example, if you want your program to start running at address 0x0123 after loading, specify --entry_point=0x0123 on the command line or in a command file. You can determine the --entry_point address by looking at the map file that the linker generates.

Valid Entry Points

NOTE: The value can be a constant, or it can be a symbol that is externally defined (for example, with a .global) in the assembly source.

11.10.4 Using the C6000 Boot Loader

This subsection explains how to use the hex conversion utility with the boot loader for C6000 devices through sample hex utility command files. Example 11-3 uses the SECTIONS directive to specify exactly which sections will be placed in the boot table.

Example 11-3. Sample Command File for Booting From a C6000 EPROM

```
abc.out /* input file */
--ascii /* ascii format */
--image /* create complete ROM image */
--zero /* reset address origin to 0 */
--memwidth 8 /* 8-bit memory */
--map=abchex.map /* create a hex map file */
--bootorg=0x90000400 /* external memory boot */

ROMS
{
  FLASH: org=0x90000000, len=0x20000, romwidth=8, files={abc.hex}
}

SECTIONS
{
  .boot_load: PADDR=0x90000000
  .text:  BOOT
  .cinit:  BOOT
  .const:  BOOT
}
```
Example 11-4 does not explicitly name the boot sections with the SECTIONS directive. Instead, it uses the --boot option to indicate that all initialized sections should be placed in the boot table. It also uses the --bootsection option to distinguish the section containing the boot routine.

**Example 11-4. Alternative Sample Command File for Booting From a C6x EPROM**

```plaintext
abc.out  /* input file */
--ascii  /* ascii format */
--image  /* create complete Rom image */
--zero  /* reset address origin to 0 */
--memwidth=8  /* 8-bit memory */
--map=abchex.map  /* create a hex map file */
--boot  /* create boot table */
--bootorg=0x90000400  /* external memory boot */
--bootsection=.boot_load 0x90000000  /* give boot section & addr */

ROMS
{
  FLASH: org=0x90000000, len=0x20000, romwidth=8, files={abc.hex}
}
```
11.11 Controlling the ROM Device Address

The hex conversion utility output address field corresponds to the ROM device address. The EPROM programmer burns the data into the location specified by the hex conversion utility output file address field. The hex conversion utility offers some mechanisms to control the starting address in ROM of each section. However, many EPROM programmers offer direct control of the location in ROM in which the data is burned.

Depending on whether or not you are using the boot loader, the hex conversion utility output file controlling mechanisms are different.

Non-boot loader mode. The address field of the hex conversion utility output file is controlled by the following mechanisms listed from low to high priority:

1. **The linker command file.** By default, the address field of the hex conversion utility output file is the load address (as given in the linker command file).
2. **The paddr parameter of the SECTIONS directive.** When the paddr parameter is specified for a section, the hex conversion utility bypasses the section load address and places the section in the address specified by paddr.
3. **The --zero option.** When you use the --zero option, the utility resets the address origin to 0 for each output file. Since each file starts at 0 and counts upward, any address records represent offsets from the beginning of the file (the address within the ROM) rather than actual target addresses of the data. You must use the --zero option in conjunction with the --image option to force the starting address in each output file to be zero. If you specify the --zero option without the --image option, the utility issues a warning and ignores the --zero option.

Boot-Loader Mode. When the boot loader is used, the hex conversion utility places the different sections that are in the boot table into consecutive memory locations. Each section becomes a boot table block whose destination address is equal to the linker-assigned section load address.

In a boot table, the address field of the hex conversion utility output file is not related to the section load addresses assigned by the linker. The address fields of the boot table are simply offsets to the beginning of the table. The section load addresses assigned by the linker will be encoded into the boot table along with the size of the section and the data contained within the section. These addresses will be used to store the data into memory during the boot load process.

The beginning of the boot table defaults to the linked load address of the first bootable section in the input file, unless you use one of the following mechanisms, listed here from low to high priority. Higher priority mechanisms override the values set by low priority options in an overlapping range.

1. **The ROM origin specified in the ROMS directive.** The hex conversion utility places the boot table at the origin of the first memory range in a ROMS directive.
2. **The --bootorg option.** The hex conversion utility places the boot table at the address specified by the --bootorg option if you select boot loading from memory.
11.12 Control Hex Conversion Utility Diagnostics

The hex conversion utility uses certain C/C++ compiler options to control hex-converter-generated diagnostics.

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

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

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

`--diag_warning=id` Categorizes the diagnostic identified by *id* as a warning. To determine the numeric identifier of a diagnostic message, use the `--display_error_number` option first in a separate link. Then use `--diag_warning=id` 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 the `TMS320C6000 Optimizing Compiler User's Guide` for more information on understanding diagnostic messages.

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

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

`--set_error_limit=count` Sets the error limit to *count*, which can be any decimal value. 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 and indicate the position of the error in the source line.
11.13 Description of the Object Formats

The hex conversion utility has options that identify each format. Table 11-3 specifies the format options. They are described in the following sections.

- You need to use only one of these options on the command line. If you use more than one option, the last one you list overrides the others.
- The default format is Tektronix (--tektronix option).

<table>
<thead>
<tr>
<th>Option</th>
<th>Alias</th>
<th>Format</th>
<th>Address Bits</th>
<th>Default Width</th>
</tr>
</thead>
<tbody>
<tr>
<td>--ascii</td>
<td>-a</td>
<td>ASCII-Hex</td>
<td>16</td>
<td>8</td>
</tr>
<tr>
<td>--intel</td>
<td>-i</td>
<td>Intel</td>
<td>32</td>
<td>8</td>
</tr>
<tr>
<td>--motorola=1</td>
<td>-m1</td>
<td>Motorola-S1</td>
<td>16</td>
<td>8</td>
</tr>
<tr>
<td>--motorola=2</td>
<td>-m2</td>
<td>Motorola-S2</td>
<td>24</td>
<td>8</td>
</tr>
<tr>
<td>--motorola=3</td>
<td>-m3</td>
<td>Motorola-S3</td>
<td>32</td>
<td>8</td>
</tr>
<tr>
<td>--ti-tagged</td>
<td>-t</td>
<td>TI-Tagged</td>
<td>16</td>
<td>16</td>
</tr>
<tr>
<td>--ti_txt</td>
<td></td>
<td>TI_TXT</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>--tektronix</td>
<td>-x</td>
<td>Tektronix</td>
<td>32</td>
<td>8</td>
</tr>
</tbody>
</table>

Address bits determine how many bits of the address information the format supports. Formats with 16-bit addresses support addresses up to 64K only. The utility truncates target addresses to fit in the number of available bits.

The default width determines the default output width of the format. You can change the default width by using the --romwidth option or by using the romwidth parameter in the ROMS directive. You cannot change the default width of the TI-Tagged format, which supports a 16-bit width only.

