VISUALDSP++™ 3.5 Assembler and Preprocessor Manual for ADSP-218x and ADSP-219x DSPs

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ANALOG DEVICES

CONTENTS

PREFACE

Thank you for purchasing Analog Devices development software for digital signal processors (DSPs).

Purpose

The *VisualDSP++ 3.5 Assembler and Preprocessor Manual for ADSP-218x and ADSP-219x DSPs* contains information about the assembler program for ADSP-218x and ADSP-219x DSPs. These are 16-bit, fixed-point processors from Analog Devices for use in computing, communications, and consumer applications.

The manual provides information on how to write assembly programs for ADSP-218x and ADSP-219x DSPs and reference information about related development software. It also provides information on new and legacy syntax for assembler and preprocessor directives and comments, as well as command-line switches.

Intended Audience

The primary audience for this manual is a programmers who are familiar with Analog Devices DSPs. This manual assumes that the audience has a working knowledge of the appropriate DSP architecture and instruction set. Programmers who are unfamiliar with Analog Devices DSPs can use this manual but should supplement it with other texts (such as Hardware Reference and Instruction Set Reference manuals that describe your target architecture).

Manual Contents

The manual consists of:

- Chapter 1, "Assembler"

  Provides an overview of the process of writing and building assembly programs. It also provides information about the assembler's switches, expressions, keywords, and directives.

- Chapter 2, "Preprocessor"

  Provides procedures for using preprocessor commands within assembly source files as well as the preprocessor's command-line interface options and command sets.

- Chapter 3, "Assembler Enhancements and Legacy Support"

  Compares Release 6.1 assembler and preprocessor features to new features added in latest VisualDSP++ releases.

- Appendix A, "Utilities"

  Describes the comment conversion utility that runs from a command line only. This utility provides support for converting legacy code developed under Release 6.1.

What's New in this Manual

This edition of the manual supports ADSP-218x and ADSP-219x processors.

Refer to *VisualDSP++ 3.5 Product Bulletin for 16-Bit Processors* for information on all new and updated features and other release information.

Technical or Customer Support

You can reach DSP Tools Support in the following ways:

- Visit the DSP Development Tools website at `www.analog.com/technology/dsp/developmentTools/index.html`
- Email questions to `dsptools.support@analog.com`
- Phone questions to **1-800-ANALOGD**
- Contact your ADI local sales office or authorized distributor
- Send questions by mail to:

```
Analog Devices, Inc.
One Technology Way
P.O. Box 9106
Norwood, MA 02062-9106
USA
```

Supported Processors

The names "ADSP-218x" and "ADSP-219x" refer to a family of Analog Devices 16-bit, fixed-point processors. VisualDSP++ currently supports the following ADSP-218x and ADSP-219x processors:

- ADSP-2191, ADSP-2192-12, ADSP-2195, ADSP-2196, ADSP-21990, ADSP-21991, and ADSP-21992 DSPs
- ADSP-2181, ADSP-2183, ADSP-2184/84L/84N, ADSP-2185/85L/85M/85N, ADSP-2186/86L/86M/86N, ADSP-2187L/84L/87N, ADSP-2188L/88N, and ADSP-2189M/89N DSPs

Product Information

You can obtain product information from the Analog Devices website, from the product CD-ROM, or from the printed publications (manuals).

Analog Devices is online at `www.analog.com`. Our website provides information about a broad range of products—analog integrated circuits, amplifiers, converters, and digital signal processors.

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Visit `www.myanalog.com` to sign up. Click **Register** to use MyAnalog.com. Registration takes about five minutes and serves as means for you to select the information you want to receive.

If you are already a registered user, just log on. Your user name is your email address.

DSP Product Information

For information on digital signal processors, visit our website at `www.analog.com/dsp`, which provides access to technical publications, datasheets, application notes, product overviews, and product announcements.

You may also obtain additional information about Analog Devices and its products in any of the following ways.

- Email questions or requests for information to `dsp.support@analog.com`
- Fax questions or requests for information to
  1-781-461-3010 (North America)
  089/76 903-557 (Europe)
- Access the Digital Signal Processing Division's FTP website at `ftp ftp.analog.com` or **ftp 137.71.23.21**
  `ftp://ftp.analog.com`

Related Documents

For information on product related development software, see the following publications:

VisualDSP++ 3.5 Getting Started Guide for 16-Bit Processors

VisualDSP++ 3.5 User's Guide for 16-Bit Processors

VisualDSP++ 3.5 C/C++ Compiler and Library Manual for ADSP-218x DSPs

VisualDSP++ 3.5 C/C++ Compiler and Library Manual for ADSP-219x DSPs

VisualDSP++ 3.5 Linker and Utilities Manual for 16-Bit DSPs

VisualDSP++ 3.5 Loader Manual for 16-Bit Processors

VisualDSP++ 3.5 Product Bulletin for 16-Bit Processors

VisualDSP++ Kernel (VDK) User's Guide

VisualDSP++ Component Software Engineering User's Guide

Quick Installation Reference Card

Online Technical Documentation

Online documentation comprises VisualDSP++ Help system and tools manuals, Dinkum Abridged C++ library and FlexLM network license manager software documentation. You can easily search across the entire VisualDSP++ documentation set for any topic of interest. For easy printing, supplementary `.PDF` files for the tools manuals are also provided.

A description of each documentation file type is as follows.

File	Description
`.CHM`	Help system files and VisualDSP++ tools manuals.
`.HTM` or `.HTML`	Dinkum Abridged C++ library and FlexLM network license manager software documentation. Viewing and printing the `.HTML` files require a browser, such as Internet Explorer 4.0 (or higher).
`.PDF`	VisualDSP++ tools manuals in Portable Documentation Format, one `.PDF` file for each manual. Viewing and printing the `.PDF` files require a PDF reader, such as Adobe Acrobat Reader (4.0 or higher).

If documentation is not installed on your system as part of the software installation, you can add it from the VisualDSP++ CD-ROM at any time.

Access the online documentation from the VisualDSP++ environment, Windows Explorer, or Analog Devices website.

From VisualDSP++

- Access VisualDSP++ online Help from the Help menu's **Contents**, **Search**, and **Index** commands.
- Open online Help from context-sensitive user interface items (toolbar buttons, menu commands, and windows).

From Windows

In addition to any shortcuts you may have constructed, there are many ways to open VisualDSP++ online Help or the supplementary documentation from Windows.

Help system files (`.CHM` files) are located in the Help folder, and `.PDF` files are located in the **Docs** folder of your VisualDSP++ installation. The **Docs** folder also contains the FlexLM network license manager software documentation.

Using Windows Explorer

- Double-click any file that is part of the VisualDSP++ documentation set.
- Double-click the `vdsp-help.chm` file, which is the master Help system, to access all the other `.CHM` files.

Using the Windows Start Button

- Access the VisualDSP++ online Help by clicking the **Start** button and choosing **Programs**, **Analog Devices**, **VisualDSP++**, and **VisualDSP++ Documentation**.
- Access the `.PDF` files by clicking the **Start** button and choosing **Programs**, **Analog Devices**, **VisualDSP++**, **Documentation for Printing**, and the name of the book.

From the Web

To download the tools manuals, point your browser at
`http://www.analog.com/technology/dsp/developmentTools/gen_purpose.html`

Select a DSP family and book title. Download archive (`.ZIP`) files, one for each manual. Use any archive management software, such as WinZip, to decompress downloaded files.

Printed Manuals

For general questions regarding literature ordering, call the Literature Center at **1-800-ANALOGD** (**1-800-262-5643**) and follow the prompts.

VisualDSP++ Documentation Set

VisualDSP++ manuals may be purchased through Analog Devices Customer Service at **1-781-329-4700**; ask for a Customer Service representative. The manuals can be purchased only as a kit. For additional information, call **1-603-883-2430**.

If you do not have an account with Analog Devices, you will be referred to Analog Devices distributors. To get information on our distributors, log onto `http://www.analog.com/salesdir/continent.asp`.

Hardware Manuals

Hardware reference and instruction set reference manuals can be ordered through the Literature Center or downloaded from the Analog Devices website. The phone number is **1-800-ANALOGD** (**1-800-262-5643**). The manuals can be ordered by a title or by product number located on the back cover of each manual.

Data Sheets

All data sheets can be downloaded from the Analog Devices website. As a general rule, any data sheet with a letter suffix (L, M, N) can be obtained from the Literature Center at **1-800-ANALOGD** (**1-800-262-5643**) or downloaded from the website. data sheets without the suffix can be downloaded from the website only—no hard copies are available. You can ask for the data sheet by a part name or by product number.

If you want to have a data sheet faxed to you, the fax number for that service is **1-800-446-6212**. Follow the prompts and a list of data sheet code numbers will be faxed to you. Call the Literature Center first to find out if requested data sheets are available.

Contacting DSP Publications

Please send your comments and recommendation on how to improve our manuals and online Help. You can contact us @ `dsp.techpubs@analog.com`.

Notation Conventions

The following table identifies and describes text conventions used in this manual.

Additional conventions, which apply only to specific chapters, may appear throughout this document.

Example	Description
Close command (**File** menu)	Text in **bold** style indicates the location of an item within the VisualDSP++ environment's menu system. For example, the **Close** command appears on the **File** menu.
`{this | that}`	Alternative required items in syntax descriptions appear within curly brackets and separated by vertical bars; read the example as `this` or `that`.
`[this | that]`	Optional items in syntax descriptions appear within brackets and separated by vertical bars; read the example as an optional `this` or `that`.
`[this,…]`	Optional item lists in syntax descriptions appear within brackets delimited by commas and terminated with an ellipsis; read the example as an optional comma-separated list of `this`.
`.SECTION`	Commands, directives, keywords, and feature names are in text with `letter gothic` font.
`filename`	Non-keyword placeholders appear in text with italic style format.

Example	Description
ⓘ	A note, providing information of special interest or identifying a related topic. In the online version of this book, the word **Note** appears instead of this symbol.
⃠	A caution, providing information about critical design or programming issues that influence operation of a product. In the online version of this book, the word **Caution** appears instead of this symbol.

1 ASSEMBLER

This chapter provides information on how to use the assembler for developing and assembling programs with ADSP-218x and ADSP-219x DSPs.

The chapter contains:

- "Assembler Guide" on page 1-2
  Describes the process of developing new programs in the ADSP-218x and ADSP-219x DSP assembly language.
- "Assembler Syntax Reference" on page 1-19
  Provides the assembler rules and conventions of syntax which is used to define symbols (identifiers), expressions, and to describe different numeric and comment formats.
- "Assembler Command-Line Reference" on page 1-82
  Provides reference information on the assembler's switches and conventions.

Assembler Guide

The `easm218x.exe` and `easm219x.exe` assemblers run from the VisualDSP++ Integrated Debugging and Development Environment (IDDE) or from an operating system command line. Each assembler processes assembly source, data, header files, and produces an object file. Assembler operations depend on two types of controls: assembler directives and assembler switches.

This section describes the process of developing new programs in the ADSP-218x and ADSP-219x DSPs assembly language. It provides information on how assemble your programs from the operating system's command line.

Software developers using the assembler should be familiar with:

- "Writing Assembly Programs" on page 1-3
- "Using Assembler Support for C Structs" on page 1-13
- "Preprocessing a Program" on page 1-14
- "Reading a Listing File" on page 1-18
- "Make Dependencies" on page 1-17
- "Specifying Assembler Options in VisualDSP++" on page 1-99

For information about the DSP architecture, including the DSP instruction set used when writing the assembly programs, see the *Hardware Reference Manual* and *Instruction Set Manual* for an appropriate DSP.

Assembler Overview

The assembler processes data from assembly source (`.ASM`), data (`.DAT`), and include header (`.H`) files to generate object files in Executable and Linkable Format (ELF), an industry-standard format for binary object files. The object file name has a `.DOJ` extension.

In addition to the object file, the assembler can produce a listing file, which shows the correspondence between the binary code and the source.

Assembler switches are specified from the VisualDSP++ or in the command used to invoke the assembler. These switches allow you to control the assembly process of source, data, and header files. Use these switches to enable and configure assembly features, such as search paths, output file names, and macro preprocessing. See "Assembler Command-Line Reference" on page 1-82.

You can also set assembler options via the **Assemble** tab of the VisualDSP++ **Project Options** dialog box (see "Specifying Assembler Options in VisualDSP++" on page 1-99).

Writing Assembly Programs

Assembler directives are coded in your assembly source file. The directives allow you to define variables, set up some hardware features, and identify program's sections for placement within DSP memory. The assembler uses directives for guidance as it translates a source program into object code.

Write assembly language programs using the VisualDSP++ editor or any editor that produces text files. Do not use a word processor that embeds special control codes in the text. Use an `.ASM` extension to source file names to identify them as assembly source files.

Assemble your source files from the VisualDSP++ environment or using any mechanism, such as a batch file or makefile, that will support invoking the assembler driver `easm218x.exe` and `easm219x.exe` with a specified command-line command. By default, the assembler processes an input file to produce a binary object file (`.DOJ`) and an optional listing file (`.LST`).

Figure 1-1 shows a graphical overview of the assembly process. The figure shows the preprocessor processing the assembly source (`.ASM`) and initialization data (`.DAT`) files.

Object files produced by the ADSP-218x and ADSP-219x DSP assemblers may be used as input to the linker and archiver. You can archive the output of an assembly process into a library file (`.DLB`), which can then be linked with other objects into an executable. Use the linker to combine separately assembled object files and objects from library files to produce an executable file.

For more information on the linker and archiver, see the *VisualDSP++ 3.5 Linker and Utilities Manual for ADSP-218x and ADSP-219x DSPs*.

A binary object file (`.DOJ`) and an optional listing (`.LST`) file are final results of the successful assembly.

The assembler listing files are text files read for information on the results of the assembly process. The listing file also provides information about the imported C data structures. It tells which imports were used within the program, followed by a more detailed section (see `.IMPORT` directive on page 1-51). It shows the name, total size and layout with offset for the members. The information appears at the end of the listing. You must specify the `-l listname.lst` option (on page 1-92) to get the information.

VisualDSP++ 3.5 assembler can process your source programs developed previous VDSP releases including Release 6.1. The assembly of these programs requires an additional processing steps described in Chapter 3, "Assembler Enhancements and Legacy Support" .

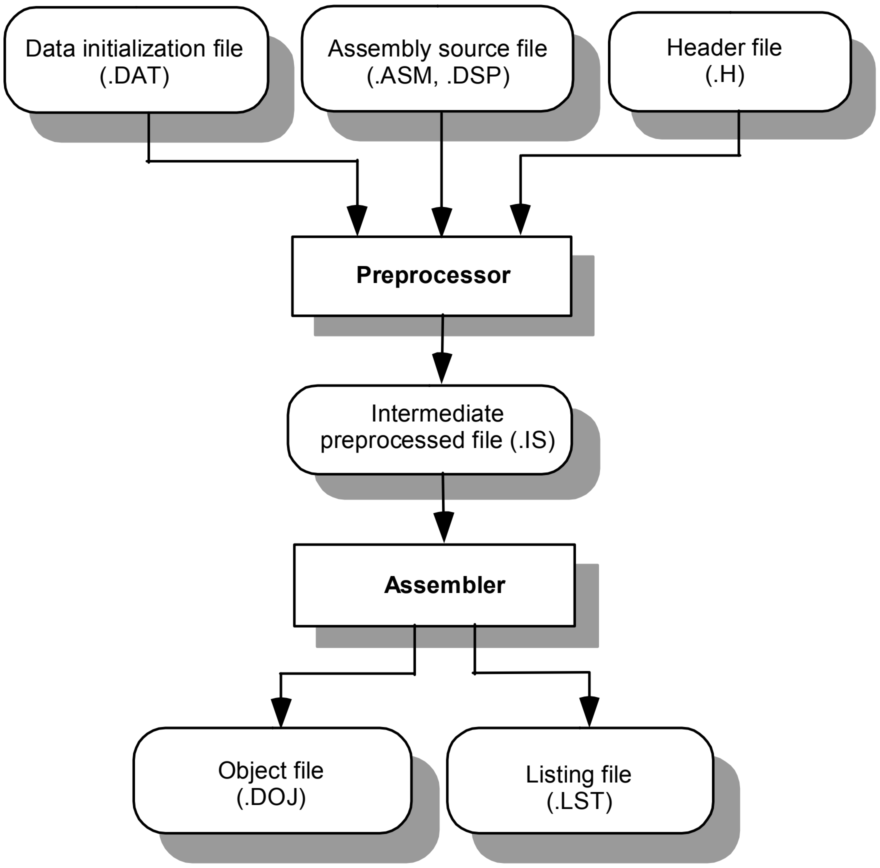


Figure 1-1. Assembler Input and Output Files

The assembly source file may contain preprocessor commands, such as `#include`, that cause the preprocessor to include header files (`.H`) into the source program. The preprocessor's only output, an intermediate source file (`.IS`), is the assembler's primary input.

Program Content

Assembly source file statements include assembly instructions, assembler directives, and preprocessor commands.

Assembly Instructions
Instructions adhere to the DSP's instruction set syntax documented in the DSP's Instruction Set manual. Terminate each instruction with a semicolon (;). Figure 1-2 on page 1-9 shows an example assembly source file.

To mark the location of an instruction, place an address label at the beginning of an instruction line or on the preceding line. End the label with a colon (:) before beginning the instruction. Your program then refer to this memory location using the label instead of an absolute address. The assembler places no restriction on the number of characters in a label.

Labels are case sensitive. The assembler treats "outer" and "Outer" as unique labels. For example,

```
outer: AR = AR-1;
Outer: I1 = AR;
jump outer;  //jumps back 2 instructions
```

Assembler Directives
Directives begin with a period (.) and end with a semicolon (;). The assembler does not differentiate between directives in lowercase or uppercase.

This manual prints directives in uppercase to distinguish them from other assembly statements.

For example,

```
.SECTION/data data1;
.VAR sqrt_coeff[2] = 0x5D1D, 0xA9ED;
```

For a complete description of the `easm218x.exe` and `easm219x.exe` assembler's directive set, see "Assembler Directives" on page 1-40.

Preprocessor Commands

Preprocessor commands begin with a pound sign (#) and end with a carriage return. The pound sign must be the first non-white space character on the line containing the command. If the command is longer than one line, use a backslash (\) and a carriage return to continue the command onto the next line.

Do not put any characters between the backslash and the carriage return. Unlike assembler directives, preprocessor commands are case sensitive and must be lowercase. For example,

```
#include "string.h"
#define MAXIMUM 100
```

For more information, see "Writing Preprocessor Commands" on page 2-3. For a list of the preprocessor commands, see "Preprocessor Command Reference" on page 2-11.

Program Structure

An assembly source file defines code (instructions) and data, and organizes the instructions and data to allow use of the Linker Description File (LDF) to describe how code and data are mapped into the memory on your target DSP. The way you structure your code and data into memory should follow the memory architecture of the target DSP.

Use the `.SECTION` directive to organize the code and data in assembly source files. The `.SECTION` directive defines a grouping of instructions and data that will occupy contiguous memory addresses in the DSP. The name given in a section directive corresponds to an input section name in the Linker Description File.

Suggested input section names that you could use in your assembly source appear in Table 1-1 on page 1-8. Using these predefined names in your sources makes it easier to take advantage of the default `.LDF` file included in your DSP system.

For more information on the `.LDF` files, see the *VisualDSP++ 3.5 Linker and Utilities Manual for 16-Bit Processors*.

Table 1-1. Suggested Input Section Names

`.SECTION` **Name**	**Description**
`data1`	A section that holds data.
`program`	A section that holds code.

You can use sections in a program to group elements to meet hardware constraints.

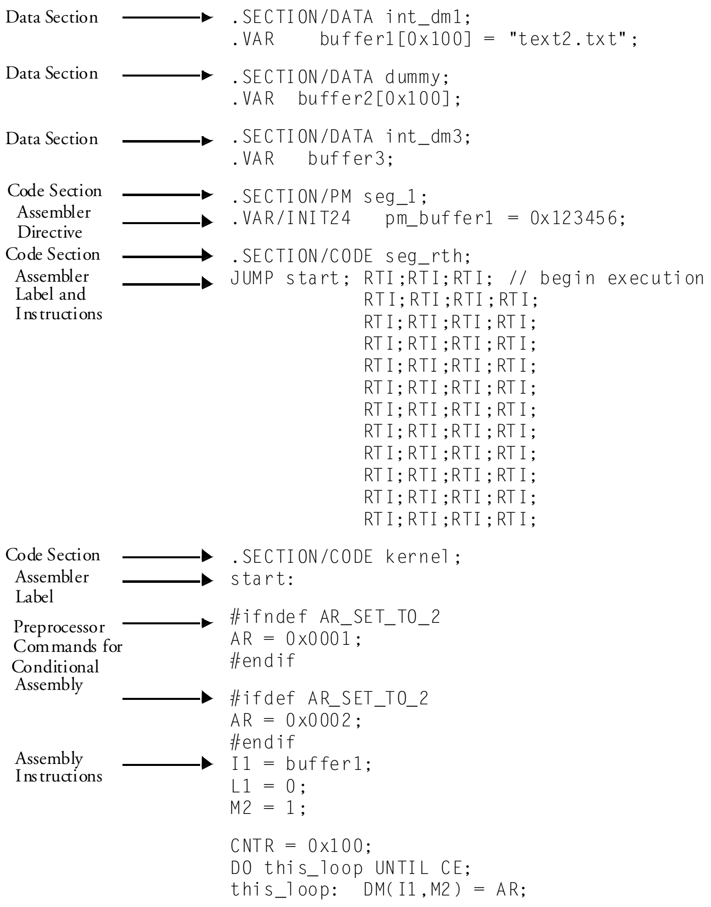
To group the code that reside in off-chip memory, declare a section for that code and place that section in the selected memory with the linker. Figure 1-2 on page 1-9 shows how a program divides into sections that match the memory segmentation of a DSP system.

The example assembly program defines four sections; each section begins with a `.SECTION` directive and ends with the occurrence of the next `.SECTION` directive or end-of-file. The source program contains two data and two program sections:

- Data Sections—`data1` and `constdata`. Variables and buffers are declared and can be initialized.
- Program Sections—`seg_rth` and `program`. Data, instructions, and statements for conditional assembly are coded.

Looking at Figure 1-2, notice that an assembly source may contain preprocessor commands, such as `#include` to include other files in your source code, `#ifdef` for conditional assembly, or `#define` to define macros.

Assembler directives, such as `.VAR`, appear within sections to declare and initialize variables.



```
.SECTION/DATA int_dm1;
.VAR    buffer1[0x100] = "text2.txt";

.SECTION/DATA dummy;
.VAR  buffer2[0x100];

.SECTION/DATA int_dm3;
.VAR   buffer3;

.SECTION/PM seg_1;
.VAR/INIT24   pm_buffer1 = 0x123456;

.SECTION/CODE seg_rth;
JUMP start; RTI;RTI;RTI; // begin execution
            RTI;RTI;RTI;RTI;
            RTI;RTI;RTI;RTI;
            RTI;RTI;RTI;RTI;
            RTI;RTI;RTI;RTI;
            RTI;RTI;RTI;RTI;
            RTI;RTI;RTI;RTI;
            RTI;RTI;RTI;RTI;
            RTI;RTI;RTI;RTI;
            RTI;RTI;RTI;RTI;
            RTI;RTI;RTI;RTI;
            RTI;RTI;RTI;RTI;

.SECTION/CODE kernel;
start:

#ifndef AR_SET_TO_2
AR = 0x0001;
#endif

#ifdef AR_SET_TO_2
AR = 0x0002;
#endif
I1 = buffer1;
L1 = 0;
M2 = 1;

CNTR = 0x100;
DO this_loop UNTIL CE;
this_loop:  DM(I1,M2) = AR;
```

Figure 1-2. Assembly Source File Structure

Listing 1-1 shows a sample user-defined Linker Description File. Looking at the LDF's `SECTIONS{}` command, notice that the `INPUT_SECTION` commands map to sections `sec_code`, `data1`, `sec_itab`, , and `seg_rth`. The LDF's `SECTIONS{}` command defines the `.SECTION` placements in the system's physical memory as defined by the linker's `Memory{}` command.

Listing 1-1. Example Linker Description File

```
ARCHITECTURE(ADSP-219x)
SEARCH_DIR($ADI_DSP\ADSP-219x\lib)
LIBS libc.dlb, libdsp.dlb
$LIBRARIES = LIBS, librt.dlb
$OBJECTS = $COMMAND_LINE_OBJECTS;
MEMORY
{
   seg_reset { TYPE(PM RAM) START(0x000000) END(0x000001F) WIDTH(24) }
   seg_itab  { TYPE(PM RAM) START(0x000020) END(0x0002ff) WIDTH(24) }
   seg_code  { TYPE(PM RAM) START(0x000300) END(0x007fff) WIDTH(24) }
   seg_data1 { TYPE(DM RAM) START(0x08000) END(0x00ffff) WIDTH(16) }
}
PROCESSOR p0      /* The processor in the system */
{
   LINK_AGAINST( $COMMAND_LINE_LINK_AGAINST)
   OUTPUT($COMMAND_LINE_OUTPUT_FILE)

   SECTIONS
   {               /* List of sections for processor P0 */
       sec_reset
       {
           IVreset_addr = .;
           INPUT_SECTIONS( $OBJECTS(IVreset))
       } > seg_reset

           sec_itab
           {
              intvectoffset = 32;
              IVpwrdwn_addr = .;
              INPUT_SECTIONS( $OBJECTS(IVpwrdwn))
              IVsinglestep_addr = IVpwrdwn_addr + intvectoffset;
              . = IVsinglestep_addr;
              INPUT_SECTIONS(   $OBJECTS(IVsinglestep))
              IVstackint_addr = IVsinglestep_addr + intvectoffset;
              . = IVstackint_addr;
              INPUT_SECTIONS( $OBJECTS(IVstackint))
              IVint4_addr = IVstackint_addr + intvectoffset;
              . = IVint4_addr;
              INPUT_SECTIONS( $OBJECTS(IVint4))
              IVint5_addr = IVint4_addr + intvectoffset;
              . = IVint5_addr;
              INPUT_SECTIONS( $OBJECTS(IVint5))
              IVint6_addr = IVint5_addr + intvectoffset;
              . = IVint6_addr;
              INPUT_SECTIONS( $OBJECTS(IVint6))
```

```
                IVint7_addr = IVint6_addr + intvectoffset;
                . = IVint7_addr;
                INPUT_SECTIONS( $OBJECTS(IVint7))
                IVint8_addr = IVint7_addr + intvectoffset;
                . = IVint8_addr;
                INPUT_SECTIONS( $OBJECTS(IVint8))
                IVint9_addr = IVint8_addr + intvectoffset;
                . = IVint9_addr;INPUT_SECTIONS( $OBJECTS(IVint9))
                IVint10_addr = IVint9_addr + intvectoffset;
                . = IVint10_addr;
                INPUT_SECTIONS( $OBJECTS(IVint10))
                IVint11_addr = IVint10_addr + intvectoffset;
                . = IVint11_addr;
                INPUT_SECTIONS( $OBJECTS(IVint11))
                IVint12_addr = IVint11_addr + intvectoffset;
                . = IVint12_addr;
                INPUT_SECTIONS( $OBJECTS(IVint12))
                IVint13_addr = IVint12_addr + intvectoffset;
                . = IVint13_addr;
                INPUT_SECTIONS( $OBJECTS(IVint13))
                IVint14_addr = IVint13_addr + intvectoffset;
                . = IVint14_addr;
                INPUT_SECTIONS( $OBJECTS(IVint14))
                IVint15_addr = IVint14_addr + intvectoffset;
                . = IVint15_addr;
                INPUT_SECTIONS( $OBJECTS(IVint15))
                . = .+31;
            } > seg_itab

        seg_code
        {
                INPUT_SECTIONS( $OBJECTS(program) )
        } > seg_code

        sec_data1
        {
                INPUT_SECTIONS( $OBJECTS(data1) )
        } > seg_data1
    }
}
```

Program Interfacing Requirements

You can interface your assembly program with a C or C++ program. The C/C++ compiler supports two methods for mixing C/C++ and assembly language:

- Embedding assembly code in C or C++ programs
- Linking together C or C++ and assembly routines

To embed (inline) assembly code in your C or C++ program, use the `asm()` construct. To link together programs that contain C/C++ and assembly routines, use assembly interface macros. These macros facilitate the assembly of mixed routines. For more information about these methods, see the *VisualDSP++ 3.5 C/C++ Compiler and Library Manuals* for the target DSPs.

When writing a C or C++ program that interfaces with assembly, observe the same rules that the compiler follows as it produces code to run on the DSP. These rules for compiled code define the compiler's run-time environment. Complying with a run-time environment means following rules for memory usage, register usage, and variable names.

The definition of the run-time environment for the ADSP-218x and ADSP-219x DSP's C/C++ compiler is provided in the *VisualDSP++ 3.5 C/C++ Compiler and Library Manuals* for the target DSPs, which also includes a series of examples to demonstrate how to mix C/C++ and assembly code.

Using Assembler Support for C Structs

The assembler supports C `typedef/struct` declarations within assembly source. These are the assembler data directives and built-ins that provide high-level programming features with C structs in the assembler:

- **Data Directives:**

`.IMPORT`	(see on page 1-51)
`.EXTERN STRUCT`	(see on page 1-47)
`.STRUCT`	(see on page 1-69)

- **C Struct in Assembly Built-ins:**

`offsetof(struct/typedef,field)`	(see on page 1-36)
`sizeof(struct/typedef)`	(see on page 1-37)

- **Struct References:**

`struct->field` (nesting supported)	(see on page 1-38)

For more information on C struct support, refer to the "-flags-compiler" command-line switch on page 1-88 and to "Reading a Listing File" on page 1-18.

C structs in assembly features accept the full set of legal C symbol names, including those that are otherwise reserved in ADSP-218x and ADSP-219x assemblers. For example, `I1`, `I2` and `I3` are reserved keywords in the DSP assembler, but it is legal to reference them in the context of the C struct in assembly features. For example:

```
.IMPORT "Samples.h";
    //   typedef struct Samples {
    //      int I1;
    //      int I2;
    //      int I3;
//   }Samples;

.SECTION/DATA data1;
```

```
.STRUCT Samples Sample1 ={
    I1 =0x1000,
    I2 =0x2000,
    I3 =0x3000
};

.SECTION/CODE program;
    doubleMe:
    // The code may look confusing, but I2 can be used both
    // as a register and a struct member name
    I2 = Sample1;
    AR = DM(I2+OFFSETOF(Sample1,I2));
    AR = AR+AR;
    DM(I2+OFFSETOF(Sample1,I2)) = AR;
```

For better code readability, avoid `.STRUCT` member names that have the same spelling as assembler keywords. This may not always be possible if your application needs to use an existing set of C header files.

Preprocessing a Program

The assembler includes a preprocessor that allows the use of C-style preprocessor commands in your assembly source files. The preprocessor automatically runs before the assembler unless you use the assembler's `-sp` (skip preprocessor) switch. Table 2-3 on page 2-12 lists preprocessor commands and provides a brief description of each command.

Preprocessor commands are useful for modifying assembly code. For example, you can use the `#include` command to fill memory, load configuration registers, and set up DSP parameters. You can use the `#define` command to define constants and aliases for frequently used instruction sequences. The preprocessor replaces each occurrence of the macro reference with the corresponding value or series of instructions.

For example, the macro `MAXIMUM` in the example on page 1-7 is replaced with the number `100` during preprocessing.

For more information on the preprocessor command set, see "Preprocessor Command Reference" on page 2-11. For more information on preprocessor usage, see "-flags-pp -opt1 [,-opt2...]" on page 1-90.

Using Assembler Feature Macros

The assembler includes the command to invoke preprocessor macros to define the context, such as the source language, the architecture, and the specific processor. These "feature macros" allow the programmer to use preprocessor conditional commands to configure the source for assembly based on the context.

The set of feature macros include:

`-D_LANGUAGE_ASM =1`	Always present
`-D__ADSP21XX__ =1`	Always present
`-D__ADSP218X__ =1`	Always defined by `easm218x`
`-D__ADSP219X__ =1`	Always defined by `easm219x`
`-D__ADSP2181__ =1`	Present when running `easm218x -proc ADSP-2181` (for ADSP-218x DSPs)
`-D__ADSP2191__ =1`	Present when running `easm219x -proc ADSP-2191` (for ADSP-219x DSPs)

The `-proc <processor>` switch allows you to specify the processor and the corresponding macro. For example, using `easm218x -proc ADSP-2189` provides you with the `-D__ADSP2189__ =1` macro, while using `easm219x -proc ADSP-2195` provides you with the `-D__ADSP2195__ =1` macro. This is true for all ADSP-218x and ADSP-219x processors.

These are two macro examples.

Example 1:

```
#ifndef __ADSP218X__
#warning Code optimized for ADSP-218x DSPs
#endif
```

Example 2:

```
#if defined(__ADSP2191__)\
   || defined(__ADSP2195__)\
   || defined(__ADSP2196__)
#define NUM_OF_DSP_CORES 1
#elif defined(__ADSP2192_12__)\
#define NUM_OF_DSP_CORES 2
#else
#error Unsupported ADSP processor
#endif
```

For the `.IMPORT` headers, the assembler calls the compiler driver with the appropriate processor option and the compiler sets the machine constants accordingly (and defines `-D_LANGUAGE_C = 1`). This macro is present when used for C compiler calls to specify headers. It replaces `-D_LANGUAGE_ASM`.

For example,

`easm218x -2189` assembly --> `cc218x -2189`

`easm219x -2191` assembly --> `cc219x -2191`

Use the `-verbose` option to verify what macro is default-defined. Refer to Chapter 1 in the *VisualDSP++ 3.5 C/C++ Compiler and Library Manuals* for target DSPs for more information.

Make Dependencies

The assembler can generate "make dependencies" for a file to allow VisualDSP++ and other makefile-based build environments to determine when to rebuild an object file due to changes in the input files. The assembler source file and any files mentioned in the `#include` commands, `.IMPORT` directives, or buffer initializations (in `.VAR` and `.STRUCT` directives) constitute the "make dependencies" for an object file.

When VisualDSP++ requests make dependencies for the assembly, the assembler produces the dependencies from buffer initializations and invokes

- The preprocessor to determine the make dependency from `#include` commands, and
- The compiler to determine the make dependencies from the `.IMPORT` headers.

The following example shows make dependencies for `VCSE_IBase.h` which includes `vcse.h`. Note that the same header `VCSE_IBase.h` when called from the assembler (with assembler `#defines`) also includes `VCSE_asm.h`, but this was not the case when called for compiling `.IMPORT`.

```
easm219x -M -l main.lst main.asm

// dependency from the assembler
main.doj": "main.asm"

// dependencies from the assembler preprocessor PP for the
// #include headers

"main.doj": "ACME_Impulse_factory.h"
"main.doj": "ACME_Impulse_types.h"
"main.doj": "VCSE_IBase.h"
"main.doj": "VCSE_asm.h"
"main.doj": "vcse.h"
```

```
// dependencies from the compiler for the .IMPORT headers
main.doj: .\ACME_IFir.h
main.doj: .\ADI_IAlg.h
main.doj: .\VCSE_IBase.h
main.doj: .\vcse.h
```

Reading a Listing File

A listing file (`.LST`) is an optional output text file that lists the results of the assembly process. Listing files provide the following information:

- Address — The first column contains the offset from the `.SECTION`'s base address.
- Opcode — The second column contains the hexadecimal opcode that the assembler generates for the line of assembly source.
- Line — The third column contains the line number in the assembly source file.
- Assembly Source — The fourth column contains the assembly source line from the file.

The assembler listing file provides information about the imported C data structures. It tells which imports were used within the program, followed by a more detailed section. It shows the name, total size and layout with offset for the members. The information appears at the end of the listing. You must specify the `-l listname.lst` option (as shown on page 1-92) to get a listing file.