11.13.1 ASCII-Hex Object Format (--ascii Option)

The ASCII-Hex object format supports 32-bit addresses. The format consists of a byte stream with bytes separated by spaces. Figure 11-6 illustrates the ASCII-Hex format.

```
Figure 11-6. ASCII-Hex Object Format

The file begins with an ASCII STX character (ctrl-B, 02h) and ends with an ASCII ETX character (ctrl-C, 03h). Address records are indicated with $AXXXXXXX, in which XXXXXXXX is a 8-digit (16-bit) hexadecimal address. The address records are present only in the following situations:

- When discontinuities occur
- When the byte stream does not begin at address 0

You can avoid all discontinuities and any address records by using the --image and --zero options. This creates output that is simply a list of byte values.
11.13.2 Intel MCS-86 Object Format (--intel Option)

The Intel object format supports 16-bit addresses and 32-bit extended addresses. Intel format consists of a 9-character (4-field) prefix (which defines the start of record, byte count, load address, and record type), the data, and a 2-character checksum suffix.

The 9-character prefix represents three record types:

<table>
<thead>
<tr>
<th>Record Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>Data record</td>
</tr>
<tr>
<td>01</td>
<td>End-of-file record</td>
</tr>
<tr>
<td>04</td>
<td>Extended linear address record</td>
</tr>
</tbody>
</table>

Record type 00, the data record, begins with a colon (:) and is followed by the byte count, the address of the first data byte, the record type (00), and the checksum. The address is the least significant 16 bits of a 32-bit address; this value is concatenated with the value from the most recent 04 (extended linear address) record to create a full 32-bit address. The checksum is the 2s complement (in binary form) of the preceding bytes in the record, including byte count, address, and data bytes.

Record type 01, the end-of-file record, also begins with a colon (:) followed by the byte count, the address, the record type (01), and the checksum.

Record type 04, the extended linear address record, specifies the upper 16 address bits. It begins with a colon (:) followed by the byte count, a dummy address of 0h, the record type (04), the most significant 16 bits of the address, and the checksum. The subsequent address fields in the data records contain the least significant bytes of the address.

Figure 11-7 illustrates the Intel hexadecimal object format.

Figure 11-7. Intel Hexadecimal Object Format
11.13.3 **Motorola Exorciser Object Format (--motorola Option)**

The Motorola S1, S2, and S3 formats support 16-bit, 24-bit, and 32-bit addresses, respectively. The formats consist of a start-of-file (header) record, data records, and an end-of-file (termination) record. Each record consists of five fields: record type, byte count, address, data, and checksum. The three record types are:

<table>
<thead>
<tr>
<th>Record Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>S0</td>
<td>Header record</td>
</tr>
<tr>
<td>S1</td>
<td>Code/data record for 16-bit addresses (S1 format)</td>
</tr>
<tr>
<td>S2</td>
<td>Code/data record for 24-bit addresses (S2 format)</td>
</tr>
<tr>
<td>S3</td>
<td>Code/data record for 32-bit addresses (S3 format)</td>
</tr>
<tr>
<td>S7</td>
<td>Termination record for 32-bit addresses (S3 format)</td>
</tr>
<tr>
<td>S8</td>
<td>Termination record for 24-bit addresses (S2 format)</td>
</tr>
<tr>
<td>S9</td>
<td>Termination record for 16-bit addresses (S1 format)</td>
</tr>
</tbody>
</table>

The byte count is the character pair count in the record, excluding the type and byte count itself.

The checksum is the least significant byte of the 1s complement of the sum of the values represented by the pairs of characters making up the byte count, address, and the code/data fields.

Figure 11-8 illustrates the Motorola-S object format.
11.13.4 Extended Tektronix Object Format (--tektronix Option)

The Tektronix object format supports 32-bit addresses and has two types of records:

- **Data records** contains the header field, the load address, and the object code.
- **Termination records** signifies the end of a module.

The header field in the data record contains the following information:

<table>
<thead>
<tr>
<th>Item</th>
<th>Number of ASCII Characters</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>%</td>
<td>1</td>
<td>Data type is Tektronix format</td>
</tr>
<tr>
<td>Block length</td>
<td>2</td>
<td>Number of characters in the record, minus the %</td>
</tr>
<tr>
<td>Block type</td>
<td>1</td>
<td>6 = data record</td>
</tr>
<tr>
<td></td>
<td></td>
<td>8 = termination record</td>
</tr>
<tr>
<td>Checksum</td>
<td>2</td>
<td>A 2-digit hex sum modulo 256 of all values in the record except the % and the checksum itself.</td>
</tr>
</tbody>
</table>

The load address in the data record specifies where the object code will be located. The first digit specifies the address length; this is always 8. The remaining characters of the data record contain the object code, two characters per byte.

**Figure 11-9** illustrates the Tektronix object format.

![Figure 11-9. Extended Tektronix Object Format](image-url)
11.13.5 Texas Instruments SDSMAC (TI-Tagged) Object Format (\texttt{--ti\_tagged} Option)

The Texas Instruments SDSMAC (TI-Tagged) object format supports 16-bit addresses, including start-of-file record, data records, and end-of-file record. Each data records consists of a series of small fields and is signified by a tag character:

<table>
<thead>
<tr>
<th>Tag Character</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>K</td>
<td>Followed by the program identifier</td>
</tr>
<tr>
<td>7</td>
<td>Followed by a checksum</td>
</tr>
<tr>
<td>8</td>
<td>Followed by a dummy checksum (ignored)</td>
</tr>
<tr>
<td>9</td>
<td>Followed by a 16-bit load address</td>
</tr>
<tr>
<td>B</td>
<td>Followed by a data word (four characters)</td>
</tr>
<tr>
<td>F</td>
<td>Identifies the end of a data record</td>
</tr>
<tr>
<td>*</td>
<td>Followed by a data byte (two characters)</td>
</tr>
</tbody>
</table>

Figure 11-10 illustrates the tag characters and fields in TI-Tagged object format.

If any data fields appear before the first address, the first field is assigned address 0000h. Address fields may be expressed but not required for any data byte. The checksum field, preceded by the tag character 7, is the 2s complement of the sum of the 8-bit ASCII values of characters, beginning with the first tag character and ending with the checksum tag character (7 or 8). The end-of-file record is a colon (:).
### 11.13.6 TI-TXT Hex Format (--ti_txt Option)

The TI-TXT hex format supports 16-bit hexadecimal data. It consists of section start addresses, data byte, and an end-of-file character. These restrictions apply:

- The number of sections is unlimited.
- Each hexadecimal start address must be even.
- Each line must have 16 data bytes, except the last line of a section.
- Data bytes are separated by a single space.
- The end-of-file termination tag q is mandatory.

The data record contains the following information:

<table>
<thead>
<tr>
<th>Item</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>@ADDR</td>
<td>Hexadecimal start address of a section</td>
</tr>
<tr>
<td>DATAn</td>
<td>Hexadecimal data byte</td>
</tr>
<tr>
<td>q</td>
<td>End-of-file termination character</td>
</tr>
</tbody>
</table>

#### Example 11-5. TI-TXT Object Format