Assembler Syntax Reference

When you develop a source program in assembly language, include preprocessor commands and assembler directives to control the program's processing and assembly. You must follow the assembler rules and conventions of syntax to define symbols (identifiers), expressions, and use different numeric and comment formats.

Software developers who write assembly programs should be familiar with:

- "Assembler Keywords and Symbols" on page 1-19
- "Assembler Expressions" on page 1-27
- "Assembler Operators" on page 1-28
- "Numeric Formats" on page 1-30
- "Comment Conventions" on page 1-33
- "Conditional Assembly Directives" on page 1-34
- "C Struct Support in Assembly Built-in Functions" on page 1-36
- "-> Struct References" on page 1-38
- "Assembler Directives" on page 1-40

Assembler Keywords and Symbols

The assembler supports predefined keywords that include register and bitfield names, assembly instructions, and assembler directives. Table 1-2 lists the assembler keywords for ADSP-218x DSPs. Table 1-3 lists the assembler keywords for ADSP-219x DSPs. Although the keywords in the listings appear in uppercase, the keywords are case insensitive in the assembler's syntax. For example, the assembler does not differentiate between "`DATA`" and "`data`".

Table 1-2. ADSP-218x DSP Assembler Keywords

.ALIGN	.ASM_ASSERT	.BYTE	.DMSEG	.ELIF
.ELSE	.END_REPEAT	.ENDIF	.ENDINCLUDE	.ENDMACRO
.ENDMOD	.ENTRY	.EXPORT	.EXTERN	.EXTERNAL
.FILE	.GLOBAL	.IF	.IMPORT	.INCLUDE
.INDENT	.INIT	.INIT24	.LEFTMARGIN	.LIST
.LIST_DATA	.LIST_DATFILE	.LIST_DEFTAB	.LIST_LOCTAB	.LIST_WRAPDATA
.LOCAL	.MACRO	.MODULE	.NEWPAGE	.NOLIST
.NOLIST_DATA	.NOLIST_DATFILE	.NOLIST_WRAPDATA	.ORG	.PAGE
.PAGELENGTH	.PAGEWIDTH	.PMSEG	.PORT	.PRECISION
.PREVIOUS	.REPEAT	.ROUND_MINUS	.ROUND_NEAREST	.ROUND_PLUS
.ROUND_ZERO	.SECTION	.SETDATA	.SIZE	.STRUCT
.TYPE	.VAR	.VCSE_METHODCALL _END	.VCSE_METHODCALL _START	.VCSE_METHODCALL _RETURNS
.WEAK				
__DATE__	__FILE__	__LINE__	__STDC__	__TIME__
ABS	AC	ADDRESS	AF	AND
AR	AR_SAT	AS	ASHIFT	ASTAT
AV	AV_LATCH	AX0	AX1	AY0
AY1				
BIT_REV	BOOT	BR	BY	
C	CALL	CE	CIRC	CLRBIT
CLRBIT	CLRINT	CNTR	CODE	CONST
DATA	DIS	DIVQ	DIVS	DM
DMOVLAY	DO			

Table 1-2. ADSP-218x DSP Assembler Keywords (Cont'd)

E_MODE	EMUIDLE	ENDINCLUDE	ENDMACRO	EO
EXP	EXPADJ			
FI	FL0	FL1	FL2	FLAG_IN
FLAG_OUT	FLUSH	FO	FOREVER	
G_MODE	GE	GM	GT	
HI	HIX			
I0	I1	I2	I3	I4
I5	I6	I7	ICNTL	IDLE
IF	IFC	IMASK	INCLUDE	INIT24
INT	INTS	IO	ISTAT	
JUMP				
L0	L1	L2	L3	L4
L5	L6	L7	LE	LENGTH
LINE	LO	LOOP	LSHIFT	LT
M0	M1	M2	M3	M4
M5	M6	M7	M_MODE	MACRO
MF	MODIFY	MR	MR0	MR1
MR2	MSTAT	MV	MX0	MX1
MY0	MY1			
NE	NEG	NONE	NOP	NORM
NOT				
OF	OFFSET	OL	OR	OWRCNTR
PAGE	PAGEID	PASS	PC	PM
PMCODE	PMDATA	PMOVLAY	POP	POS
PUSH	PX			

Table 1-2. ADSP-218x DSP Assembler Keywords (Cont'd)

RAM	RESET	RND	ROM	RTI
RTS	RX0	RX1		
SAT	SB	SE	SEC_REG	SEG
SET	SETBIT	SETINT	SHIFT	SHT_DEBUGINFO
SHT_DM	SHT_DYNAMIC	SHT_DYNSYM	SHT_HASH	SHT_LDF
SHT_NOBITS	SHT_NOTE	SHT_NULL	SHT_PMCODE	SHT_PMDATA
SHT_PROCESSORTYPE	SHT_PROGBITS	SHT_REL	SHT_RELA	SHT_SEGMENINFO
SHT_SHLIB	SHT_STRTAB	SHT_SYMTAB	SI	SIMIDLE
SIZEOF	SR	SR0	SR1	SS
SSTAT	STATIC	STRUCT	STS	STT_FUNC
STT_OBJECT	SU			
TGLBIT	TI	TIMER	TOGGLE	TOPLOOPSTACKH
TOPLOOPSTACKL	TOPPCSTACK	TRAP	TRUE	TSTBIT
TX0	TX1			
UNTIL	US	UU		
XOR				

Table 1-3. ADSP-219x DSP Assembler Keywords

.ALIGN	.ASM_ASSERT	.BYTE	.DATA	.DMBSS
.DMSEG	.DW	.ELIF	.ELSE	.END_REPEAT
.ENDIF	.ENDINCLUDE	.ENDMACRO	.ENDMOD	.ENTRY
.EXPORT	.EXTERN	.EXTERNAL	.FILE	.GENLABEL
.GLOBAL	.IF	.IMPORT	.INCLUDE	.INDENT
.INIT	.INIT24	.LEFTMARGIN	.LIST	.LIST_DATA
.LIST_DATFILE	.LIST_DEFTAB	.LIST_LOCTAB	.LIST_WRAPDATA	.LOCAL

Table 1-3. ADSP-219x DSP Assembler Keywords (Cont'd)

.MACRO	.MODULE	.NEWPAGE	.NOLIST	.NOLIST_DATA
.NOLIST_DATFILE	.NOLIST_WRAPDATA	.ORG	.PAGE	.PAGELENGTH
.PAGEWIDTH	.PMBSS	.PMSEG	.PORT	.PRECISION
.PREVIOUS	.REPEAT	.ROUND_MINUS	.ROUND_NEAREST	.ROUND_PLUS
.ROUND_ZERO	.SECTION	.SETDATA	.SIZE	.STRUCT
.TYPE	.VAR	.WEAK		
__DATE__	__FILE__	__LINE__	__STDC__	__TIME__
ABS	AC	ADDRESS	AF	AND
AR	AR_SAT	AS	ASHIFT	ASTAT
AV	AV_LATCH	AX0	AX1	AY0
AY1				
B0	B1	B2	B3	B4
B5	B6	B7	BIT_REV	BOOT
BR	BY			
C	CACHE	CACTL	CALL	CCODE
CE	CIRC	CLRBIT	CLRINT	CNTR
CODE				
DATA	DB	DIS	DIVQ	DIVS
DM	DMPG1	DMPG2	DO	DW
DX				
E_MODE	EMUIDLE	ENA	ENDINCLUDE	ENDMACRO
EQ	ETRAP	EXP	EXPADJ	
FL0	FL1	FL2	FLAG_OUT	FLUSH

Table 1-3. ADSP-219x DSP Assembler Keywords (Cont'd)

FOREVER				
GE	GT			
HI	HIX			
I0	I1	I2	I3	I4
I5	I6	I7	INCTL	IDLE
IF	IJPG	IMASK	INCLUDE	INIT24
INT	IO	IOPG	IRPTL	
JUMP	KTRAP			
L0	L1	L2	L3	L4
L5	L6	L7	LCALL	LE
LENGTH	LINE	LJUMP	LO	LOOP
LPSTACKA	LPSTACKP	LSHIFT	LT	
M0	M1	M2	M3	M4
M5	M6	M7	M_MODE	MACRO
MF	MM	MODIFY	MR	MR0
MR1	MR2	MSTAT	MV	MX0
MX1	MY0	MY1		
NE	NEG	NONE	NOP	NORM
NOT				
OF	OFFSETOF	OL	OR	
PAGE	PAGEID	PASS	PC	PM
PMCODE	PMDATA	POP	POS	PUSH
PX				
RAM	REG	RESET	RND	ROM
RTI	RTS			

Table 1-3. ADSP-219x DSP Assembler Keywords (Cont'd)

SAT	SB	SD	SE	SEC_DAG
SEC_REG	SEG	SET	SETBIT	SETINT
SHIFT	SHT_DEBUGINFO	SHT_DM	SHT_DYNAMIC	SHT_DYNSYM
SH_HASH	SHT_LDF	SHT_NOBITS	SHT_NOTE	SHT_NULL
SHT_PMCODE	SHT_PMDATA	SHT_PROCESSORTYPE	SHT_PROGBITS	SHT_REL
SHT_RELA	SHT_SEGMENTINFO	SHT_SHLIB	SHT_STRTAB	SHT_SYMTAB
SI	SIMIDLE	SIZEOF	SR	SR0
SR1	SR2	SS	SSTAT	STACKA
STACKP	STATIC	STEP	STRUCT	STS
STT_FUNC	STT_OBJECT	SU	SV	SWCOND
SYSCTL				
TGLBIT	TI	TIMER	TOGGLE	TRAP
TRUE	TSTBIT	TX0	TX1	
UNTIL	US	UU		
XOR				
WAIT	WARNING	WRITE	WEAK	
XOR				

Extend these sets of keywords with symbols that declare sections, variables, constants, and address labels. When defining symbols in assembly source code, follow these conventions:

- Define symbols that are unique within the file in which they are declared. If you use a symbol in more than one file, use the .GLOBAL assembly directive to export the symbol from the file in which it is defined. Then use the .EXTERN assembly directive to import the symbol into other files.

- Begin symbols with alphabetic characters.

  Symbols can use alphabetic characters (`A–Z` and `a–z`), digits (`0–9`), and special characters `$` and `_` (dollar sign and underscore) as well as . (dot).

  Symbols are case sensitive; so `input_addr` and `INPUT_ADDR` define unique variables.

  The dot, point, or period, '.' as the first character of a symbol triggers special behavior in the VisualDSP++ environment. Such symbols will not appear in the symbol table accessible in the debugger. A symbol name in which the first two characters are points will not appear even in the symbol table of the object.

  The compiler and runtimes prepend '_' to avoid using symbols in the user name space that begin with an alphabetic character.

- Do not use a reserved keyword to define a symbol.
- Match source and LDF sections' symbols.

  Ensure that .`SECTION` name symbols do not conflict with the linker's keywords in the LDF. The linker uses sections' name symbols to place code and data in DSP memory. For more details, see the *VisualDSP++ 3.5 Linker and Utilities Manual for 16-Bit Processors*.

  Ensure that .`SECTION` name symbols do not begin with the '.' (dot).

- Terminate address label symbols with a colon (:).
- The reserved word list for ADSP-218x and ADSP-219x DSPs includes some keywords with commonly used spellings; therefore, ensure correct syntax spelling.

Address label symbols may appear at the beginning of an instruction line or stand alone on the preceding line. The following disassociated lines of code demonstrate symbol usage.

```
.VAR xoperand;                // xoperand is a 16-bit variable
.VAR/INIT24 input_array[10]; // input_array is a 24-bit wide
                              // data buffer in PM
sub_routine_1:                // sub_routine_1 is a label
.SECTION/PM kernel;           // kernel is a section in PM
```

Assembler Expressions

The assembler can evaluate simple expressions in source code. The assembler supports two types of expressions: constant and symbolic.

Constant expressions
A constant expression is acceptable where a numeric value is expected in an assembly instruction or in a preprocessor command. Constant expressions contain an arithmetic or logical operation on two or more numeric constants. For example,

```
2.9e-5 + 1.29
(128 - 48) / 3
0x55&0x0f
7.6r — .8r
```

For information about fraction type support, refer to "Fractional Type Support" on page 1-31.

Symbolic expressions
Symbolic expressions contain symbols, whose values may not be known until link time:

```
data/8
(data_buffer1 + data_buffer2) & 0xF
strtup + 2
data_buffer1 + LENGTH(data_buffer2)*2
```

Symbols in this type of expression are data variables, data buffers, and program labels. In the first three examples above, the symbol name represents the address of the symbol. The fourth combines that meaning of a symbol with a use of the length operator (see Table 1-5).

Assembler Operators

Table 1-4 lists the assembler's numeric and bitwise operators used in constant expressions and address expressions. These operators are listed in the order they are processed while the assembler evaluates your expressions. Relational operators are only supported in relational expressions in conditional assembly, as described in "Conditional Assembly Directives" on page 1-34.

Table 1-4. Operator Precedence

Operator	Usage Description	Designation
`(expression)`	`expression` in parentheses evaluates first	
~ -	Ones complement Unary minus	Tilde Minus
* / %	Multiply Divide Modulus	Asterisk Slash Percentage
+ —	Addition Subtraction.	Plus Minus
<< >>	Shift left Shift right	
&	Bitwise AND (preprocessor only)	
|	Bitwise inclusive OR	
^	Bitwise exclusive OR (preprocessor only)	

The assembler also supports special "symbol" and "length of" operators. Table 1-5 lists and describes these operators used in constant and address expressions.

Table 1-5. Special Assembler Operators

Operator	Usage Description
`ADDRESS(symbol)`	Least significant 16 address bits of `symbol`
`symbol`	Address pointer to `symbol`
`LENGTH(symbol)`	Length of `symbol` in words
`PAGE(symbol)`	Most significant 8 address bits associated with `symbol`.

The "length of" operator can be used with external symbols—apply it to symbols that are defined in other sections as `.GLOBAL` symbols.

The following example demonstrates how the assembler operators are used to load the length and address information into registers (when setting up circular buffers in ADSP-219x processors).

```
.SECTION/DATA data1;        // data section
.VAR real_data [n];         // n=number of input sample

.SECTION/CODE program;      // code section
    I5=real_data;           // buffer's base address
    L5=length(real_data);   // buffer's length
    AR=I5;                  // load address to data register
    REG(B5)=AR;
    M=1;                    // post-modify I5 by 1
    CNTR=DO loop1 UNTIL CE;
    AX0=DM(I5,M4);          // get next sample
    …
loop1:  …
```

This code fragment initializes `I5` and `L5` to the base address and length, respectively, of the circular buffer `real_data`. The buffer length value contained in `L5` determines when addressing wraps around the top of the buffer. For further information on circular buffers, refer to the target processor's Hardware Reference Manual.

The following example illustrates how the `PAGE()` operator can be used to handle overlays on ADSP-218x processors.

```
.SECTION/PM IVreset;
jump start;

.SECTION/PM program;

start:
      pmovlay = PAGE(func4);
      call func4;
      ar = ay0;
      dmovlay = PAGE(dmovl3var);
      ay0 = dm(dmovl3var);
      ar = ar + ay0;
      idle;

.SECTION/PM pmovl4;
func4:
      ay0 = 0x0004;
      rts;
.SECTION/DM dmovl3;
.VAR dmovl3var = 0x0104;
```

Numeric Formats

The assembler supports binary, decimal, hexadecimal, and fractional numeric formats (bases) within expressions and assembly instructions. Table 1-6 describes the conventions of notation the assembler uses to distinguish between numeric formats.

Table 1-6. Numeric Formats

Convention	Description
`0x`*number*	"`0x`" prefix indicates a hexadecimal number
`B#`*number* `b#`*number*	"`B#`" or "b#" prefix indicates a binary number
number	No prefix indicates a decimal number
numberr	"r" suffix indicates a fractional number

Fractional Type Support

Fractional (fract) constants are specially marked floating-point constants to be represented in fixed-point. A fract constant uses the floating-point representation with a trailing "`r`", where `r` stands for `fract`.

The legal range is [– `1…1`). Fracts are represented as signed values, which means the values must be greater than or equal – `1` and less than `1`.

For example,

```
.VAR myFracts[] = 0.5r, -0.5e-4r, -0.25e-3r, 0.875r;
      /* Constants are examples of legal fracts */
.VAR OutOfRangeFract = 1.5r;
      /* [Error ea1036] "fractErr.asm":3 Fract constant '1.5r'
      is out of range. Fract constants must be greater than
      or equal to -1 and less than 1.
      Constants .5r and .2r are examples of legal fracts in
      assembly source */
```

1.15 Fracts

The ADSP-218x and ADSP-219x DSs support fracts that use 1.15 format, meaning a sign bit and "15 bits of fraction". This is –`1` to `+1`–`2**15`. For example, 1.15 maps the constant `0.5r` to `2**14`.

The conversion formula used by a ADSP-218x or ADSP-219x DSP to convert from the floating-point format to fixed-point format uses a scale factor of 15:

```
   fractValue = (short) (doubleValue * (1 << 15))
```

For example:

```
.VAR myFract = 0.5r;
   // Fract output for 0.5r is 0x4000
   // sign bit + 15 bits
   //  0100 0000 0000 0000
   //    4    0    0    0      = 0x4000 = .5r
VAR myFract = -1.0r;
   // Fract output for -1.0r is 0x8000
   // sign bit + 15 bits
   //  1000 0000 0000 0000
   //    8    0    0    0      = 0x8000 = -1.0r
```

1.0r Special Case

`1.0r` is out of the range fract. Specify `0x7FFF` for the closest approximation of `1.0r` within the 1.15 representation.

Fractional Arithmetic

The assembler provides supports for arithmetic expressions using operations on fractional constants, consistent with the support for other numeric types in constant expressions, as described in "Assembler Expressions" on page 1-27.

The internal (intermediate) representation for expression evaluation is a double floating-point value. Fract range checking is deferred until the expression is evaluated. For example,

```
   #define fromSomewhereElse  0.875r
   .SECTION/dm data1;
```

```
.VAR localOne = fromSomewhereElse + 0.005r;
                    // Result .88r is within the legal range
.VAR xyz = 1.5r -0.9r;
                    // Result .6r is within the legal range
.VAR abc = 1.5r;    // Error: 1.5r out of range
```

Mixed Type Arithmetic

The assembler does not support arithmetic between fracts and integers. For example,

```
.SECTION/code program;
.VAR myFract = 1 - 0.5r;

 [Error ea1998] "fract.asm":2 Assembler Error: Illegal
 mixing of types in expression.
```

Comment Conventions

The assembler supports C and C++ style formats for inserting comments in assembly sources. The `easm218x` and `easm219x` assemblers do not support nested comments. Table 1-7 lists and describes assembler comment conventions.

Table 1-7. Comment Conventions

Convention	Description
`/* comment */`	A "`/* */`" string encloses a multiple-line comment.
// `comment`	A pair of slashes "//" begin a single-line comment.

Conditional Assembly Directives

Conditional assembly directives are used for evaluation of assembly-time constants using relational expressions. The expressions may include relational and logical operations. In addition to integer arithmetic, the operands may be the C struct in assembly built-in functions `SIZEOF()`and `OFFSETOF()` that return integers.

The conditional assembly directives are:

- `.IF` *`constant-relational-expression;`*
- `.ELIF` *`constant-relational-expression;`*
- `.ELSE;`
- `.ENDIF;`

All conditional assembly blocks begin with an `.IF` directive and end with a `.ENDIF` directive. Table 1-8 shows examples of conditional directives.

Table 1-8. Relational Operators for Conditional Assembly

Relational Operators	**Conditional Directive Examples**
`not !`	`.if !0;`
`greater than >`	`.if ( sizeof(myStruct) > 16 );`
`greater than equal >=`	`.if ( sizeof(myStruct) >= 16 );`
`less than <`	`.if ( sizeof(myStruct) < 16 );`
`less than equal <=`	`.if ( sizeof(myStruct) <= 16 );`
`equality ==`	`.if ( 8 == sizeof(myStruct) );`
`not equal !=`	`.if ( 8 != sizeof(myStruct) );`
`logical or ||`	`.if (2 !=4 ) || (5 == 5);`
`logical and &&`	`.if (sizeof(char) == 2 && sizeof(int) == 4);`

Optionally, any number of `.ELIF` and a final `.ELSE` directive may appear within the `.IF` and `.ENDIF`. The conditional directives are each terminated with a semi-colon `";"` just like all existing assembler directives. Conditional directives do not have to appear alone on a line. These directives are in addition to the C-style preprocessing directives `#if`, `#elif`, `#else`, and `#endif`.

The `".IF"`, `".ELSE"`, `".ELIF "` and `".ENDIF"` directives (in any case) are reserved keywords.

The `.IF` conditional assembly directives must be used to query about C structs in assembly using the `SIZEOF()` and/or `OFFSETOF()` built-ins. These built-ins are evaluated at assembly time, so they cannot appear in expressions in the `#if` preprocessor directives.

In addition, the `SIZEOF()` and `OFFSETOF()` built-in functions (see "C Struct Support in Assembly Built-in Functions" on page 1-36) can be used in relational expressions. Different code sequences can be included based on the result of the expression.

For example, a `SIZEOF(struct/typedef/C base type)` is permitted.

The assembler supports nested conditional directives. The outer conditional result propagates to the inner condition, just as it does in C preprocessing.

Assembler directives are distinct from preprocessor directives:

- The # directives are evaluated during preprocessing by the `PP` preprocessor. Therefore, preprocessor `#IF` directives cannot use the assembler built-in functions (see "C Struct Support in Assembly Built-in Functions").

- The conditional assembly directives are processed by the assembler in a later pass. Therefore, you would be able to write a relational or logical expression whose value will depend on the value of a `#define`:. For example,

```
.IF tryit == 2
<some code>
.ELIF tryit >= 3
<some more code>
```

If you have "`#define tryit 2`", then the code `<some code>` will be assembled, `<some more code>` will not be.

- There are no parallel assembler directives for C-style directives `#define`, `#include`, `#ifdef`, `#if defined(name)`, `#ifndef`, etc.

C Struct Support in Assembly Built-in Functions

The assembler supports built-in functions that enable you to pass information obtained from the imported C struct layouts. The supported built-in functions are `OFFSETOF()` and `SIZEOF()`.

OFFSETOF() Built-In

The `OFFSETOF()` built-in function is used to calculate the offset of a specified member from the beginning of its parent data structure. For ADSP-218x and ADSP-219x DSPs, `OFFSETOF()` units are in words.

```
OFFSETOF( struct/typedef, memberName )
```

where:

`struct/typedef`—struct `VAR` or a `typedef` can be supplied as the first argument

`memberName`—a member name within the `struct` or `typedef` (second argument)

SIZEOF() Built-In

The `SIZEOF()` built-in function returns the amount of storage associated with an imported C struct or data member. It provides functionality similar to its C counterpart.

```
SIZEOF(struct/typedef/C base type);
```

where:

`SIZEOF()` takes a symbolic reference as its single argument. A symbolic reference is a name followed by zero or more qualifiers to members. The `SIZEOF()` built-in function gives the amount of storage associated with:

- An aggregate type (structure)
- A C base type (`int`, `char`, etc.)
- A member of a structure (any type)

For example,

```
.IMPORT "Celebrity.h";
.EXTERN STRUCT Celebrity StNick;
.SECTION/CODE program;
l3 = SIZEOF(Celebrity);    // typedef
l3 = SIZEOF(StNick);       // struct var of typedef Celebrity
l3 = SIZEOF(char);              // C built-in type
l3 = SIZEOF(StNick->Town);      // member of a struct var
l3 = SIZEOF(Celebrity->Town);   // member of a struct typedef
```

The `SIZEOF()` built-in function returns the size in the units appropriate for its processor. For ADSP-218x and ADSP-219x DSPs, units are in words.

When applied to a structure type or variable, `sizeof()` returns the actual size, which may include padding bytes inserted for alignment. When applied to a statically dimensioned array, `sizeof()` returns the size of the entire array.

-> Struct References

A reference to a `struct VAR` provides an absolute address. For a fully qualified reference to a member, the address is offset to the correct location within the struct. The assembler syntax for `struct` references is "->". For example,

```
myStruct->Member5
```

references the address of `Member5` located within `myStruct`. If the struct layout changes, there is no need to change the reference. The assembler re-calculates the offset when the source is re-assembled with the updated header. Nested `struct` references are supported.

For example,

```
myStruct->nestedRef->AnotherMember
```

Unlike `struct` members in C, `struct` members in the assembler are always referenced with "->" (and not ".") because "."“is a legal character in identifiers in assembly and not available as a `struct` reference.

References within nested structures are permitted. A nested struct definition can be provided in a single reference in assembly code while a nested `struct` via a pointer type requires more than one instruction. Make use of the `OFFSETOF()` built-in function to avoid hard-coded offsets that could become invalid if the struct layout changes in the future.

Following are two nested `struct` examples for `.IMPORT "CHeaderFile.h";`.

Example 1: Nested Reference Within the Struct Definition with Appropriate C Declarations

C code

```
struct Location {
      char Town[16];
      char State[16];
};

struct myStructTag
      int field1;
      struct Location NestedOne;
};
```

Assembly Code

```
.EXTERN STRUCT myStructTag _myStruct;
AR = _myStruct->NestedOne->State;
```

Example 2: Nested Reference When Nested via a Pointer with Appropriate C Declarations

When nested via a pointer `myStructTagWithPtr`, which has `pNestedOne`, use pointer register offset instructions.

C Code

```
// from C header
struct Location {
      char Town[16];
      char State[16];
};

struct myStructTagWithPtr {
      int field1;
      struct Location *pNestedOne;
};
```

Assembly Code

```
// in assembly file
.EXTERN STRUCT myStructTagWithPtr _myStructWithPtr;

AR = _myStructWithPtr->pNestedOne;
AR = AR+OFFSETOF(Location,State);
```

Assembler Directives

Directives in an assembly source file control the assembly process. Unlike assembly instructions, directives do not produce opcodes during assembly. Use the following general syntax for assembler directives

```
.directive [/qualifiers |arguments];
```

Each assembler directive starts with a period (.) and ends with a semicolon (;). Some directives take qualifiers and arguments. A directive's qualifier immediately follows the directive and is separated by a slash (/); arguments follow qualifiers. Assembler directives can be uppercase or lowercase; uppercase distinguishes directives from other symbols in your source code.

The ADSP-218x and ADSP-219x DSP assemblers support the directives shown in Table 1-9. A description of each directive appears in the following sections.

Table 1-9. Assembler Directive Summary

Directive	Description
.ALIGN (see on page 1-44)	Specifies a byte alignment requirement
.ELSE (see on page 1-34)	Conditional assembly directive
.ENDIF (see on page 1-34)	Conditional assembly directive

Table 1-9. Assembler Directive Summary (Cont'd)

Directive	Description
`.EXTERN` (see on page 1-46)	Allows reference to a global symbol
`.EXTERN STRUCT` (see on page 1-47)	Allows reference to a global symbol (`struct`) that was defined in another file
`.FILE` (see on page 1-49)	Overrides `filename` given on the command line. Used by C compiler
`.GLOBAL` (see on page 1-50)	Changes a symbol's scope from local to global
`.IF` (see on page 1-34)	Conditional assembly directive
`.IMPORT` (see on page 1-50)	Provides the assembler with the structure layout (C struct) information
`.LEFTMARGIN` (see on page 1-53)	Defines the width of the left margin of a listing
`.LIST` (see on page 1-54)	Starts listing of source lines
`.LIST_DATA` (see on page 1-55)	Starts listing of data opcodes
`.LIST_DATFILE` (see on page 1-56)	Starts listing of data initialization files
`.LIST_DEFTAB` (see on page 1-57)	Sets the default tab width for listings
`.LIST_LOCTAB` (see on page 1-58)	Sets the local tab width for listings
`.LIST_WRAPDATA` (see on page 1-59)	Starts wrapping opcodes that don't fit listing column
`.NEWPAGE` (see on page 1-60)	Inserts a page break in a listing
`.NOLIST` (see on page 1-54)	Stops listing of source lines

Table 1-9. Assembler Directive Summary (Cont'd)

Directive	Description
`.NOLIST_DATA` (see on page 1-55)	Stops listing of data opcodes
`.NOLIST_DATFILE` (see on page 1-56)	Stops listing of data initialization files
`.NOLIST_WRAPDATA` (see on page 1-59)	Stops wrapping opcodes that don't fit listing column
`.PAGELENGTH` (see on page 1-61)	Defines the length of a listing page
`.PAGEWIDTH` (see on page 1-62)	Defines the width of a listing page
`.PREVIOUS` (see on page 1-63)	Reverts to a previously described `.SECTION`
`.REPEAT/.END_REPEAT` (see on page 1-65)	Provides an automated way for loop unrolling.
`.SECTION` (see on page 1-67)	Marks the beginning of a section
`.STRUCT` (see on page 1-69)	Defines and initializes data objects based on C `typedefs` from `.IMPORT` C header files
`.TYPE` (see on page 1-74)	Changes the default data type of a symbol. Used by C compiler
`.VAR` (see on page 1-75)	Defines and initializes 32-bit data objects
`.VCSE_` (see on page 1-80)	Used as optimization directives for VCSE components
`.WEAK` (see on page 1-81)	Creates a weak definition or reference

The ADSP-218x and ADSP-219x DSP assemblers also support Release 6.1 directives shown in Table 3-2 on page 3-4. To re-assemble a program that uses any of these directives with `easm218x` or `easm219x` assemblers, use the `-legacy` switch. For more information about the legacy directives and syntax conventions, see Chapter 3, "Assembler Enhancements and Legacy Support".

ⓘ Current (and future) DSP development tools may not support legacy directives or conventions of syntax. Analog Devices strongly recommends to revise source programs developed under Release 6.1 for use with VisualDSP++ tools.

.ALIGN, Specify an Address Alignment

The `.ALIGN` directive forces the address alignment of an instruction or data item. Use it to ensure section alignments in the `.LDF` file. You may use `.ALIGN` to ensure the alignment of the first element of a section, therefore providing the alignment of the object section ("input section" to the linker). You may also use the `INPUT_SECTION_ALIGN(#number)` linker command in the `.LDF` file to force all the following input sections to the specified alignment.

Refer to Chapter 2 "*Linker*" in the *VisualDSP++ 3.5 Linker and Utilities Manual for 16-Bit Processors* for more information on section alignment.

Syntax:

```
.ALIGN expression;
```

where

> *expression* — evaluates to an integer. It specifies the byte alignment requirement; its value must be a power of 2. When aligning a data item or instruction, the assembler adjusts the address of the current location counter to the next address that can be evenly divided by the value of *expression*. The expression set to 0 or 1 signifies no address alignment requirement.

In the absence of the `.ALIGN` directive, the default address alignment is 1.

Example

```
.ALIGN 0;   /* no alignment requirement */
…
.ALIGN 1;   /* no alignment requirement */
…
.SECTION/DM data1;
```

```
.ALIGN 2;
.VAR single;
     /* aligns the data item in DM on the word boundary,
        at the location with the address value that can be
        evenly divided by 2 */
.ALIGN 4;
.VAR samples1[100]=”data1.dat”;
     /* aligns the first data item in DM on the double-word
        boundary at the location with the address value that
        can be evenly divided by 4; advances other data items
        consequently */
```

.EXTERN, Refer to a Globally Available Symbol

The `.EXTERN` directive allows a code module to reference global data structures, symbols, etc. that are declared as `.GLOBAL` in other files. For additional information, see the `.GLOBAL` directive on page 1-50.

Syntax:

```
    .EXTERN symbolName1[, symbolName2, …];
```

where

> *`symbolName`* — the name of a global symbol to import. A single `.EXTERN` directive can reference any number of symbols on one line, separated by commas.

Example:

```
.EXTERN coeffs;
        // This code declares an external symbol to reference
        // the global symbol coeffs declared in the example code
        // in the .GLOBAL directive description.
```

.EXTERN STRUCT, Refer to a Struct Defined Elsewhere

The `.EXTERN STRUCT` directive allows a code module to reference a struct that was defined in another file. Code in the assembly file can then reference the data members by name, just as if they were declared locally.

Syntax:

```
.EXTERN STRUCT typedef structvarName;
```

where

`typedef` — the type definition for a struct VAR

`structvarName` — a struct VAR name

The `.EXTERN STRUCT` directive specifies a struct symbol name that was declared in another file. The naming conventions are the same for structs as for variables and arrays:

- If a struct was declared in a C file, refer to it with a leading _.
- If a struct was declared in an `.asm` file, use the name "as is", no leading _ is necessary.

The `.EXTERN STRUCT` directive optionally accepts a list, such as

```
.EXTERN STRUCT typedef structvarName [,STRUCT typedef structvarName
...]
```

The key to the assembler knowing the layout is the `.IMPORT` directive and the `.EXTERN STRUCT` directive associating the *`typedef`* with the struct VAR. To reference a data structure that was declared in another file, use the `.IMPORT` directive with the `.EXTERN` directive. This mechanism can be used for structures defined in assembly source files as well as in C files.

The .EXTERN directive supports variables in the assembler. If the program does reference struct members, .EXTERN STRUCT must be used because the assembler must consult the struct layout to calculate the offset of the struct members. If the program does not reference struct members, you can use .EXTERN for struct VARs.

Example:

```
.IMPORT "MyCelebrities.h";
   // 'Celebrity' is the typedef for struct var 'StNick'
   // .EXTERN means that '_StNick' is referenced within this
   // file, but not locally defined. This example assumes
   // StNick was declared in a C file and it must be
   // referenced with a leading underscore.
.EXTERN STRUCT Celebrity _StNick;
   // 'isSeniorCitizen' is one of the members of the 'Celebrity'
   // type
AR = _StNick->isSeniorCitizen;
```

.FILE, Override the Name of a Source File

The `.FILE` directive overrides the name of the source file. This directive may appear in the C/C++ compiler-generated assembly source file (`.S`). The `.FILE` directive is used to ensure that the debugger has the correct file name for the source file that had generated the object file.

Syntax:

```
.FILE “filename.ext”;
```

where

> *`filename`* — the name of the source file to associate with the object file. The argument is enclosed in double quotes.

Example:

```
.FILE “vect.c”;       // the argument may be a *.c file
.SECTION/DM data1;
      …
      …
```

.GLOBAL, Make a Symbol Globally Available

The `.GLOBAL` directive changes the scope of a symbol from local to global, making the symbol available for reference in object files that are linked to the current one.

By default, a symbol has local binding, meaning the linker can resolve references to it only from the local file, that is, the same file in which it is defined. It is visible only in the file in which it is declared. Local symbols in different files can have the same name, and the linker considers them to be independent entities. Global symbols are recognizable from other files; all references from other files to an external symbol by the same name will resolve to the same address and value, corresponding to the single global definition of the symbol.

You change the scope of one or more symbols with the `.GLOBAL` directive. Once the symbol is declared global, other files may refer to it with `.EXTERN`. For more information, refer to the `.EXTERN` directive on page 1-46. Note that `.GLOBAL` (or `.WEAK`) scope is required for symbols that appear in the `RESOLVE` commands in the `.LDF` file.

Syntax:

```
   .GLOBAL symbolName1[, symbolName2,…];
```

where

> *`symbolName`* — the name of a global symbol. A single `.GLOBAL` directive may define the global scope of any number of symbols on one line, separated by commas.

Example:

```
.VAR coeffs[10];        // declares a buffer
.VAR taps=100;          // declares a variable
.GLOBAL coeffs, taps;   // makes the buffer and the variable
                        // visible to other files
```

.IMPORT, Provide Structure Layout Information

The `.IMPORT` directive makes `struct` layouts visible inside an assembler program. The `.IMPORT` directive provides the assembler with the following structure layout information:

- The names of `typedefs` and `structs` available
- The name of each data member
- The sequence and offset of the data members
- Information as provided by the C compiler for the size of C base types (alternatively, for the `SIZEOF()` C base types).