```
@F000
31 40 00 03 B2 40 80 5A 20 01 D2 D3 22 00 D2 E3
21 00 3F 40 E8 FD 1F 83 FE 23 F9 3F
@FFE
00 F0
Q
```
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.

<table>
<thead>
<tr>
<th>Topic</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
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<td>278</td>
</tr>
<tr>
<td>12.2 Notes on C/C++ Conversions</td>
<td>278</td>
</tr>
<tr>
<td>12.3 Notes on C++ Specific Conversions</td>
<td>282</td>
</tr>
<tr>
<td>12.4 Special Assembler Support</td>
<td>283</td>
</tr>
</tbody>
</table>
Overview of the .cdecls Directive

12.1 Overview of the .cdecls Directive

The .cdecls directive allows programmers in mixed assembly and C/C++ environments to share C headers containing declarations and prototypes between the 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. This allows the programmer to reference the C/C++ constructs in assembly code — calling functions, allocating space, and accessing structure members — using the equivalent assembly mechanisms. While function and variable definitions are ignored, most common C/C++ elements are converted to assembly: enumerations, (non function-like) macros, function and variable prototypes, structures, and unions.

See the .cdecls topic for details on the syntax of the .cdecls assembler directive.

The .cdecls directive can appear anywhere in an assembly source file, and can occur multiple times within a file. However, the C/C++ environment created by one .cdecls is not inherited by a later .cdecls; the C/C++ environment starts over for each .cdecls instance.

For example, the following code causes the warning to be issued:

```
.cdecls C,NOLIST
{%
  #define ASMTEST 1
%
}
.cdecls C,NOLIST
{%
  ifndef ASMTEST
    #warn ’ASMTEST not defined!’ /* will be issued */
  #endif
%
}
```

Therefore, a typical use of the .cdecls block is expected to be a single usage near the beginning of the assembly source file, in which all necessary C/C++ header files are included.

Use the compiler --include_path=path options to specify additional include file paths needed for the header files used in assembly, as you would when compiling C files.

Any C/C++ errors or warnings generated by the code of the .cdecls are emitted as they normally would for the C/C++ source code. C/C++ errors cause the directive to fail, and any resulting converted assembly is not included.

C/C++ constructs that cannot be converted, such as function-like macros or variable definitions, cause a comment to be output to the converted assembly file. For example:

`; ASM HEADER WARNING - variable definition 'ABCD' ignored`

The prefix ASM HEADER WARNING appears at the beginning of each message. To see the warnings, either the WARN parameter needs to be specified so the messages are displayed on STDERR, or else the LIST parameter needs to be specified so the warnings appear in the listing file, if any.

Finally, note that the converted assembly code does not appear in the same order as the original C/C++ source code and C/C++ constructs may be simplified to a normalized form during the conversion process, but this should not affect their final usage.

12.2 Notes on C/C++ Conversions

The following sections describe C and C++ conversion elements that you need to be aware of when sharing header files with assembly source.

12.2.1 Comments

Comments are consumed entirely at the C level, and do not appear in the resulting converted assembly file.
12.2.2 Conditional Compilation (#if/#else/#ifdef/etc.)

Conditional compilation is handled entirely at the C level during the conversion step. Define any necessary macros either on the command line (using the compiler --define=\textit{name}=\textit{value} option) or within a .cdecls block using \textit{#define}. The \textit{#if}, \textit{#ifdef}, etc. C/C++ directives are \textbf{not} converted to assembly .if, .else, .elseif, and .endif directives.

12.2.3 Pragmas

Pragmas found in the C/C++ source code cause a warning to be generated as they are not converted. They have no other effect on the resulting assembly file. See the .cdecls topic for the \textit{WARN} and NOWARN parameter discussion for where these warnings are created.

12.2.4 The \texttt{#error} and \texttt{#warning} Directives

These preprocessor directives are handled completely by the compiler during the parsing step of conversion. If one of these directives is encountered, the appropriate error or warning message is emitted. These directives are not converted to .emsg or .wmsg in the assembly output.

12.2.5 Predefined symbol \texttt{__ASM_HEADER__}

The C/C++ macro \texttt{__ASM_HEADER__} is defined in the compiler while processing code within .cdecls. This allows you to make changes in your code, such as not compiling definitions, during the .cdecls processing.

\textbf{Be Careful With the \texttt{__ASM_HEADER__} Macro}

\textbf{NOTE:} You must be very careful not to use this macro to introduce any changes in the code that could result in inconsistencies between the code processed while compiling the C/C++ source and while converting to assembly.

12.2.6 Usage Within C/C++ \texttt{asm( )} Statements

The .cdecls directive is not allowed within C/C++ \texttt{asm( )} statements and will cause an error to be generated.

12.2.7 The \texttt{#include} Directive

The C/C++ \texttt{#include} preprocessor directive is handled transparently by the compiler during the conversion step. Such #includes can be nested as deeply as desired as in C/C++ source. The assembly directives .include and .copy are not used or needed within a .cdecls. Use the command line --include_path option to specify additional paths to be searched for included files, as you would for C compilation.

12.2.8 Conversion of \texttt{#define} Macros

Only object-like macros are converted to assembly. Function-like macros have no assembly representation and so cannot be converted. Pre-defined and built-in C/C++ macros are not converted to assembly (i.e., \texttt{__FILE__}, \texttt{__TIME__}, \texttt{__TI_COMPILER_VERSION__}, etc.). For example, this code is converted to assembly because it is an object-like macro:

\begin{verbatim}
#define NAME Charley
\end{verbatim}

This code is not converted to assembly because it is a function-like macro:

\begin{verbatim}
#define MAX(x,y) (x>y ? x : y)
\end{verbatim}

Some macros, while they are converted, have no functional use in the containing assembly file. For example, the following results in the assembly substitution symbol FOREVER being set to the value \texttt{while(1)}, although this has no useful use in assembly because \texttt{while(1)} is not legal assembly code.

\begin{verbatim}
#define FOREVER while(1)
\end{verbatim}
Macro values are **not** interpreted as they are converted. For example, the following results in the assembler substitution symbol OFFSET being set to the literal string value 5+12 and **not** the value 17. This happens because the semantics of the C/C++ language require that macros are evaluated in context and not when they are parsed.