Syntax:

```
.IMPORT "headerfilename1" [, "headerfilename2"…];
```

where

`headerfilename` —one or more comma-separated C header files enclosed in double quotes.

The `.IMPORT` directive does not allocate space for a variable of this type—that requires the `.STRUCT` directive.

The assembler takes advantage of knowing the struct layouts. The assembly programmer may reference struct data members by name in assembler source, as one would do in C. The assembler calculates the offsets within the structure based on the size and sequence of the data members.

If the structure layout changes, the assembly code need not change. It just needs to get the new layout from the header file, via the compiler. The make dependencies track the `.IMPORT` header files and know when a re-build is needed. Use the `-flags-compiler` assembler switch option (see on page 1-88) to pass options to the C compiler for the `.IMPORT` header file compilations.

The `.IMPORT` directive with one or more `.EXTERN` directives allows code in the module to refer to a struct variable that was declared and initialized elsewhere. The C struct can either be declared in C compiled code or another assembly file.

The `.IMPORT` directive with one or more `.STRUCT` directives declares and initializes variables of that structure type within the assembler section in which it appears.

For more information, refer to the `.EXTERN` directive on page 1-46 and the `.STRUCT` directive on page 1-46.

Example:

```
.IMPORT "CHeaderFile.h";
.IMPORT "ACME_IIir.h","ACME_IFir.h";
.SECTION/CODE program;
      // ... code that uses CHeaderFile, ACME_IIir, and
      // ACME_IFir C structs
```

.LEFTMARGIN, Set the Margin Width of a Listing File

The `.LEFTMARGIN` directive sets the margin width of a listing page. It specifies the number of empty spaces at the left margin of the listing file (`.LST`), which the assembler produces when you use the `-l` switch. In the absence of the `.LEFTMARGIN` directive, the assembler leaves no empty spaces for the left margin.

The assembler checks the `.LEFTMARGIN` and `.PAGEWIDTH` values against one another. If the specified values do not allow enough room for a properly formatted listing page, the assembler issues a warning and adjusts the directive that was specified last to allow an acceptable line width.

Syntax:

```
   .LEFTMARGIN expression;
```

where

> *`expression`* — evaluates to an integer from 0 to 100. Default is 0. Therefore, the minimum left margin value is 0 and maximum left margin value is 100. To change the default setting for the entire listing, place the `.LEFTMARGIN` directive at the beginning of your assembly source file.

Example:

```
.LEFTMARGIN 9;   /* the listing line begins at column 10. */
```

You can set the margin width only once per source file. If the assembler encounters multiple occurrences of the `.LEFTMARGIN` directive, it ignores all of them except the last directive.

.LIST/.NOLIST, Listing Source Lines and Opcodes

The `.LIST/.NOLIST` directives (on by default) turn on and off the listing of source lines and opcodes.

If `.NOLIST` is in effect, no lines in the current source, or any nested source, will be listed until a `.LIST`directive is encountered in the same source, at the same nesting level. The `.NOLIST` directive operates on the next source line, so that the line containing a `.NOLIST` will appear in the listing (and thus account for the missing lines).

Syntax:

```
.LIST;

.NOLIST;
```

These directives can appear multiple times anywhere in a source file, and their effect depends on their location in the source file.

.LIST_DATA/.NOLIST_DATA, Listing Data Opcodes

The `.LIST_DATA/.NOLIST_DATA` directives (off by default) turn the listing of data opcodes on or off. If `.NOLIST_DATA` is in effect, opcodes corresponding to variable declarations will not be shown in the opcode column. Nested source files inherit the current setting of this directive pair, but a change to the setting made in a nested source file will not affect the parent source file.

Syntax:

```
.LIST_DATA;

.NOLIST_DATA;
```

These directives can appear multiple times anywhere in a source file, and their effect depends on their location in the source file.

.LIST_DATFILE/.NOLIST_DATFILE, Listing Data Initialization Files

The `.LIST_DATFILE/.NOLIST_DATFILE` directives (off by default) turn the listing of data initialization files on or off. Nested source files inherit the current setting of this directive pair, but a change to the setting made in a nested source file will not affect the parent source file.

Syntax:

```
.LIST_DATFILE;

.NOLIST_DATFILE;
```

These directives can appear multiple times anywhere in a source file, and their effect depends on their location in the source file. They are used in assembly source files, but not in data initialization files.

.LIST_DEFTAB, Set the Default Tab Width for Listings

Tab characters in source files are expanded to blanks in listing files under the control of two internal assembler parameters that set the tab expansion width. The default tab width is normally in control, but it can be overridden if the local tab width is explicitly set with a directive.

The `.LIST_DEFTAB` directive sets the default tab width while the `.LIST_LOCTAB` directive sets the local tab width (see on page 1-58).

Both the default tab width and the local tab width can be changed any number of times via the `.LIST_DEFTAB` and `.LIST_LOCTAB` directives. The default tab width is inherited by nested source files, but the local tab width only affects the current source file.

Syntax:

```
.LIST_DEFTAB expression;
```

where

> *`expression`* — evaluates to an integer greater than or equal to 0. In the absence of a `.LIST_DEFTAB` directive, the default tab width defaults to 4. A value of 0 sets the default tab width.

Example:

```
// Tabs here are expanded to the default of 4 columns
.LIST_DEFTAB 8;
// Tabs here are expanded to 8 columns
.LIST_LOCTAB 2;
// Tabs here are expanded to 2 columns
// But tabs in "include_1.h" will be expanded to 8 columns
#include "include_1.h"
.LIST_DEFTAB 4;
// Tabs here are still expanded to 2 columns
// But tabs in "include_2.h" will be expanded to 4 columns
#include "include_2.h"
```

.LIST_LOCTAB, Set the Local Tab Width for Listings

Tab characters in source files are expanded to blanks in listing files under the control of two internal assembler parameters that set the tab expansion width. The default tab width is normally in control, but it can be overridden if the local tab width is explicitly set with a directive.

The `.LIST_LOCTAB` directive sets the local tab width, and the `.LIST_DEFTAB` directive sets the default tab width (see on page 1-57).

Both the default tab width and the local tab width can be changed any number of times via the `.LIST_DEFTAB` and `.LIST_LOCTAB` directives. The default tab width is inherited by nested source files, but the local tab width only affects the current source file.

Syntax:

```
.LIST_LOCTAB expression;
```

where

> *`expression`* — evaluates to an integer greater than or equal to 0. A value of 0 sets the local tab width to the current setting of the default tab width.

In the absence of a `.LIST_LOCTAB` directive, the local tab width defaults to the current setting for the default tab width.

Example: See the `.LIST_DEFTAB` example on page 1-57.

.LIST_WRAPDATA/.NOLIST_WRAPDATA

The `.LIST_WRAPDATA/.NOLIST_WRAPDATA` directives control the listing of opcodes that are too big to fit in the opcode column. By default, the `.NOLIST_WRAPDATA` directive is in effect.

This directive pair applies to any opcode that would not fit, but in practice, such a value will almost always be data (alignment directives can also result in large opcodes).

- If `.LIST_WRAPDATA` is in effect, the opcode value is wrapped so that it fits in the opcode column (resulting in multiple listing lines).
- If `.NOLIST_WRAPDATA` is in effect, the printout is what fits in the opcode column.

Nested source files inherit the current setting of this directive pair, but a change to the setting made in a nested source file will not affect the parent source file.

Syntax:

```
.LIST_WRAPDATA;

.NOLIST_WRAPDATA;
```

These directives can appear multiple times anywhere in a source file, and their effect depends on their location in the source file.

.NEWPAGE, Insert a Page Break in a Listing File

The .NEWPAGE directive inserts a page break in the printed listing file (.LST), which the assembler produces when you use the -l switch. The assembler inserts a page break at the location of the .NEWPAGE directive.

Syntax:

```
.NEWPAGE;
```

This directive may appear anywhere in your source file. In the absence of the .NEWPAGE directive, the assembler generates a page break after 66 lines from the previous page break.

.PAGELENGTH, Set the Page Length of a Listing File

The `.PAGELENGTH` directive controls the page length of the listing file produced by the assembler when you use the `-l` switch.

Syntax:

```
.PAGELENGTH expression;
```

where

> *`expression`* — evaluates to an integer from 0 to 66.
> It specifies the number of text lines per printed page. The default page length is now 0, which means the listing will have no page breaks.

To format the entire listing, place the `.PAGELENGTH` directive at the beginning of your assembly source file. If a page length value greater than 0 is too small to allow a properly formatted listing page, the assembler will issue a warning and use its internal minimum page length (approximately 10 lines).

Example:

```
.PAGELENGTH 50;   // starts a new page after printing 50 lines
```

ⓘ You can set the page length only once per source file. If the assembler encounters multiple occurrences of the directive, it ignores all of them except the last directive.

.PAGEWIDTH, Set the Page Width of a Listing File

The `.PAGEWIDTH` directive sets the page width of the listing file produced by the assembler when you use the `-l` switch (see on page 1-92).

Syntax:

```
.PAGEWIDTH expression;
```

where

`expression`—evaluates to an integer. Depending on setting of the `.LEFTMARGIN` directive, this integer should be at least equal to the `LEFTMARGIN` value plus 51.

The *`expression`* value can be any integer over 51. You cannot set this integer to be less than 51. There is no upper limit. If `LEFTMARGIN` = 0 and the `.PAGEWIDTH` value is not specified, the actual page width is set to 51.

To change the default number of characters per line in the entire listing, place the `.PAGEWIDTH` directive at the beginning of the assembly source file.

Example:

```
.PAGEWIDTH 72;    // starts a new line after 72 characters
                  // are printed on one line, assuming
                  // the .LEFTMARGIN setting is 0.
```

ⓘ You can set the page width only once per source file. If the assembler encounters multiple occurrences of the directive, it ignores all of them except the last directive.

.PREVIOUS, Revert to the Previously Defined Section

The `.PREVIOUS` directive instructs the assembler to set the current section in memory to the section that has been described immediately before the current one. The `.PREVIOUS` directive operates on a stack.

Syntax:

```
.PREVIOUS;
```

The following examples provide illegal and legal cases of the use of the consecutive `.PREVIOUS` directives.

Example of Illegal Directive Use

```
.SECTION/DATA data1;    // data
.SECTION/CODE program;  // instructions
.PREVIOUS;              // previous section ends, back to data1
.PREVIOUS;              // no previous section to set to
```

Example of Legal Directive Use

```
#define MACRO1
.SECTION/DATA data1;
   .VAR vd = 4;
.PREVIOUS;

.SECTION/DATA data1;        // data
   .VAR va = 1;
.SECTION/CODE program;      // instructions
   .VAR vb = 2;

// MACRO1
   MACRO1
   .PREVIOUS;
      .VAR vc = 3;
```

evaluates as:

```
.SECTION/DATA data1;         // data
   .VAR va = 1;
.SECTION/CODE program;       // instructions
   .VAR vb = 2;

// MACRO1
.SECTION/DATA data2;
   .VAR vd = 4;
.PREVIOUS;                   // end data2, section program
.PREVIOUS;                   // end program, start data1
   .VAR vc = 3;
```

.REPEAT()/.END_REPEAT, Repeat an Instruction Sequence

The `.REPEAT()/.END_REPEAT` directive pair is implemented only for ADSP-219x DSPs.

The `.REPEAT()/.END_REPEAT` directive pair provides an automated way for loop unrolling. The `.REPEAT()` directive marks the beginning of a code block to be generated by the assembler specified number of times. Statements between `.REPEAT()` and the following `.END_REPEAT` directive comprise the contents of the code block, which is a single instruction or a multiple instruction sequence. The instruction(s) within the `REPEAT` block are inlined by the assembler.

Repeat directives must not span section boundaries and are applicable to code sequences only, not data. Ensure that each `.REPEAT()` directive has a terminating `.END_REPEAT`; likewise, each closing `.END_REPEAT` has a beginning `.REPEAT()`. Repeat code blocks can not contain local labels to avoid the duplication of a code block with a local label. Nested repeat blocks are not supported.

The syntax for the `.REPEAT()` directive is:

```
.REPEAT(expression);
/* sequence of one or more instructions */
.END_REPEAT;
```

where

> *`expression`* — evaluates to a constant at assembly time. The expression is the total number of times the instruction sequence repeats. The lowest meaningful number is 1; therefore, `.REPEAT(1);` is valid.

For example,

```
/* The following assembler REPEAT directive example: */
#define NUM_REPEAT 3

.SECTION/CODE program;

.REPEAT(NUM_REPEAT);
    nop;
    nop;
.END_REPEAT;

/* assemles to: */
    nop;
    nop;
    nop;
    nop;
    nop;
    nop;
```

.SECTION, Declare a Memory Section

The `.SECTION` directive marks the beginning of a logical section mirroring an array of contiguous locations in your processor memory. Statements between one `.SECTION` and the following `.SECTION` directive, or the end-of-file, comprise the content of the section.

Syntax:

```
.SECTION/ type sectionName [sectionType];
```

where

- `/type` keyword — maps a section into the DSP memory. This mapping should follow from the chip's memory architecture. The *`type`* must match the memory type of the input section of the same name used by the Linker Description File (LDF) to place the section. The `.SECTION` directive types are:

Memory/Section Type	Description
`PM` or `CODE`	**ADSP-218x DSPs:** 24-bit PM Memory or Section that contains instructions and possibly data **ADSP-219x DSPs:** 24-bit Memory or Section that contains instructions and possibly 24-bit data
`DM` or `DATA`	**ADSP-218x DSPs:** 16-bit DM Memory or Section that contains data **ADSP-219x DSPs:** Memory or Section that contains 16-bit data

- *`sectionName`* — section name symbol which is not limited in length and is case-sensitive. Section names must match the corresponding input section names used by the `.LDF` file to place the section. Use the default `.LDF` file included in the `...\ADSP-218x and ADSP-219x\ldf` subdirectory of the VisualDSP++ installation directory, or write your own LDF.

Note: Some section names starting with "." have certain meaning within the linker. The dot (.) should not be used as the initial character in *sectionName*.

- *sectionType* — an optional ELF section type identifier. The assembler uses the default `SHT_PROGBITS` when this identifier is absent. Valid `sectionTypes` are described in the `ELF.h` header file, which is available from third-party software development kits. For more information on the ELF file format, see the *VisualDSP++ 3.5 Linker and Utilities Manual for 16-Bit Processors*.

Example:

```
/* Declared below memory sections correspond to the
   default LDF's input sections. */
.SECTION/DM data1;         // memory section
.SECTION/CODE code;        // memory section
…
```

.STRUCT, Create a Struct Variable

The `.STRUCT` directive allows you to define and initialize high-level data objects within the assembly code. The `.STRUCT` directive creates a struct variable using a C-style *`typedef`* as its guide from `.IMPORT` C header files.

Syntax:

```
.STRUCT typedef structName;
.STRUCT typedef structName = {};
.STRUCT typedef structName = { struct-member-initializers
        [ ,struct-member-initializers... ] };
.STRUCT typedef ArrayOfStructs[] =
        { struct-member-initializers
        [ ,struct-member-initializers... ] };
```

where

`typedef` — the type definition for a struct VAR

`structName` — a `struct` name

`struct-member-initializers` — per struct member initializers

The `{ }` curly braces are used for consistency with the C initializer syntax. Initialization can be in "long" or "short" form where data member names are not included. The short form corresponds to the syntax in C compiler struct initialization with these changes:

- Change C compiler keyword "`struct`" to "`.struct`"
- Change C compiler constant string syntax "`MyString`" to `'MyString'`

The long form is assembler specific and provides the following benefits:

- Provides better error checking
- Supports self-documenting code
- Protects from possible future changes to the layout of the `struct`. If an additional member is added before the member is initialized, the assembler will continue to offset to the correct location for the specified initialization and zero-initialize the new member.

Any members that are not present in a long-form initialization are initialized to zero. For example, if struct `StructThree` has three members (`member1`, `member2`, and `member3`)

```
.STRUCT StructThree myThree {
   member1 = 0xaa,
   member3 = 0xff
};
```

then `member2` will be initialized to 0 because no initializer was present for it. If no initializers are present, the entire `struct` is zero-initialized.

If data member names are present, the assembler validates that the assembler and compiler are in agreement about these names. The initialization of data struct members declared via the assembly `.STRUCT` directive is processor-specific.

Example 1. Long-Form .STRUCT Directive

```
#define NTSC 1
   // contains layouts for playback and capture_hdr
.IMPORT "comdat.h";
.STRUCT capture_hdr myLastCapture = {
   captureInt = 0,
   captureString = ‘InitialState’
   };
.STRUCT myPlayback playback = {
   theSize = 0,
   ready = 1,
   stat_debug = 0,
   last_capture = myLastCapture,
   watchdog = 0,
   vidtype = NTSC
   };
```

Example 2. Short-Form .STRUCT Directive

```
#define NTSC 1
   // contains layouts for playback and capture_hdr
.IMPORT "comdat.h";
.STRUCT capture_hdr myLastCapture = { 0, ‘InitialState’ };
.STRUCT playback myPlayback = { 0, 1, 0, myLastCapture, 0, NTSC };
```

Example 3. Long-Form .STRUCT Directive to Initialize an Array

```
.STRUCT structWithArrays XXX = {
   scalar = 5,
   array1 = { 1,2,3,4,5 },
   array2 = { "file1.dat" },
   array3 = "WithBraces.dat"  // must have { } within dat
   };
```

In the short-form, nested braces can be used to perform partial initializations as in C. In Example 4 below, if the second member of the struct is an array with more than four elements, the remaining elements will be initialized to zero.

Example 4. Short-Form .STRUCT Directive to Initialize an Array

```
.STRUCT structWithArrays XXX = { 5, { 1,2,3,4 }, 1, 2 };
```

Example 5. Initializing a Pointer

A struct may contain a pointer. Initialize pointers with symbolic references.

```
.EXTERN outThere;
.VAR myString[] = 'abcde',0;
.STRUCT structWithPointer PPP = {
        scalar = 5,
        myPtr1 = myString,
        myPtr2 = outThere
   };
```

Example 6. Initializing a Nested Structure

A struct may contain a struct. Use fully qualified references to initialize nested struct members. The struct name is implied.

For example, the reference "`scalar`" ("`nestedOne->scalar`" implied) and "`nested->scalar1`" ("`nestedOne->nested->scalar1`" implied).

```
.STRUCT NestedStruct nestedOne = {
   scalar = 10,
   nested->scalar1 = 5,
   nested->array = { 0x1000, 0x1010, 0x1020 }
   };
```

Example 7. Array of Structs

The following is an example of an array of structs.

```
// C file ovl_struct.h
//
// typedef struct  {
//      int run_addr;
//      int live_addr;
//      int run_size;
//      int live_size;
//      int run_page;
//      int live_page;
// } ovl_struct;

.IMPORT "ovl_struct.h";

.SECTION/DATA data1;

.EXTERN _ov_word_size_live_1, _ov_word_size_live_2,
        _ov_word_size_live_3;
.EXTERN _ov_word_size_run_1, _ov_word_size_run_2,
        _ov_word_size_run_3;
.EXTERN _ov_startaddress_1, _ov_startaddress_2,
        _ov_startaddress_3;
.EXTERN _ov_runtimestartaddress_1, _ov_runtimestartaddress_2,
        __ov_runtimestartaddress_3;

.STRUCT ovl_struct _ovl_tab[] = {
      {
           PAGE (_ov_startaddress_1),
                 _ov_startaddress_1, ov_word_size_live_1,
           PAGE (_ov_runtimestartaddress_1),
                 _ov_runtimestartaddress_1, ov_word_size_run_1
      },
      {
           PAGE (_ov_startaddress_2),
                 _ov_startaddress_2, ov_word_size_live_2,
           PAGE (_ov_runtimestartaddress_2),
                 _ov_runtimestartaddress_2, ov_word_size_run_2
      },
      {
           PAGE (_ov_startaddress_3),
                 _ov_startaddress_3, ov_word_size_live_3,
           PAGE (_ov_runtimestartaddress_3),
                 _ov_runtimestartaddress_3, ov_word_size_run_3
      },
    };
```

.TYPE, Change Default Symbol Type

The `.TYPE` directive directs the assembler to change the default symbol type of an object.

Syntax:

```
.TYPE symbolName, symbolType;
```

where

- *`symbolName`* — the name of the object to which the *`symbolType`* should be applied.
- *`symbolType`* — an ELF symbol type `STT_*`. Valid ELF symbol types are listed in the `ELF.h` header file. By default, a label has an `STT_FUNC` symbol type, and a variable or buffer name defined in a storage directive has an `STT_OBJECT` symbol type.

This directive may appear in the compiler-generated assembly source file (`.S`).

.VAR, Declare a Data Variable or Buffer

The `.VAR` directive declares and optionally initializes 16-bit or 24-bit variables and data buffers. A variable uses a single memory location, and a data buffer uses an array of memory locations.

When declaring or initializing variables:

- A `.VAR` directive may appear only within a section. The assembler associates the variable with the memory type of the section in which the `.VAR` appears.
- A single `.VAR` directive can declare any number of variables or buffers, separated by commas, on one line.

  Unless the absolute placement for a variable is specified with the `RESOLVE()` command (from an `.LDF` file), the linker places variables in consecutive memory locations.
  For example, `.VAR d,f,k[50];` sequentially places symbols `x`, `y` and 50 elements of the buffer `z` in the DSP memory. Therefore, code example may look as:

  ```
  .VAR d;
  .VAR f;
  .VAR k[50];
  ```

  An optional initializer can specify the default value after boot time. By default, initializer values are 16-bit wide (in 24-bit section left aligned). For example,

  ```
  .VAR myhex = 0x1234;
  .VAR myint = -25;
  .VAR myfract = 0.25r;
  .VAR myarray[4] = 0x0, 0x1, 0x2, 0x3;
  ```

- The number of initializer values may not exceed the number of variables or buffer locations that you declare.

```
.SECTION/DATA data1;
    .VAR buffer [] = {1,2,3,4};
.SECTION/CODE program;
    LO = LENGTH( buffer );   // Returns 4
```

Syntax:

The `.VAR` directive takes one of the following forms:

```
.VAR varName1[,varName2,…];
.VAR = initExpression1, initExpression2,…;
.VAR varName1 = initexpression1 [,varName2 = initexpression2,…];
.VAR bufferName[] = initExpression1, initExpression2,…;
.VAR bufferName[] = "fileName";
.VAR bufferName[length] = "fileName";
.VAR bufferName1[length] [,bufferName2[length],…];
.VAR bufferName[length] = initExpression1,initExpression2,…;
```

where:

- *`varName`* —represents user-defined symbols that identify variables.
- *`bufferName`* —represents user-defined symbols that identify buffers.
- *`fileName`* parameter—indicates that the elements of a buffer get their initial values from the *`fileName`* data file. `<fileName>` can consist of the actual name and path specification for the data file. If the initialization file is in current directory of your operating system, only the *`fileName`* need be given inside brackets.

  Initializing from files is useful for loading buffers with data, such as filter coefficients or FFT phase rotation factors that are generated by other programs. The assembler determines how the values are stored in memory when it reads the data files.

- Ellipsis (…)—represents a comma-delimited list of parameters.
- `[`*`length`*`]`—optional parameter that defines the length (in words) of the associated buffer. When length is not provided, the buffer size is determined by the number of initializers.
- Brackets (`[ ]`)—enclosing the optional [*`length`*] is required. For more information, see the following `.VAR` examples.
- *`initExpressions`* parameters—set initial values for variables and buffer elements.

The following lines of code demonstrate some `.VAR` directives:

```
.VAR samples[] = 10, 11, 12, 13, 14;
      // declare and initialize an implicit-length buffer
      // since there are five values, this has the same effect
      // as samples[5]
.VAR Ins, Outs, Remains;
      // declare three uninitialized variables
.VAR samples[100] = "inits.dat";
      // declare a 100-location buffer and initialize it
      // with the contents of the inits.dat file;
.VAR taps=100;
      // declare a variable and initialize the variable
      // to 100
.VAR twiddles[10] = "phase.dat";
      // declare a 10-location buffer and load the buffer
      // with the contents of the phase.dat file
```

File Initializers

Arrays often store coefficients that have been calculated by third-party tools. In such cases, the file initialization is helpful. For example,

```
.VAR twididdles[16] = "phase.dat";
     // declare a 10-location buffer and load the buffer
     // with the contents of the phase.dat file
```

The VisualDSP++ assembler opens the file and reads word by word. Hexadecimal values require a leading '`0x`' and fractional values a trailing '`r`'. The individual values are separated by either commas, blanks, tabs or line breaks (carriage return).

In case the file is located in a different directory, use the `-I` switch (see on page 1-92) to specify an additional `include` path.

.VAR and ASCII String Initialization Support

The `easm218x` and `easm219x` assemblers support ASCII string initialization. This allows the full use of the ASCII character set, including digits, and special characters. The characters are stored in the lower byte of 16-bit words. The MSBs are cleared.

String initialization takes one of the following forms:

```
.VAR symbolString[length] = 'initString',0;
.VAR symbolString[] = 'initString', 0;
```

The trailing zero character is optional. It simulates ANSI-C string representation. Note that the number of initialization characters defines length of a string (implicit-size initialization). For example,

```
.VAR x[13] = 'Hello world!', 0;
.VAR x[] = 'Hello world!', 0;
```

The assembler also accepts ASCII characters within comments. Please note special characters handling:

```
.VAR s1[] = '1st line',13,10,'2nd line',13,10,0;
                                     // carriage return
.VAR s2[] = 'say:"hello"',13,10,0;   // quotation marks
.VAR s2[] = 'say:',39,'hello',39,13,10,0;
                                    // simple quotation marks
```

.VAR/CIRC Qualifier

The VisualDSP++ 3.5 assembler supports circular buffer declaration and addressing. This is accomplished with the `.VAR/CIRC` qualifier. For more information about the `/CIRC` qualifier and circular buffers, refer to ".VAR/CIRC, Declare a Circular Buffer" on page 3-25.

The `.VAR/CIRC` qualifier is used only with ADSP-218x DSPs.

.VAR/INIT24 Directive

A special case of the `.VAR` directive, `.VAR/INIT24`, allows declaration and and initialization of 24-bit wide data structures in program memory sections. The `.VAR/INIT24` directive takes this form:

```
.VAR/INIT24 varName, … = initExpression, …;
```

Example:

```
.SECTION/PM program;
.VAR/INIT24 myPMdata = 0x157001;
            // declare a 24-bit variable in program memory
```

Note that the following variables are initialized in the same way.

```
.VAR x = 1;
.VAR/INIT24 y = 256;
.VAR/INIT24 z = 0x100;
```

.VCSE Optimization Directives

The `.VCSE_` directives are the optimization directives for VCSE components. You will be able to see them generated in the VCSE assembler code for the purposes of providing the linker with sufficient information to enable space efficient and speed optimizations that would otherwise be missed.

The `.VCSE_METHODCALL_START` and `.VCSE_METHODCALL_END` directives mark VCSE methods for linker code/data elimination. The linker is provided the interface name and actual offset of the corresponding entry in the method table.

The `.VCSE_RETURNS` directive is used for marking VCSE constant methods.

.WEAK, Support a Weak Symbol Definition and Reference

The `.WEAK` directive supports weak binding for a symbol. Use this directive where the symbol is defined, replacing the `.GLOBAL` directive to make a weak definition and the `.EXTERN` directive to make a weak reference.

Syntax:

```
.WEAK symbol;
```

where

symbol — the user-defined symbol

While the linker will generate an error if two objects define global symbols with identical names, it will allow any number of instances of weak definitions of a name. All will resolve to the first, or to a single, global definition of a symbol.

One difference between `.EXTERN` and `.WEAK` references is that the linker will not extract objects from archives to satisfy weak references. Such references, left unresolved, have the value of 0.

ⓘ The `.WEAK` (or `.GLOBAL` scope) directive is required for symbols that appear in the `RESOLVE` commands in the `.LDF` file.

Assembler Command-Line Reference

This section describes the assembler command-line interface and switch set. It describes the assembler's switches, which are accessible from the operating system's command line or from the VisualDSP++ environment.

This section contains:

- "Running the Assembler" on page 1-83
- "Command-Line Switch Summary and Descriptions" on page 1-85

Command-line switches control certain aspects of the assembly process, including debugging information, listing, and preprocessing. Because the assembler automatically runs the preprocessor as your program is being assembled (unless you use the `-sp` switch, described on on page 1-97), the assembler's command line can receive input for the preprocessor program and direct its operation. For more information on the preprocessor, see Chapter 2 "Preprocessor".

When developing a DSP project, you may find it useful to modify the assembler's default options settings. The way you set the assembler's options depends on the environment used to run the DSP development software.

See "Specifying Assembler Options in VisualDSP++" on page 1-99 for more information.

Running the Assembler

To run the assembler from the command line, type the name of the assembler program followed by arguments in any order, and the name of the assembly source file.

```
easm218x [ -switch1 [ -switch2 … ] ] sourceFile
easm219x [ -switch1 [ -switch2 … ] ] sourceFile
```

where:

`easm218x` or `easm219x`	Name of the assembler program for the ADSP-218x or ADSP-219x processors, respectively.
`-switch`	Switch (or switches) to process. The command-line interface offers many optional switches that select operations and modes for the assembler and preprocessor. Some assembler switches take a file name as a required parameter.
`sourceFile`	Name of the source file to assemble.

The name of the source file to assemble can be provided as:

- *`ShortFileName`* — a file name without quotes (no special characters)
- *`LongFileName`* — a quoted file name (may include spaces and other special path name characters)

The assembler outputs a list of command-line options when run without arguments (same as `-h[elp]`).

The assembler supports relative and absolute path names. When you specify an input or output file name as a parameter, follow these guidelines for naming files:

- Include the drive letter and path string if the file is not in the current project directory.

- Enclose long file names in double quotation marks; for example, “long file name”.
- Append the appropriate file name extension to each file.

Table 1-10 summarizes file extension conventions accepted by the VisualDSP++ environment.

Table 1-10. File Name Extension Conventions

Extension	File Description
`.asm`	Assembly source file **Note:** The assembler treats files with unrecognized extensions as assembly source files.
`.is`	Preprocessed assembly source file
`.h`	Header file
`.lst`	Listing file
`.doj`	Assembled object file in ELF/DWARF-2 format
`.dat`	Data initialization file

Assembler command-line switches are case-sensitive. For example, the following command line

```
easm219x -proc ADSP-2195 -l p1.lst -Dmaximum=100 -v -o bin\p1.doj p1.asm
```

runs the assembler with

`-proc ADSP-2195` — specifies assembles instructions unique to ADSP-2195 processor.

`-l p1.lst` — directs the assembler to output the listing file.

`-Dmaximum=100` — defines the preprocessor macro to be 100.

`-v` — displays verbose information on each phase of the assembly.

`-o bin\p1.doj` — specifies the name and directory for the assembled object file.

`p1.asm` — identifies the assembly source file to assemble.

Command-Line Switch Summary and Descriptions

This section describes the assembler command-line switches in ASCII collation order. A summary of the assembler switches appears in Table 1-11. Detailed descriptions of each assembler switch start on page 1-87.

Table 1-11. Assembler Command-Line Switch Summary

Switch Name	Purpose
`-Ao` *`filename`* (on page 1-87)	Writes `RESOLVE()` LDF commands for absolute placement to the specified `.LDF` file.
`-c` (on page 1-87)	Directs the assembler to preserve the case-sensitive mode.
`-Dd`*`macro`*`[=`*`definition`*`]` (on page 1-88)	Passes macro definition to the preprocessor.
`-flags-compiler -opt1 [,-opt2...]` (on page 1-88)	Passes each comma-separated option to the compiler. (Used when compiling `.IMPORT` C header files.)
`-flags-pp -opt1 [,-opt2...]` (on page 1-90)	Passes each comma-separated option to the preprocessor.
`-g` (on page 1-90)	Generates debug information (DWARF-2 format).
`-h[elp]` (on page 1-91)	Outputs a list of assembler switches.
`-i|-I` *`pathname`* (on page 1-91)	Searches a directory for included files.
`-l` *`filename`* (on page 1-92)	Outputs the named listing file.
`-li` *`filename`* (on page 1-92)	Outputs the named listing file with `#include` files expanded.
`-legacy` (on page 1-92)	Calls an additional preprocessing step and processes the source program written in Release 6.1 assembly language.
`-M` (on page 1-93)	Generates make dependencies for `#include` and data files only; does not assemble. .

Table 1-11. Assembler Command-Line Switch Summary (Cont'd)

Switch Name	Purpose
`-MM` (on page 1-93)	Generates make dependencies for `#include` and data files. Use `-MM` for make dependencies with assembly.
`-Mo` *`filename`* (on page 1-94)	Writes make dependencies to the *`filename`* specified. If `-Mo` is not present, the default is `<stdout>` display.
`-Mt` *`filename`* (on page 1-94)	Specifies the make dependencies target name. If `-Mt` is not present, the default is base name plus `'DOJ'`.
`-o` *`filename`* (on page 1-94)	Outputs the named object [binary] file.
`-pp` (on page 1-95)	Runs the preprocessor only; does not assemble.
`-proc` *`processor`* (on page 1-95)	Specifies a processor for which the assembler should produce suitable code.
`-si-revision` *`version`* -- NEW??? (on page 1-96)	Specifies a silicon revision of the specified processor.
`-sp` (on page 1-97)	Assembles without preprocessing.
`-v[erbose]` (on page 1-97)	Displays information on each assembly phase.
`-version` (on page 1-97)	Displays version information for the assembler and preprocessor programs.
`-w` (on page 1-98)	Removes all assembler-generated warnings.
`-Wnumber[,number ...]` (on page 1-98)	Selectively disables warnings by one or more message numbers. For example, `-W1092` disables warning message `ea1092`.

A description of each command-line switch includes information about case-sensitivity, equivalent switches, switches overridden/contradicted by the one described, and naming and spacing constraints on parameters.

-Ao filename

The `-Ao filename` switch directs the assembler to write resolve commands to the specified Linker Description File (`.LDF`). This switch is optional for legacy assembly of source programs with absolute placement directives.

The assembler generates a `RESOLVE()` command for each `.VAR/ABS=address` directive in a legacy source program, a program developed under Release 5x/6x. The assembler outputs a resolve `.LDF` header file. The linker inputs the file (if manually referenced with the `INCLUDE()` command) in your project's LDF. You can use a default resolve `.LDF` file name, composed of the '`resolve_`' prefix and the `.LDF` extension, or override it with the `filename` argument.

For example,

```
easm218x -legacy -c cmn.dsp
// generates cmn.doj and resolve_cmn.ldf.

easm218x -legacy -c cmn.dsp -Ao resolve1.ldf
// generates cmn.doj and resolve1.ldf
```

Note that the symbols in the assembler-generated `RESOLVE()` commands are global. For more information about the `RESOLVE()` command, see the *VisualDSP++ 3.5 Linker and Utilities Manual for 16-Bit Processors* and ".VAR/ABS, Place a Variable at the Specified Address" on page 3-25.

-c

The `-c` (preserve case) switch directs the assembler to preserve the case-sensitive mode. By default, previous versions of the assembler software set program symbols to upper-case, whereas the `easm218x` and `easm219x` assemblers do not. Use the `-c` switch in combination with `-legacy` to preserve the original case of program symbols when reassembling or linking legacy (coded in the previous version of the assembler language) and/or `easm218x`-written routines.

For example, Release 6.1 assembler processes the `CALL Start;` statement coded in your `p1.dsp` program:

```
asm21 p1.dsp       // produces a relocation against START
asm21 p1.dsp -c    // produces a relocation against Start
```

VisualDSP++ 3.5 assembler re-assembles `p1.dsp`. For example,

```
easm218x p1.dsp -legacy -proc ADSP-2181
         /* produces a relocation against START */
easm218x p1.dsp -legacy -c -proc ADSP-2181
         /* produces a relocation against Start */
```

VisualDSP++ 3.5 assembler differentiates between lowercase and uppercase characters by default—Release 6.1 assembler did not. Refer to Chapter 3, "Assembler Enhancements and Legacy Support" for more information.