```
#define OFFSET 5+12
```

Because macros in C/C++ are evaluated in their usage context, C/C++ printf escape sequences such as `\n` are not converted to a single character in the converted assembly macro. See Section 12.2.11 for suggestions on how to use C/C++ macro strings.

Macros are converted using the new `.define` directive (see Section 12.4.2), which functions similarly to the `.asg` assembler directive. The exception is that `.define` disallows redefinitions of register symbols and mnemonics to prevent the conversion from corrupting the basic assembly environment. To remove a macro from the assembly scope, `.undef` can be used following the `.cdecls` that defines it (see Section 12.4.3).

The macro functionality of `#` (stringize operator) is only useful within functional macros. Since functional macros are not supported by this process, `#` is not supported either. The concatenation operator `##` is only useful in a functional context, but can be used degenerately to concatenate two strings and so it is supported in that context.

### 12.2.9 The `#undef` Directive
Symbols undefined using the `#undef` directive before the end of the `.cdecls` are not converted to assembly.

### 12.2.10 Enumerations

Enumeration members are converted to `.enum` elements in assembly. For example:

```
enum state { ACTIVE=0x10, SLEEPING=0x01, INTERRUPT=0x100, POWEROFF, LAST};
```

is converted to the following assembly code:

```
state .enum
ACTIVE .emember 16
SLEEPING .emember 1
INTERRUPT .emember 256
POWEROFF .emember 257
LAST .emember 258
.endenum
```

The members are used via the pseudo-scoping created by the `.enum` directive.

The usage is similar to that for accessing structure members, `enum_name.member`.

This pseudo-scoping is used to prevent enumeration member names from corrupting other symbols within the assembly environment.

### 12.2.11 C Strings

Because C string escapes such as `\n` and `\t` are not converted to hex characters `0x0A` and `0x09` until their use in a string constant in a C/C++ program, C macros whose values are strings cannot be represented as expected in assembly substitution symbols. For example:

```
#define MSG "\tHI\n"
```

becomes, in assembly:

```
.define "\tHI\n" , MSG ; 6 quoted characters! not 5!
```

When used in a C string context, you expect this statement to be converted to 5 characters (`tab`, `H`, `I`, newline, `NULL`), but the `.string` assembler directive does not know how to perform the C escape conversions.

You can use the `.cstring` directive to cause the escape sequences and NULL termination to be properly handled as they would in C/C++. Using the above symbol MSG with a `.cstring` directive results in 5 characters of memory being allocated, the same characters as would result if used in a C/C++ strong context. (See Section 12.4.7 for the `.cstring` directive syntax.)
12.2.12 C/C++ Built-In Functions

The C/C++ built-in functions, such as sizeof(), are not translated to their assembly counterparts, if any, if they are used in macros. Also, their C expression values are not inserted into the resulting assembly macro because macros are evaluated in context and there is no active context when converting the macros to assembly.

Suitable functions such as $sizeof() are available in assembly expressions. However, as the basic types such as int/char/float have no type representation in assembly, there is no way to ask for $sizeof(int), for example, in assembly.

12.2.13 Structures and Unions

C/C++ structures and unions are converted to assembly .struct and .union elements. Padding and ending alignments are added as necessary to make the resulting assembly structure have the same size and member offsets as the C/C++ source. The primary purpose is to allow access to members of C/C++ structures, as well as to facilitate debugging of the assembly code. For nested structures, the assembly .tag feature is used to refer to other structures/unions.

The alignment is also passed from the C/C++ source so that the assembly symbol is marked with the same alignment as the C/C++ symbol. (See Section 12.2.3 for information about pragmas, which may attempt to modify structures.) Because the alignment of structures is stored in the assembly symbol, built-in assembly functions like $sizeof() and $alignof() can be used on the resulting structure name symbol.

When using unnamed structures (or unions) in typedefs, such as:

typedef struct { int a_member; } mystrname;

This is really a shorthand way of writing:

struct temporary_name { int a_member; };
typedef temporary_name mystrname;

The conversion processes the above statements in the same manner: generating a temporary name for the structure and then using .define to output a typedef from the temporary name to the user name. You should use your mystrname in assembly the same as you would in C/C++, but do not be confused by the assembly structure definition in the list, which contains the temporary name. You can avoid the temporary name by specifying a name for the structure, as in:

typedef struct a_st_name { ... } mystrname;

If a shorthand method is used in C to declare a variable with a particular structure, for example:

extern struct a_name { int a_member; } a_variable;

Then after the structure is converted to assembly, a .tag directive is generated to declare the structure of the external variable, such as:

_a_variable .tag a_st_name

This allows you to refer to _a_variable.a_member in your assembly code.

12.2.14 Function/Variable Prototypes

Non-static function and variable prototypes (not definitions) will result in a .global directive being generated for each symbol found.

See Section 12.3.1 for C++ name mangling issues.

Function and variable definitions will result in a warning message being generated (see the WARN/NOWARN parameter discussion for where these warnings are created) for each, and they will not be represented in the converted assembly.

The assembly symbol representing the variable declarations will not contain type information about those symbols. Only a .global will be issued for them. Therefore, it is your responsibility to ensure the symbol is used appropriately.

See Section 12.2.13 for information on variables names which are of a structure/union type.
12.2.15 C Constant Suffixes

The C constant suffixes u, l, and f are passed to the assembly unchanged. The assembler will ignore these suffixes if used in assembly expressions.

12.2.16 Basic C/C++ Types

Only complex types (structures and unions) in the C/C++ source code are converted to assembly. Basic types such as int, char, or float are not converted or represented in assembly beyond any existing .int, .char, .float, etc. directives that previously existed in assembly.

Typedefs of basic types are therefore also not represented in the converted assembly.

12.3 Notes on C++ Specific Conversions

The following sections describe C++ specific conversion elements that you need to be aware of when sharing header files with assembly source.

12.3.1 Name Mangling

Symbol names may be mangled in C++ source files. When mangling occurs, the converted assembly will use the mangled names to avoid symbol name clashes. You can use the demangler (dem430) to demangle names and identify the correct symbols to use in assembly.

To defeat name mangling in C++ for symbols where polymorphism (calling a function of the same name with different kinds of arguments) is not required, use the following syntax:

extern "C" void somefunc(int arg);

The above format is the short method for declaring a single function. To use this method for multiple functions, you can also use the following syntax:

extern "C"
{
    void somefunc(int arg);
    int anotherfunc(int arg);
    ...
}

12.3.2 Derived Classes

Derived classes are only partially supported when converting to assembly because of issues related to C++ scoping which does not exist in assembly. The greatest difference is that base class members do not automatically become full (top-level) members of the derived class. For example:

```cpp
class base
{
    public:
    int b1;
};

class derived : public base
{
    public:
    int d1;
}
```

In C++ code, the class derived would contain both integers b1 and d1. In the converted assembly structure "derived", the members of the base class must be accessed using the name of the base class, such as derived.__b_base.b1 rather than the expected derived.b1.

A non-virtual, non-empty base class will have __b_ prepended to its name within the derived class to signify it is a base class name. That is why the example above is derived.__b_base.b1 and not simply derived.base.b1.

12.3.3 Templates

No support exists for templates.
12.3.4 Virtual Functions

No support exists for virtual functions, as they have no assembly representation.

12.4 Special Assembler Support

12.4.1 Enumerations (.enum/.emember/.endenum)

New directives have been created to support a pseudo-scoping for enumerations.

The format of these new directives is:

```
ENUM_NAME .enum
MEMBER1 .emember [value]
MEMBER2 .emember [value]
...
.endenum
```

The `.enum` directive begins the enumeration definition and `.endenum` terminates it.

The enumeration name (`ENUM_NAME`) cannot be used to allocate space; its size is reported as zero.

The format to use the value of a member is `ENUM_NAME.MEMBER`, similar to a structure member usage.

The `.emember` directive optionally accepts the value to set the member to; just as in C/C++. If not specified, the member takes a value one more than the previous member. As in C/C++, member names cannot be duplicated, although values can be. Unless specified with `.emember`, the first enumeration member will be given the value 0 (zero), as in C/C++.

The `.endenum` directive cannot be used with a label, as structure `.endstruct` directives can, because the `.endenum` directive has no value like the `.endstruct` does (containing the size of the structure).

Conditional compilation directives (.if/.else/.elseif/.endif) are the only other non-enumeration code allowed within the `.enum/.endenum` sequence.

12.4.2 The .define Directive

The new `.define` directive functions in the same manner as the `.asg` directive, except that `.define` disallows creation of a substitution symbol that has the same name as a register symbol or mnemonic. It does not create a new symbol name space in the assembler, rather it uses the existing substitution symbol name space. The syntax for the directive is:

```
.define substitution string , substitution symbol name
```

The `.define` directive is used to prevent corruption of the assembly environment when converting C/C++ headers.

12.4.3 The .undefine/.unasg Directives

The `.undef` directive is used to remove the definition of a substitution symbol created using `.define` or `.asg. This directive will remove the named symbol from the substitution symbol table from the point of the `.undef` to the end of the assembly file. The syntax for these directives is:

```
.undefine substitution symbol name
.unasg substitution symbol name
```

This can be used to remove from the assembly environment any C/C++ macros that may cause a problem.

Also see Section 12.4.2, which covers the `.define` directive.
12.4.4 The $defined() Directive

The $defined directive returns true/1 or false/0 depending on whether the name exists in the current substitution symbol table or the standard symbol table. In essence $defined returns TRUE if the assembler has any user symbol in scope by that name. This differs from $isdefined in that $isdefined only tests for NON-substitution symbols. The syntax is:

$$defined( \text{substitution symbol name} )$$

A statement such as ".if $defined(macroname)" is then similar to the C code "<<if defined macroname>>

See Section 12.4.2 and Section 12.4.3 for the use of .define and .undef in assembly.

12.4.5 The $sizeof Built-In Function

The new assembly built-in function $sizeof( ) can be used to query the size of a structure in assembly. It is an alias for the already existing $structsz( ). The syntax is:

$$sizeof( \text{structure name} )$$

The $sizeof function can then be used similarly to the C built-in function sizeof( ).

The assembler's $sizeof( ) built-in function cannot be used to ask for the size of basic C/C++ types, such as $sizeof(int), because those basic type names are not represented in assembly. Only complex types are converted from C/C++ to assembly.

Also see Section 12.2.12, which notes that this conversion does not happen automatically if the C/C++ sizeof( ) built-in function is used within a macro.

12.4.6 Structure/Union Alignment & $alignof( )

The assembly .struct and .union directives now take an optional second argument which can be used to specify a minimum alignment to be applied to the symbol name. This is used by the conversion process to pass the specific alignment from C/C++ to assembly.

The assembly built-in function $alignof( ) can be used to report the alignment of these structures. This can be used even on assembly structures, and the function will return the minimum alignment calculated by the assembler.

12.4.7 The .cstring Directive

You can use the new .cstring directive to cause the escape sequences and NULL termination to be properly handled as they would in C/C++.

cstring "String with C escapes.\nWill be NULL terminated.\012"

See Section 12.2.11 for more information on the new .cstring directive.
Symbolic Debugging Directives

The assembler supports several directives that the TMS320C6000™ C/C++ compiler uses for symbolic debugging. These directives differ for the two debugging formats, DWARF and COFF.

These directives are not meant for use by assembly-language programmers. They require arguments that can be difficult to calculate manually, and their usage must conform to a predetermined agreement between the compiler, the assembler, and the debugger. This appendix documents these directives for informational purposes only.

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A.1 DWARF Debugging Format

A subset of the DWARF symbolic debugging directives are always listed in the assembly language file that the compiler creates for program analysis purposes. To list the complete set used for full symbolic debug, invoke the compiler with the `--symdebug:dwarf` option, as shown below:

```
c16x --symdebug:dwarf --keep_asm input_file
```

The `--keep_asm` option instructs the compiler to retain the generated assembly file.

To disable the generation of all symbolic debug directives, invoke the compiler with the `-symdebug:none` option:

```
c16x --symdebug:none --keep_asm input_file
```

The DWARF debugging format consists of the following directives:

- The `.dwtag` and `.dwendtag` directives define a Debug Information Entry (DIE) in the `.debug_info` section.
- The `.dwattr` directive adds an attribute to an existing DIE.
- The `.dwpsn` directive identifies the source position of a C/C++ statement.
- The `.dwcie` and `.dwendentry` directives define a Common Information Entry (CIE) in the `.debug_frame` section.
- The `.dwfde` and `.dwendentry` directives define a Frame Description Entry (FDE) in the `.debug_frame` section.
- The `.dwcfi` directive defines a call frame instruction for a CIE or FDE.

A.2 COFF Debugging Format

COFF symbolic debug is now obsolete. These directives are supported for backwards-compatibility only. The decision to switch to DWARF as the symbolic debug format was made to overcome many limitations of COFF symbolic debug, including the absence of C++ support.

The COFF debugging format consists of the following directives:

- The `.sym` directive defines a global variable, a local variable, or a function. Several parameters allow you to associate various debugging information with the variable or function.
- The `.stag`, `.etag`, and `.utag` directives define structures, enumerations, and unions, respectively. The `.member` directive specifies a member of a structure, enumeration, or union. The `.eos` directive ends a structure, enumeration, or union definition.
- The `.func` and `.endfunc` directives specify the beginning and ending lines of a C/C++ function.
- The `.block` and `.endblock` directives specify the bounds of C/C++ blocks.
- The `.file` directive defines a symbol in the symbol table that identifies the current source filename.
- The `.line` directive identifies the line number of a C/C++ source statement.
### A.3 Debug Directive Syntax

Table A-1 is an alphabetical listing of the symbolic debugging directives. For information on the C/C++
compiler, refer to the *TMS320C6000 Optimizing Compiler User’s Guide*

**Table A-1. Symbolic Debugging Directives**

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<th>Label</th>
<th>Directive</th>
<th>Arguments</th>
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<tr>
<td>.block</td>
<td></td>
<td>beginning line number</td>
</tr>
<tr>
<td>.dattr</td>
<td></td>
<td>DIE label, DIE attribute name (DIE attribute value)</td>
</tr>
<tr>
<td>.dcl</td>
<td></td>
<td>call frame instruction opcode</td>
</tr>
<tr>
<td>.dend</td>
<td></td>
<td>version, return address register</td>
</tr>
<tr>
<td>CIE label</td>
<td>.dwcie</td>
<td>version, return address register</td>
</tr>
<tr>
<td></td>
<td>.dwendentry</td>
<td></td>
</tr>
<tr>
<td></td>
<td>.dwendtag</td>
<td></td>
</tr>
<tr>
<td></td>
<td>.dwfde</td>
<td>CIE label</td>
</tr>
<tr>
<td></td>
<td>.dwpsn</td>
<td>&quot;filename&quot;, line number, column number</td>
</tr>
<tr>
<td>DIE label</td>
<td>.dwtag</td>
<td>DIE tag name, DIE attribute name (DIE attribute value)</td>
</tr>
<tr>
<td></td>
<td>.dte</td>
<td></td>
</tr>
<tr>
<td></td>
<td>.file</td>
<td>&quot;filename&quot;</td>
</tr>
<tr>
<td></td>
<td>.func</td>
<td>[beginning line number]</td>
</tr>
<tr>
<td></td>
<td>.line</td>
<td>line number, address</td>
</tr>
<tr>
<td></td>
<td>.member</td>
<td>name, value, type, storage class, size, tag, dims</td>
</tr>
<tr>
<td></td>
<td>.stag</td>
<td>name, size</td>
</tr>
<tr>
<td></td>
<td>.sym</td>
<td>name, value, type, storage class, size, tag, dims</td>
</tr>
<tr>
<td></td>
<td>.utag</td>
<td>name, size</td>
</tr>
</tbody>
</table>
XML Link Information File Description

The TMS320C6000™ linker supports the generation of an XML link information file via the --xml_link_info file option. This option causes the linker to generate a well-formed XML file containing detailed information about the result of a link. The information included in this file includes all of the information that is currently produced in a linker-generated map file.

As the linker evolves, the XML link information file may be extended to include additional information that could be useful for static analysis of linker results.

This appendix enumerates all of the elements that are generated by the linker into the XML link information file.

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B.1 XML Information File Element Types

These element types will be generated by the linker:

- **Container elements** represent an object that contains other elements that describe the object. Container elements have an id attribute that makes them accessible from other elements.
- **String elements** contain a string representation of their value.
- **Constant elements** contain a 32-bit unsigned long representation of their value (with a 0x prefix).
- **Reference elements** are empty elements that contain an idref attribute that specifies a link to another container element.

In Section B.2, the element type is specified for each element in parentheses following the element description. For instance, the <link_time> element lists the time of the link execution (string).

B.2 Document Elements

The root element, or the document element, is <link_info>. All other elements contained in the XML link information file are children of the <link_info> element. The following sections describe the elements that an XML information file can contain.

B.2.1 Header Elements

The first elements in the XML link information file provide general information about the linker and the link session:

- The <banner> element lists the name of the executable and the version information (string).
- The <copyright> element lists the TI copyright information (string).
- The <link_time> is a timestamp representation of the link time (unsigned 32-bit int).
- The <output_file> element lists the name of the linked output file generated (string).
- The <entry_point> element specifies the program entry point, as determined by the linker (container) with two entries:
  - The <name> is the entry point symbol name, if any (string).
  - The <address> is the entry point address (constant).

**Example B-1. Header Element for the hi.out Output File**

```xml
<banner>TMS320Cxx Linker Version x.xx (Jan 6 2008)</banner>
<copyright>Copyright (c) 1996-2008 Texas Instruments Incorporated</copyright>
<link_time>0x43dfd8a4</link_time>
<output_file>hi.out</output_file>
<entry_point>
  <name>_c_int00</name>
  <address>0xaf80</address>
</entry_point>
```
### B.2.2 Input File List

The next section of the XML link information file is the input file list, which is delimited with a `<input_file_list>` container element. The `<input_file_list>` can contain any number of `<input_file>` elements.

Each `<input_file>` instance specifies the input file involved in the link. Each `<input_file>` has an id attribute that can be referenced by other elements, such as an `<object_component>`. An `<input_file>` is a container element enclosing the following elements:

- The `<path>` element names a directory path, if applicable (string).
- The `<kind>` element specifies a file type, either archive or object (string).
- The `<file>` element specifies an archive name or filename (string).
- The `<name>` element specifies an object file name, or archive member name (string).

#### Example B-2. Input File List for the hi.out Output File

```xml
<input_file_list>
  <input_file id="fl-1">
    <kind>object</kind>
    <file>hi.obj</file>
    <name>hi.obj</name>
  </input_file>
  <input_file id="fl-2">
    <path>/tools/lib/</path>
    <kind>archive</kind>
    <file>rtsxxx.lib</file>
    <name>boot.obj</name>
  </input_file>
  <input_file id="fl-3">
    <path>/tools/lib/</path>
    <kind>archive</kind>
    <file>rtsxxx.lib</file>
    <name>exit.obj</name>
  </input_file>
  <input_file id="fl-4">
    <path>/tools/lib/</path>
    <kind>archive</kind>
    <file>rtsxxx.lib</file>
    <name>printf.obj</name>
  </input_file>
  ...
</input_file_list>
```
### B.2.3 Object Component List

The next section of the XML link information file contains a specification of all of the object components that are involved in the link. An example of an object component is an input section. In general, an object component is the smallest piece of object that can be manipulated by the linker.

The `<object_component_list>` is a container element enclosing any number of `<object_component>` elements.

Each `<object_component>` specifies a single object component. Each `<object_component>` has an id attribute so that it can be referenced directly from other elements, such as a `<logical_group>`. An `<object_component>` is a container element enclosing the following elements:

- The `<name>` element names the object component (string).
- The `<load_address>` element specifies the load-time address of the object component (constant).
- The `<run_address>` element specifies the run-time address of the object component (constant).
- The `<size>` element specifies the size of the object component (constant).
- The `<input_file_ref>` element specifies the source file where the object component originated (reference).

#### Example B-3. Object Component List for the fl-4 Input File