-Dmacro[=definition]

The `-D` (define macro) switch directs the assembler to define a macro and pass it to the preprocessor. See "Using Assembler Feature Macros" on page 1-15 for the list of predefined macros. For example,

```
-Dinput             // defines input as 1
-Dsamples=10        // defines samples as 10
-Dpoint="Start"     // defines point as the string "Start"
```

-flags-compiler

The `-flags-compiler -opt1 [-opt2...]` switch passes each comma-separated option to the C compiler. The switch takes a list of one or more comma-separated compiler options that are passed on the compiler command line for compiling `.IMPORT` headers. The assembler calls the compiler to process each header file in an `.IMPORT` directive. It calls the compiler with the `-debug-types` option along with any `-flags-compiler` options given on the assembler command line. For example,

```
// file.asm has .IMPORT "myHeader.h";
easm219x -flags-compiler -I\Path,-I. file.asm
```

The rest of the assembly program, including its `#include` files, are processed by the assembler preprocessor. The `-flags-compiler` switch processes a list of one or more legal C compiler options, including `-D` and `-I` options.

User-Specified Defines Options

The `-D` (defines) options on the assembler command line are passed to the assembler preprocessor, but they are not passed to the compiler for `.IMPORT` header processing. If you have `#defines` for the `.IMPORT` header compilation, they must be explicitly specified with the `-flags-compiler` switch.

For example,

```
// file.asm has .IMPORT "myHeader.h";
easm219x -DaDef -flags-compiler -DbDef,-DbDefTwo=2. file.asm
// -DaDef is not passed to the compiler
cc219x -debug-types -flags-compiler -DbDef,-DbDefTwo=2 myHeader.h
```

See "Using Assembler Feature Macros" on page 1-15 for the list of predefined macros including default macros.

Include Options

The `-I` (include search path) options and `-flags-compiler` options are passed to the C compiler for each `.IMPORT` header compilation. The compiler `include` path is always present automatically. Using the

`-flags-compiler` option, you can control the order the `include` directories are searched. The `-flags-compiler` switch attributes always take precedence from the assembler's `-I` options.

For example,

```
easm219x -I\aPath -DaDef -flags-compiler -I\cPath,-I. file.asm

cc219x -I\aPath -DaDef -flags-compiler -I\cPath,-I. myHeader.h
```

The `IMPORT` C header files are preprocessed by the C compiler preprocessor. The `struct` headers are standard C headers and the standard C compiler preprocessor is needed. The rest of the assembly program, including its `#include` files, are processed by the assembler preprocessor.

Assembly programs are pre-processed using the `PP` preprocessor (the assembler/linker preprocessor) as well as `-I` and `-D` options from the assembler command-line. However, the `pp` call does not receive the `-flags-compiler` switch options.

-flags-pp -opt1 [,-opt2...]

The `-flags-pp` switch passes each comma-separated option to the preprocessor.

Use `-flags-pp` with caution. For example, if the `pp` legacy comment syntax is enabled, the comment characters become unavailable for non-comment syntax.

-g

The `-g` (generate debug information) switch directs the assembler to generate complete data type information for arrays, functions, and the C structs. It will also generate DWARF2 function information with starting and ending ranges based on the `myFunc: … myFunc.end:` label boundaries, as well as line number and symbol information in DWARF2 binary format, allowing you to debug the assembly source files.

With assembler's `-g` debugging is in effect, the assembler produces a warning when it is unable to match a `*.end` label to a matching beginning label. This feature can be disabled using the `-Wnnnn` switch (see on page 1-98).

-h[elp]

The `-h` or `-help` switch directs the assembler to output to standard out a list of command-line switches with a syntax summary.

-i|I directory

The `-i directory` or `-I directory` (include directory) switch directs the assembler to append the specified directory or a list of directories separated by semicolons (;) to the search path for included files. These files are:

- Header files (`.h`) included with the `#include` preprocessor command
- Data initialization files (`.dat`) specified with the `.VAR` assembly directive

The assembler passes this information to the preprocessor; the preprocessor searches for included files in the following order:

1. Current project directory (`.DPJ`)
2. `…\218x\include` subdirectory (for ADSP-218x DSPs) or `…\219x\include` subdirectory (for ADSP-219x DSPs) of the VisualDSP++ installation directory
3. Specified directory (or list of directories). The order of the list defines the order of multiple searches.

Current directory is your `*.dpj` project directory, not the directory of the assembler program. Usage of full path names for the `-I` switch on the command line is recommended. For example,

```
easm219x -proc ADSP-2195 -I \bin\include
```

-l filename

The `-l filename` (listing) switch directs the assembler to generate the named listing file. Each listing file (`.LST`) shows the relationship between your source code and instruction opcodes that the assembler produces. For example,

```
easm219x -proc ADSP-2195 -flags-compiler -I\path,-I. -l file.lst file.asm
```

The file name is a required argument to the `-l` option. For more information, see "Reading a Listing File" on page 1-18.

-li filename

The `-l` (listing) switch directs the assembler to generate the named listing file with `#include` files. The file name is a required argument to the `-l` option. For more information, see "Reading a Listing File" on page 1-18.

-legacy

The `-legacy` (accept legacy code) switch directs the assembler to process source programs developed using Release 6.x (and older) assembler software.

Note that the new C structs features (see "Using Assembler Support for C Structs" on page 1-13) are not available with the `-legacy` switch.

The assembler accepts legacy directives listed in Table 3-2 on page 3-4. Note that Release 5x/6x assembler automatically uppercases symbols. To preserve the original case of program symbols, use the `-legacy -c` combination. For more information about the `-c` switch, see "-c" on page 1-87.

You may need to revise source code programs when re-assembling with `easm218x` and `easm219x` assemblers. Please review any diagnostic or error messages issued during the assembly of Release 6.1

source programs. For information on how to revise Release 5x/6x programs to comply with VisualDSP++ assembler syntax, see Chapter 3, "Assembler Enhancements and Legacy Support".

-M

The `-M` (generate make rule only) assembler switch directs the assembler to generate make dependency rules, which is suitable for the make utility, describing the dependencies of the source file. No object file is generated when you use the `-M` switch. For make dependencies with assembly, use `-MM`.

The output, an assembly make dependencies list, is written to `stdout` in the standard command-line format:

```
"target_file": "dependency_file.ext"
```

where *`dependency_file.ext`* may be an assembly source file, a header file included with the `#include` preprocessor command, a data file, or a header file imported via the `.IMPORT` directive.

The `-Mo` *`filename`* switch (on page 1-94) writes make dependencies to the *`filename`* specified instead of `<stdout>`. For consistency with the compilers, when the `-o` *`filename`* is used with `-M`, the assembler outputs the make dependencies list to the named file. The `-Mo` *`filename`* takes precedence if both `-o` *`filename`* and `-Mo` *`filename`* are present with `-M`.

-MM

The `- MM` (generate make rule and assemble) assembler switch directs the assembler to output a rule, which is suitable for the make utility, describing the dependencies of the source file. The assembly of the source into an object file proceeds normally. The output, an assembly make dependencies list, is written to `stdout`.The only difference between `-MM` and `-M` actions is that the assembling continues with `-MM`. See "-M" for more information.

-Mo filename

The `-Mo` (output make rule) assembler switch specifies the name of the make dependencies file which the assembler generates when you use the `-M` or `-MM` switch. If `-Mo` is not present, the default is `<stdout>` display. If the named file is not in the current directory, you must provide the path name in double quotation marks (“ ”).

The `-Mo` *`filename`* option takes precedence over the `-o` *`filename`* option.

-Mt filename

The -`Mt` *`filename`* (output make rule for the named object) assembler switch specifies the name of the object file for which the assembler generates the make rule when you use the `-M` or `-MM` switch. If the named file is not in the current directory, you must provide the path name. If `-Mt` is not present, the default is the base name plus the .`DOJ` extension.
See “-M” for more information.

-o filename

The `-o` *`filename`* (output file) switch directs the assembler to use the specified *`filename`* argument for the output file. This switch names the output, whether for conventional production of an object, a preprocessed, assemble produced file (.`pp`), or make dependency (`-M`). The assembler uses the root input file name for the output and appends a `.DOJ` extension.

Some examples of this switch syntax are:

```
easm219x -proc ADSP-2195 -pp -o test1.is test.asm
         // preprocessed output goes into test1.is

easm219x -proc ADSP-2195 -o “C:\bin\prog3.doj” prog3.asm
         // specify directory for the object file
```

-pp

The `-pp` (proceed with preprocessing only) switch directs the assembler to run the preprocessor, but stop without assembling the source into an object file. When assembling with the `-pp` switch, the `.IS` file is the final result of the assembly. By default, the output file name uses the same root name as the source, with the extension `.is`.

-proc processor

The `-proc` *`processor`* (target processor) switch specifies that the assembler should produce code suitable for the specified processor. The *`processor`* identifier has a “`ADSP-21xx`” format.

The *`processor`* identifiers directly supported in VisualDSP++ 3.5 are:

- **For the ADSP-218x DSPs** — `ADSP-2181`, `ADSP-2183`, `ADSP-2184`, `ADSP-2184L`, `ADSP-2184N`, `ADSP-2185`, `ADSP-2185L`, `ADSP-2185M`, `ADSP-2185N`, `ADSP-2186`, `ADSP-2186L`, `ADSP-2186M`, `ADSP-2186N`, `ADSP-2187L`, `ADSP-2184L`, `ADSP-2187N`, `ADSP-2188L`, `ADSP-2188N`, `ADSP-2189M`, `ADSP-2189N`
- **For the ADSP-219x DSPs** — `ADSP-2191`, `ADSP-2192-12`, `ADSP-2195`, `ADSP-2196`, `ADSP-21990`

For example,

```
easm219x -proc ADSP-2191 -o bin\p1.doj p1.asm
```

If the processor identifier is unknown to the assembler, it attempts to read required switches for code generation from the file `<processor>.ini`. The assembler searches for the `.ini` file in the VisualDSP ++ System folder. For custom processors, the assembler searches the section “`proc`” in the `<processor>.ini` for key '`architecture`'. The custom processor must be based on an architecture key that is one of the known processors.

For example, `-proc Custom-xxx` searches the `Customxxx.ini` file.

See also "-si-revision version" on page 1-96 for more information on silicon revision of the specified processor.

-si-revision version

The `-si-revision` *`version`* (silicon revision) switch directs the assembler to provides a silicon revision of the specified processor. For example,

```
easm2191 -proc ADSP-2196 -si-revision 0.1
```

The parameter "*`version`*" represents a silicon revision of the processor specified by the `-proc` switch (on page 1-95). The revision version will take one of two forms:

- One or more decimal digits, followed by a point, followed by one or two decimal digits. Examples of revisions are: 0.0; 0.1; 1.12; 23.1. Version 0.1 is distinct from and "lower" than version 0.10. The digits to the left of the point specify the chip tapeout number; the digits to the right of the point identify the metal mask revision number. The number to the right of the point cannot exceed decimal 255.

- A version value of *`none`* is also supported, indicating that the assembler should not concern itself with silicon errata.

The `-si-revision` switch without a valid version value—that is, `-si-revision` alone or with an invalid parameter—shall generate an error.

This switch will:

- Generate warnings about "potential" anomalous conditions

- Generate errors if any anomalous conditions occur

In the absence of silicon revision entry, the assembler selects the greatest silicon revision it "knows" about, if any.

The assembler will define a macro `__SILICON_REVISION__` prior to preprocessing. The value assigned to this macro will correspond to the chip tapeout number converted to hexadecimal value and shifted left eight bits. Thus, revision 0.0 is `0x0`, 0.1 is `0x1`, 1.0 is `0x100`, and 10.21 is `0xa15`, etc. If the silicon revision is specified as "`none`", the macro is not defined.

When the silicon revision number is greater than the largest number for which the assembler has been defined, the assembler will be set for the greatest known revision, and then will emit a warning that it is defaulting to the earlier revision.

When an assembler has no embedded support for silicon revisions of a processor, no warning shall be generated when the silicon revision is specified. When no silicon revision is specified, no warning is generated and the `__SILICON_REVISION__` macro is not set.

-sp

The `-sp` (skip preprocessing) switch directs the assembler to assemble the source file into an object file without running the preprocessor. When the assembler skips preprocessing, no preprocessed assembly file (`.IS`) is created.

-v[erbose]

The `-v` or `-verbose` (verbose) switch directs the assembler to display version and command-line information for each phase of assembly.

-version

The `-version` (display version) switch directs the assembler to display version information for the assembler and preprocessor programs.

-w

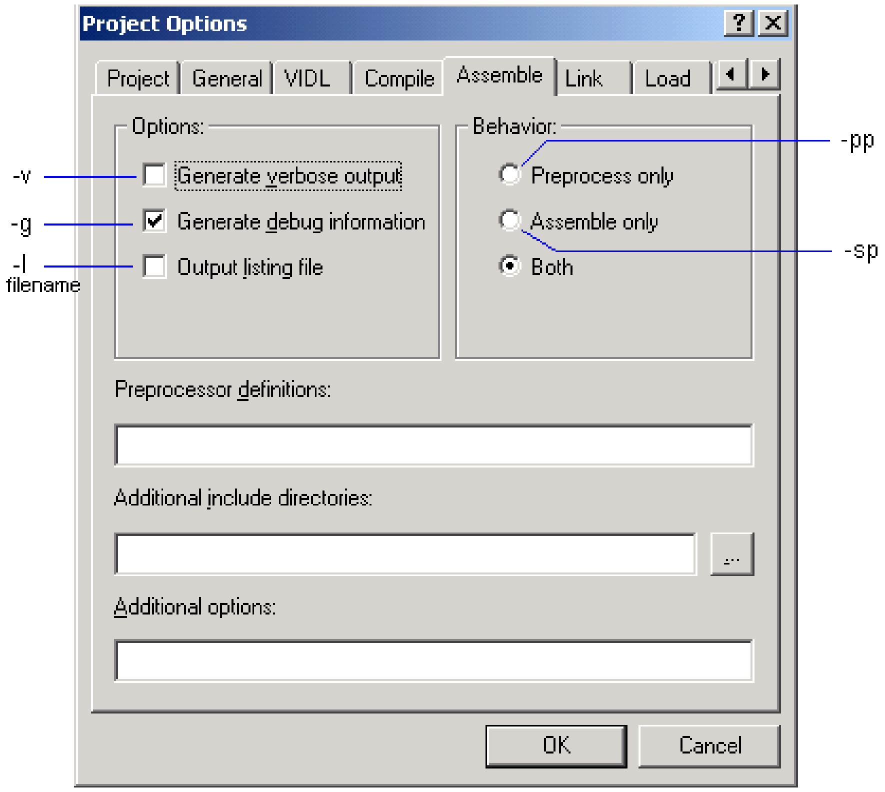
The `-w` (disable all warnings) switch directs the assembler not to display warning messages generated during assembly.

-Wnumber[,number]

The `-Wnumber` (warning suppression) switch selectively disables warnings specified by one or more message numbers. For example, `-W1092` disables warning message `ea1092`. This switch optionally accepts a list , such as `[,number ...]`.

Specifying Assembler Options in VisualDSP++

When using the VisualDSP++ IDDE, use the **Assemble** property page from the **Project Options** dialog box to set assembler functional options.



[ ] Generate verbose output
[✓] Generate debug information
[ ] Output listing file

( ) Preprocess only
( ) Assemble only
(●) Both

Figure 1-3. Project Options – Assemble Property Page

For more information on assembler configuration, use the VisualDSP++ online Help.

Callouts in Figure 1-3 refer to the corresponding assembler command-line switches described in "Command-Line Switch Summary and Descriptions" on page 1-85. The **Additional options** field is used to enter the appropriate file names and options that do not have corresponding controls on the **Assemble** property page but are available as assembler switches.

The assembler options apply to directing calls to `easm218x` or `easm219x` when assembling `*.asm` files. Changing assembler options in VisualDSP++ does not affect the assembler calls made by the compiler during the compilation of `*.c/*.cpp` files.

2 PREPROCESSOR

The preprocessor program (`pp.exe`) evaluates and processes preprocessor commands in source files. With these commands, you direct the preprocessor to define macros and symbolic constants, include header files, test for errors, and control conditional assembly and compilation. The preprocessor supports ANSI C standard preprocessing with extensions, such as "?" and "...".

The `pp` preprocessor is run by other build tools (assembler and linker) from the operating system's command line or within the VisualDSP++ 3.5 environment. These tools accept command information for the preprocessor and pass it to the preprocessor. The `pp` preprocessor can also operate from the command line with its own command-line switches.

The chapter contains:

Preprocessor Guide

This section contains the PP preprocessor information on how to build programs from a command line or from the VisualDSP++ 3.5 environment. Software developers using the preprocessor should be familiar with:

- "Writing Preprocessor Commands"
- "Header Files and #include Command" on page 2-4
- "Writing Macros" on page 2-6
- "Using Predefined Macros" on page 2-8
- "Specifying Preprocessor Options" on page 2-10

The compiler also has it own preprocessor that allows you to use preprocessor commands within your C/C++ source. The compiler preprocessor automatically runs before the compiler. This preprocessor is separate from the assembler and has some features that may not be used within your assembly source files. For more information, see the *VisualDSP++ 3.5 C/C++ Compiler and Library Manuals* for the target DSPs.

The assembler preprocessor differs from the ANSI C standard preprocessor in several ways. First, the assembler preprocessor supports a ”?” operator (see on page 2-32) that directs the preprocessor to generate a unique lavel for each macro expansion. Second, the preprocessor does not treat '.' as a separate token. Instead, '.' is always treated as part of an identifier. This behavior matches the assembler's which uses '.' to start directives and accepts '.' in symbol names. For example,

```
#define VAR my_var
.VAR x;
```

will not cause any change to the variable declaration. The text '.VAR' is treated as a single identifier which does not match the macro name 'VAR'.