```xml
<object_component id="oc-20">
    <name>.text</name>
    <load_address>0xac00</load_address>
    <run_address>0xac00</run_address>
    <size>0xc0</size>
    <input_file_ref idref="fl-4"/>
</object_component>
<object_component id="oc-21">
    <name>.data</name>
    <load_address>0x80000000</load_address>
    <run_address>0x80000000</run_address>
    <size>0x0</size>
    <input_file_ref idref="fl-4"/>
</object_component>
<object_component id="oc-22">
    <name>.bss</name>
    <load_address>0x80000000</load_address>
    <run_address>0x80000000</run_address>
    <size>0x0</size>
    <input_file_ref idref="fl-4"/>
</object_component>
```
B.2.4 Logical Group List

The `<logical_group_list>` section of the XML link information file is similar to the output section listing in a linker-generated map file. However, the XML link information file contains a specification of GROUP and UNION output sections, which are not represented in a map file. There are three kinds of list items that can occur in a `<logical_group_list>`:

- The `<logical_group>` is the specification of a section or GROUP that contains a list of object components or logical group members. Each `<logical_group>` element is given an id so that it may be referenced from other elements. Each `<logical_group>` is a container element enclosing the following elements:
  - The `<name>` element names the logical group (string).
  - The `<load_address>` element specifies the load-time address of the logical group (constant).
  - The `<run_address>` element specifies the run-time address of the logical group (constant).
  - The `<size>` element specifies the size of the logical group (constant).
  - The `<contents>` element lists elements contained in this logical group (container). These elements refer to each of the member objects contained in this logical group:
    - The `<object_component_ref>` is an object component that is contained in this logical group (reference).
    - The `<logical_group_ref>` is a logical group that is contained in this logical group (reference).

- The `<overlay>` is a special kind of logical group that represents a UNION, or a set of objects that share the same memory space (container). Each `<overlay>` element is given an id so that it may be referenced from other elements (like from an `<allocated_space>` element in the placement map). Each `<overlay>` contains the following elements:
  - The `<name>` element names the overlay (string).
  - The `<run_address>` element specifies the run-time address of overlay (constant).
  - The `<size>` element specifies the size of logical group (constant).
  - The `<contents>` container element lists elements contained in this overlay. These elements refer to each of the member objects contained in this logical group:
    - The `<object_component_ref>` is an object component that is contained in this logical group (reference).
    - The `<logical_group_ref>` is a logical group that is contained in this logical group (reference).

- The `<split_section>` is another special kind of logical group that represents a collection of logical groups that is split among multiple memory areas. Each `<split_section>` element is given an id so that it may be referenced from other elements. The id consists of the following elements:
  - The `<name>` element names the split section (string).
  - The `<contents>` container element lists elements contained in this split section. The `<logical_group_ref>` elements refer to each of the member objects contained in this split section, and each element referenced is a logical group that is contained in this split section (reference).
Example B-4. Logical Group List for the fl-4 Input File

```xml
<logical_group_list>
  ...
  <logical_group id="lg-7">
    <name>.text</name>
    <load_address>0x20</load_address>
    <run_address>0x20</run_address>
    <size>0xb240</size>
    <contents>
      <object_component_ref idref="oc-34"/>
      <object_component_ref idref="oc-108"/>
      <object_component_ref idref="oc-e2"/>
    </contents>
  </logical_group>
  ...
  <overlay id="lg-b">
    <name>UNION_1</name>
    <run_address>0xb600</run_address>
    <size>0xc0</size>
    <contents>
      <object_component_ref idref="oc-45"/>
      <logical_group_ref idref="lg-8"/>
    </contents>
  </overlay>
  ...
  <split_section id="lg-12">
    <name>.task_scn</name>
    <size>0x120</size>
    <contents>
      <logical_group_ref idref="lg-10"/>
      <logical_group_ref idref="lg-11"/>
    </contents>
  </split_section>
  ...
</logical_group_list>
```
B.2.5 Placement Map

The `<placement_map>` element describes the memory placement details of all named memory areas in the application, including unused spaces between logical groups that have been placed in a particular memory area.

The `<memory_area>` is a description of the placement details within a named memory area (container). The description consists of these items:

- The `<name>` names the memory area (string).
- The `<page_id>` gives the id of the memory page in which this memory area is defined (constant).
- The `<origin>` specifies the beginning address of the memory area (constant).
- The `<length>` specifies the length of the memory area (constant).
- The `<used_space>` specifies the amount of allocated space in this area (constant).
- The `<unused_space>` specifies the amount of available space in this area (constant).
- The `<attributes>` lists the RWXI attributes that are associated with this area, if any (string).
- The `<fill_value>` specifies the fill value that is to be placed in unused space, if the fill directive is specified with the memory area (constant).
- The `<usage_details>` lists details of each allocated or available fragment in this memory area. If the fragment is allocated to a logical group, then a `<logical_group_ref>` element is provided to facilitate access to the details of that logical group. All fragment specifications include `<start_address>` and `<size>` elements.
  - The `<allocated_space>` element provides details of an allocated fragment within this memory area (container):
    - The `<start_address>` specifies the address of the fragment (constant).
    - The `<size>` specifies the size of the fragment (constant).
    - The `<logical_group_ref>` provides a reference to the logical group that is allocated to this fragment (reference).
  - The `<available_space>` element provides details of an available fragment within this memory area (container):
    - The `<start_address>` specifies the address of the fragment (constant).
    - The `<size>` specifies the size of the fragment (constant).

Example B-5. Placement Map for the fl-4 Input File

```
<placement_map>
  <memory_area>
    <name>PMEM</name>
    <page_id>0x0</page_id>
    <origin>0x20</origin>
    <length>0x100000</length>
    <used_space>0xb240</used_space>
    <unused_space>0xf4dc0</unused_space>
    <attributes>RWXI</attributes>
    <usage_details>
      <allocated_space>
        <start_address>0x20</start_address>
        <size>0xb240</size>
        <logical_group_ref idref="lg-7"/>
      </allocated_space>
      <available_space>
        <start_address>0xb260</start_address>
        <size>0xf4dc0</size>
      </available_space>
    </usage_details>
  </memory_area>
  ...
</placement_map>
```
B.2.6 Far Call Trampoline List

The `<far_call_trampoline_list>` is a list of `<far_call_trampoline>` elements. The linker supports the generation of far call trampolines to help a call site reach a destination that is out of range. A far call trampoline function is guaranteed to reach the called function (callee) as it may utilize an indirect call to the called function.

The `<far_call_trampoline_list>` enumerates all of the far call trampolines that are generated by the linker for a particular link. The `<far_call_trampoline_list>` can contain any number of `<far_call_trampoline>` elements. Each `<far_call_trampoline>` is a container enclosing the following elements:

- The `<callee_name>` element names the destination function (string).
- The `<callee_address>` is the address of the called function (constant).
- The `<trampoline_object_component_ref>` is a reference to an object component that contains the definition of the trampoline function (reference).
- The `<trampoline_address>` is the address of the trampoline function (constant).
- The `<caller_list>` enumerates all call sites that utilize this trampoline to reach the called function (container).
- The `<trampoline_call_site>` provides the details of a trampoline call site (container) and consists of these items:
  - The `<caller_address>` specifies the call site address (constant).
  - The `<callee_object_component_ref>` is the object component where the call site resides (reference).

Example B-6. Fall Call Trampoline List for the fl-4 Input File

```xml
<far_call_trampoline_list>
  ...
  <far_call_trampoline>
    <callee_name>_foo</callee_name>
    <callee_address>0x08000030</callee_address>
    <trampoline_object_component_ref idref="oc-123"/>
    <trampoline_address>0x2020</trampoline_address>
    <caller_list>
      <call_site>
        <caller_address>0x1800</caller_address>
        <callee_object_component_ref idref="oc-23"/>
      </call_site>
      <call_site>
        <caller_address>0x1810</caller_address>
        <callee_object_component_ref idref="oc-23"/>
      </call_site>
    </caller_list>
  </far_call_trampoline>
  ...
</far_call_trampoline_list>
```
B.2.7 Symbol Table

The `<symbol_table>` contains a list of all of the global symbols that are included in the link. The list provides information about a symbol's name and value. In the future, the symbol_table list may provide type information, the object component in which the symbol is defined, storage class, etc.

The `<symbol>` is a container element that specifies the name and value of a symbol with these elements:

- The `<name>` element specifies the symbol name (string).
- The `<value>` element specifies the symbol value (constant).

Example B-7. Symbol Table for the fl-4 Input File

```xml
<symbol_table>
  <symbol>
    <name>_c_int00</name>
    <value>0xaf80</value>
  </symbol>
  <symbol>
    <name>_main</name>
    <value>0xb1e0</value>
  </symbol>
  <symbol>
    <name>_printf</name>
    <value>0xac00</value>
  </symbol>
  ...
</symbol_table>
```
**ABI**— Application binary interface.

**absolute address**— An address that is permanently assigned to a TMS320C6000™ memory location.

**absolute lister**— A debugging tool that allows you to create assembler listings that contain absolute addresses.

**alignment**— A process in which the linker places an output section at an address that falls on an \( n \)-byte boundary, where \( n \) is a power of 2. You can specify alignment with the SECTIONS linker directive.

**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.

**ASCII**— American Standard Code for Information Interchange; a standard computer code for representing and exchanging alphanumeric information.

**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.

**assembly-time constant**— A symbol that is assigned a constant value with the .set directive.

**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**

**binding**— A process in which you specify a distinct address for an output section or a symbol.

**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.

**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.

conditional processing— A method of processing one block of source code or an alternate block of source code, according to the evaluation of a specified expression.

configured memory— Memory that the linker has specified for allocation.

constant— A type whose value cannot change.

cross-reference lister— A utility that produces an output file that lists the symbols that were defined, what file they were defined in, what reference type they are, what line they were defined on, which lines referenced them, and their assembler and linker final values. The cross-reference lister uses linked object files as input.

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.

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).

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 TMS320C6000 operation.

entry point— A point in target memory where execution starts.

environment variable— A system symbol that you define and assign to a string. Environmental variables are often included in Windows batch files or UNIX shell scripts such as .cshrc or .profile.

epilog— The portion of code in a function that restores the stack and returns. See also pipelined-loop epilog.

executable 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.

field— For the TMS320C6000, a software-configurable data type whose length can be programmed to be any value in the range of 1-32 bits.

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.

GROUP— An option of the SECTIONS directive that forces specified output sections to be allocated contiguously (as a group).

hex conversion utility— A utility that converts object files into one of several standard ASCII hexadecimal formats, suitable for loading into an EPROM programmer.

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.
hole— An area between the input sections that compose an output section that contains no code.

incremental linking— Linking files in several passes. Incremental linking is useful for large applications, because you can partition the application, link the parts separately, and then link all of the parts together.

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.

ISO— International Organization for Standardization; a worldwide federation of national standards bodies, which establishes international standards voluntarily followed by industries.

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.

macro library— An archive library composed of macros. Each file in the library must contain one macro; its name must be the same as the macro name it defines, and it must have an extension of .asm.

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.

member— The elements or variables of a structure, union, archive, or enumeration.

memory map— A map of target system memory space that is partitioned into functional blocks.

mnemonic— An instruction name that the assembler translates into machine code.

model statement— Instructions or assembler directives in a macro definition that are assembled each time a macro is invoked.

named section— An initialized section that is defined with a .sect directive.

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.
Appendix C

operand— An argument of an assembly language instruction, assembler directive, or macro directive that supplies information to the operation performed by the instruction or directive.

optimizer— A software tool that improves the execution speed and reduces the size of C programs. See also assembly optimizer.

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

output 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.

partial linking— Linking files in several passes. Incremental linking is useful for large applications because you can partition the application, link the parts separately, and then link all of the parts together.

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.

ROM width— The width (in bits) of each output file, or, more specifically, the width of a single data value in the hex conversion utility file. The ROM width determines how the utility partitions the data into output files. After the target words are mapped to memory words, the memory words are broken into one or more output files. The number of output files is determined by the ROM width.

run address— The address where a section runs.

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.

section program counter (SPC)— An element that keeps track of the current location within a section; each section has its own SPC.

sign extend— A process that fills the unused MSBs of a value with the value's sign bit.

simulator— A software development system that simulates TMS320C6000 operation.

source file— A file that contains C/C++ code or assembly language code that is compiled or assembled to form an object file.

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.

tag— An optional type name that can be assigned to a structure, union, or enumeration.

target memory— Physical memory in a system into which executable object code is loaded.

.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.

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.

UNION— An option of the SECTIONS directive that causes the linker to allocate the same address to multiple sections.

union— A variable that can hold objects of different types and sizes.

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.

well-defined expression— A term or group of terms that contains only symbols or assembly-time constants that have been defined before they appear in the expression.

word— A 32-bit addressable location in target memory
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