The standard C preprocessor would treat '`.VAR`' as two tokens, '.' and '`VAR`', and will make the following substitution:

```
.my-var x;
```

ⓘ This preprocessor's behavior is introduced in VisualDSP++ 3.5.

The assembler preprocessor also produces assembly-style strings (single quote delimiters) instead of C-style strings.

Finally, the assembler preprocessor supports (under command-line switch control) legacy assembler commenting formats ("!" and "{ }").

Writing Preprocessor Commands

Preprocessor commands begin with a pound sign (#) and end with a carriage return. The pound sign must be the first non-white space character on the line containing the command. If the command is longer than one line, use a backslash (\) and a carriage return to continue the command on the next line. Do not put any characters between the backslash and the carriage return. Unlike assembly directives, preprocessor commands are case sensitive and must be lowercase.

For more information on preprocessor commands, see "Preprocessor Command Reference" on page 2-11.

For example,

```
#include "string.h"
#define MAXIMUM 100
```

When the preprocessor runs, it modifies your source code by:

- Including system and user-defined header files
- Defining macros and symbolic constants
- Providing conditional assembly and compilation

You specify preprocessing options with preprocessor commands—lines starting with #. Without any commands, the preprocessor performs these three global substitutions:

- Replaces comments with single spaces
- Deletes line continuation characters (`\`)
- Replaces predefined macro references with corresponding expansions

The following cases are notable exceptions to the described substitutions:

- The preprocessor does not recognize comments or macros within the file name delimiters of an `#include` command.
- The preprocessor does not recognize comments or predefined macros within a character or string constant.

Header Files and #include Command

A header file (`.h`) contains lines of source code to be included (textually inserted) into another source file. Typically, the header file contains declarations and macro definitions. The `#include` preprocessor command includes a copy of the header file at the location of the command. There are three forms for the `#include` command:

1. System Header Files
Syntax: `#include <filename>`
where a filename is within angle brackets. The filename in this form is interpreted as a "system" header file. These files are used to declare global definitions, especially memory mapped registers, system architecture and processors.

Example:

```
#include <device.h>
#include <major.h>
```

System header files are installed in the `...\VisualDSP\218x\include` and `...\VisualDSP\219x\include` folders

2. User Header Files
Syntax: `#include "filename"`
where a filename is within double quotes. The filename in this form is interpreted as a "user" header file. These files contain declarations for interfaces between the source files of your program.

Example:

```
#include "def219x.h"
#include "my_local_file.h"
```

3. Sequence of Tokens
Syntax: `#include text`
In this case, "text" is a sequence of tokens that will be subject to macro expansion by the preprocessor. It is an error if after macro expansion the text does not match one of the two header file forms.

In other words, if the text on the line after the "`#include`" is not included in either double quotes (as a user header) or angle brackets (as a system header), then the preprocessor will perform macro expansion on the text. After that expansion, the line needs to have either of the two header file forms. It is important to note that unlike most preprocessor commands, the text after the `#include` is available for macro expansion.

Examples:

```
// define preprocessor macro with name for include file
#define includefilename "header.h"
// use the preprocessor macro in a #include command
#include includefilename
// above evaluates to #include "header.h"

// define preprocessor macro to build system include file
#define syshdr(name) <name ## .h>
// use the preprocessor macro in a #include command
```

```
#include syshdr(adi)
// above evaluates to #include <adi.h>
```

Include Path Search

It is a good programming practice to distinguish between system and user header files. The only technical difference between the two different notations is the directory order the assembler searches the specified header file:

The `#include <file>` search order is:

1. include path specified by the `-I` switch
2. `...\VisualDSP/218x|219x/include` folders

The `#include "file"` search order is:

1. local directory—the directory in which the source file resides
2. include path specified by the `-I` switch
3. `...\VisualDSP/218x|219x/include` folders

If you use both the -I and -I- switches on the command line, the system search path (`#include < >`) is modified in such a manner that search directories specified with the `-I` switch that appear before the directory specified with the `-I-` switch are ignored.

For syntax information and usage examples on the `#include` preprocessor command, see "#include" on page 2-23.

Writing Macros

The preprocessor processes macros in your C, C++, assembly source files, and Linker Description Files (LDF). Macros are useful for repeating instruction sequences in your source code or defining symbolic constants. The term *macro* defines a macro-identifying symbol and corresponding definition that the preprocessor uses to substitute the macro reference(s). Macros allow text replacement, file inclusion, conditional assembly, conditional compilation, and macro definition.

Macro definitions start with `#define` and end with a carriage return. If a macro definition is longer than one line, place the backslash character (`\`) at the end of each line except the last, for line continuation. This character indicates that the macro definition continues on the next line and allows to break a long line for cosmetic purposes without changing its meaning.

The macro definition can be any text that would occur in the source file, instructions, commands, or memory descriptions. The macro definition may also have other macro names that will be replaced with their own definitions.

Macro nesting (macros called within another macro) is limited only by the memory that is available during preprocessing. However, recursive macro expansion is not allowed. For example,

```
#define N 1024
#define false 0
#define min(a,b) ((a) < (b) ? (a):(b))
#define ccall(x)\
   r2=i6; i6=i7; \
   jump (pc, x) (db); \
   dm(i7+=m7)=r2;\
   dm(i7+=m7)=pc
```

A macro can have arguments. When you pass parameters to a macro, the macro serves as a general-purpose routine that is usable in many different programs. The block of instructions that the preprocessor substitutes can vary with each new set of arguments. A macro, however, differs from a subroutine call.

During assembly, each instance of a macro inserts a copy of the same block of instructions, so multiple copies of that code appear in different locations in the object code. By comparison, a subroutine appears only once in the object code, and the block of instructions at that location are executed for every call.

If a macro ends with a semicolon (`;`), then when it appears in an assembly statement, the semicolon is not needed. However, if a macro does not end with a semicolon character (";"), it must be followed by the semicolon when appearing in the assembly statement. Users should be consistent in treatment of the semicolon in macro definitions. For example,

```
// macro definition
#define mac mr=mr+mx0*my0 (ss)

// macro invocation
   mx0 = 5;
   my0 = dm(i1+=m0);
   mac;
```

For more syntax information and usage examples for the `#define` preprocessor command, see "#define" on page 2-13.

Using Predefined Macros

In addition to macros you define, the `pp` preprocessor provides a set of predefined and feature macros that you can use in your assembly code. The preprocessor automatically replaces each occurrence of the macro reference found throughout the program with the specified (predefined) value. The DSP development tools also define feature macros that you can use in your code.

Note that the `__DATE__`, `__FILE__`, and `__TIME__` macros return strings within the single quotation marks (' ') suitable for initialization of character buffers (see ".VAR and ASCII String Initialization Support" on page 1-78).

Table 2-1 describes the predefined macros provided by the `pp` preprocessor. Table 2-2 lists feature macros that are defined by the DSP tools to specify the architecture and language being processed.

Table 2-1. Predefined Preprocessor Macros

Macro	Definition
`ADI`	Defines `ADI` as 1.
`__LASTSUFFIX__`	The `__LASTSUFFIX__` macro specifies the last value of suffix that was used to build preprocessor generated labels.
`__LINE__`	The `__LINE__` macro is replaced with the line number in the source file that the macro appears on.
`__FILE__`	Defines `__FILE__` as the name and extension of the file in which the macro is defined, for example, ‘`macro.asm`’.
`__TIME__`	Defines `__TIME__` as current time in the 24-hour format ‘`hh:mm:ss`’, for example, ‘`06:54:35`’.
`__DATE__`	Defines `__DATE__` as current date in the format ‘`Mm dd yyyy`’, for example, ‘`Oct 02 2000`’.

Table 2-2. Feature Preprocessor Macros

Macro	Definition
`__ADSP21XX__`	Always 1 for ASDP-21xx DSP tools
`__ADSP218X__`	Equal 1 when used for ASDP-218x DSP
`__ADSP219X__`	Equal 1 when used for ASDP-219x DSP
`_LANGUAGE_ASM`	Always set to 1 by `easm218x` or `easm219x`
`_LANGUAGE_C`	Equal 1 when used for C compiler calls to specify `.IMPORT` headers. Replaces `_LANGUAGE_ASM`.

Some examples of feature macros are:

```
__ADSP2185M__
__ADSP2191__
__ADSP2192_12__
```

Specifying Preprocessor Options

When developing a DSP project, it may be useful to modify the preprocessor's default options. Because the assembler, compiler, and linker automatically run the preprocessor as your program is built (unless you skip the processing entirely), these DSP tools can receive input for the preprocessor program and direct its operation. The way the preprocessor options are set depends on the environment used to run the DSP development software.

You can specify preprocessor options either from the preprocessor's command line or via the VisualDSP++ environment:

- From the operating system command line, you select the preprocessor's command-line switches. For more information on these switches, see "Preprocessor Command-Line Switches" on page 2-35.
- From the VisualDSP++ environment, you select the preprocessor's options in the **Assemble** and **Link** tabs of the **Project Options** dialog boxes, accessible from the **Project** menu.

  For more information, see the *VisualDSP++ 3.5 User's Guide for 16-Bit Processors* and online Help. Refer to "Specifying Assembler Options in VisualDSP++" on page 1-99 for the **Assemble** property page.

Preprocessor Command Reference

This section provides reference information about the DSP's preprocessor commands and operators used in source code, including their syntax and usage examples. It provides the summary and descriptions of all preprocessor command and operators.

The preprocessor reads code from a source file (`.ASM`), modifies it according to preprocessor commands, and generates an altered preprocessed source file. The preprocessed source file is a primary input file for the assembler or linker; it is purged when the a binary object file (`.DOJ`) is created.

Preprocessor command syntax must conform to these rules:

- Must be the first non white space character on its line.
- Cannot be more than one line in length unless the backslash character (`\`) is inserted
- Can contain comments containing the backslash character (\)
- Cannot come from a macro expansion

The preprocessor operators are special operators when used in a `#define` command.

Preprocessor Commands and Operators

This section describes preprocessor commands and operators.

Table 2-3 lists the preprocessor command set. Table 2-4 lists the preprocessor operator set. Sections that begin on page 2-13 describe each of the preprocessor commands and operators.

Table 2-3. Preprocessor Command Summary

Command/Operator	Description
`#define` (on page 2-13)	Defines a macro
`#elif` (on page 2-16)	Subdivides an `#if` … `#endif` pair
`#else` (on page 2-17)	Identifies alternative instructions within an `#if` … `#endif` pair
`#endif` (on page 2-18)	Ends an `#if` … `#endif` pair
`#error` (on page 2-19)	Reports an error message
`#if` (on page 2-20)	Begins an `#if` … `#endif` pair
`#ifdef` (on page 2-21)	Begins an `#ifdef` … `#endif` pair and tests if macro is defined
`#ifndef` (on page 2-22)	Begins an `#ifndef` … `#endif` pair and tests if macro is not defined
`#include` (on page 2-23)	Includes contents of a file
`#line` (on page 2-25)	Sets a line number during preprocessing
`#pragma` (on page 2-26)	Takes any sequence of tokens
`#undef` (on page 2-27)	Removes macro definition
`#warning` (on page 2-28)	Reports a warning message

Table 2-4. Preprocessor Operator Summary

Command/Operator	Description
# (on page 2-29)	Converts a macro argument into a string constant. By default, this operator is OFF. Use the command-line switch "-stringize" on page 2-42 to enable it.
## (on page 2-30)	Concatenates two tokens
? (on page 2-32)	Generates unique labels for repeated macro expansions
... (on page 2-14)	Specifies a variable length argument list

#define

The `#define` command defines macros.

When you define a macro in your source code, the preprocessor substitutes each occurrence of the macro with the defined text. Defining this type of macro has the same effect as using the **Find/Replace** feature of a text editor, although it does not replace literals in double quotation marks (“ “) and does not replace a match within a larger token.

For macro definitions that are longer than one line, use the backslash character (`\`) at the end of each line except for the last line. You can add arguments to the macro definition. The arguments are symbols separated by commas that appear within parentheses.

Syntax:

```
#define macroSymbol replacementText
#define macroSymbol[(arg1,arg2,…)] replacementText
```

where

`macroSymbol` — macro identifying symbol.

(`arg1,arg2,…`) — optional list of arguments enclosed in parenthesis and separated by commas. No space is permitted between the macro name and the left parenthesis. If there is a space, the parenthesis and arguments are treated as part of the definition.

`replacementText` — text to substitute each occurrence of `macroSymbol` in your source code.

Examples:

```
#define BUFFER_SIZE 1020
        /* Defines a constant named BUFFER_SIZE and sets its
        value to 1020.*/

#define MINIMUM (X, Y) ((X) < (Y)? (X): (Y))
        /* Defines a macro named MINIMUM that selects the
        minimum of two numeric arguments. */
#define copy(src,dest)
r0=DM(src); \
PM(dest)=r0
/*define a macro named copy with two arguments.
            The definition includes two instructions that copy
            a word from memory to memory.
            For example,
               copy (0x3f,0xC0);
            calls the macro, passing parameters to it.
            The preprocessor replaces the macro with the code:
               r0=DM(0x3f);
               PM(0xC0)=r0
*/
```

Variable Length Argument Definitions

The definition of a macro can also be defined with a variable length argument list (using the ... operator).

```
   #define test(a, ...)  <definition>
```

defines a macro `test` which takes two or more arguments. It is invoked as any other macro, although the number of arguments can vary.

For example,

`test(1)`	Error; the macro must have at least one more argument than formal parameters, not counting "..."

`test(1,2)`	Valid entry
`test(1,2,3,4,5)`	Valid entry

In the macro definition, the identifier `__VA_ARGS__` is available to take on the value of all of the trailing arguments, including the separating commas, all of which are merged to form a single item. For example,

```
#define test(a, ...) bar(a); testbar(__VA_ARGS__);
```

expands as

```
test (1,2) -> bar(1); testbar(2);

test (1,2,3,4,5) -> bar(1); testbar(2,3,4,5);
```

#elif

The `#elif` command (else if) is used within an `#if` … `#endif` pair. The `#elif` includes an alternative condition to test when the initial `#if` condition evaluates as `FALSE`. The preprocessor tests each `#elif` condition inside the pair and processes instructions that follow the first true `#elif`. You can have an unlimited number of `#elif` commands inside one `#if` … `#end` pair.

Syntax:

```
   #elif condition
```

where

condition — expression to evaluate as `TRUE` (non zero) or `FALSE` (zero)

Example:

```
#if X == 1
   …
#elif X == 2
   …
      /* The preprocessor includes text within the section if
      the test is true and excludes all alternatives within
      #if ... elif pair.  */
#else
   …
#endif
```

#else

The #else command is used within an #if … #endif pair. It adds an alternative instruction to the #if … #endif pair. Only one #else command can be used inside the pair. The preprocessor executes instructions that follow #else after all the preceding conditions are evaluated as FALSE (zero). If no #else text is specified, and all preceding #if and #elif conditions are FALSE, the preprocessor does not include any text inside the #if … #endif pair.

Syntax:

```
#else
```

Example:

```
#if X == 1
   …
#elif X == 2
   …
#else
   …
      /* The preprocessor includes text within the section
      and excludes all other text before #else when
      x!=1 and x!=2. */
#endif
```

#endif

The `#endif` command is required to terminate `#if` … `#endif`, `#ifdef` … `#endif`, and `#ifndef` … `#endif` pairs. Make sure that the number of `#if` commands matches the number of `#endif` commands.

Syntax:

```
#endif
```

Example:

```
#if condition
    …
    …
#endif
        /* The preprocessor includes text within the section only
        if the test is true. */
```

#error

The `#error` command causes the preprocessor to raise an error. The preprocessor uses the text following the `#error` command as the error message.

Syntax:

```
#error messageText
```

where

`messageText` — user-defined text

To break a long *`messageText`* without changing its meaning, place the backslash character (\) at the end of each line except for the last line.

Example:

```
#ifndef __ADSP219X__
#error \
       MyError:\
       Expecting a ADSP-219X . \
       Check the Linker Description File!
#endif
```

#if

The `#if` command begins an `#if … #endif` pair. Statements inside an `#if … #endif` pair can include other preprocessor commands and conditional expressions. The preprocessor processes instructions inside the `#if … #endif` pair only when *condition* that follows the `#if` evaluates as `TRUE`. Every `#if` command must terminated with an `#endif` command.

Syntax:

```
#if condition
```

where

condition — expression to evaluate as `TRUE` (non zero) or `FALSE` (zero)

Example:

```
#if x!=100   /* test for TRUE condition */
…
…    /* The preprocessor includes text within the section if
      the test is true and excludes all other text
      after #if only when x!=100 */
#endif
```

More examples:

```
#if (x!=100) && (y==20)

#if defined(__ADSP218X__)

#if !defined(__ADSP2192_12__)

#if defined(__ADSP218X__) || defined(__ADSP219X__)
```

#ifdef

The `#ifdef` (if defined) command begins an `#ifdef` … `#endif` pair and instructs the preprocessor to test whether macro is defined. The number of `#ifdef` commands must match the number of `#endif` commands.

Syntax:

```
#ifdef macroSymbol
```

where

`macroSymbol` — macro identifying symbol

Example:

```
#ifdef __ADSP219X__
      /* Includes text after #ifdef only when __ADSP219X__ has
      been defined */
#endif
```

#ifndef

The `#ifndef` command (if not defined) begins an `#ifndef` … `#endif` pair and directs the preprocessor to test for an undefined macro. The preprocessor considers a macro undefined if it has no defined value. The number of `#ifndef` commands must equal the number of `#endif` commands.

Syntax:

```
#ifndef macroSymbol
```

where

`macroSymbol` — macro identifying symbol

Example:

```
#ifndef __ADSP219X__
      /* Includes text after #ifndef only when __ADSP219X__ has
      been not defined */
#endif
```

#include

The `#include` command directs the preprocessor to insert the text from a header file at the command location. There are two types of header files: *system* and *user*. However, the `#include` command may be presented in three forms:

- `#include <filename>` — used with system headers
- `#include “filename”` — used with user headers
- `#include text` — used with a sequence of tokens.
  That sequence will be subject to macro expansion by the preprocessor. After macro expansion, the text must match one of the header file forms.

The only difference to the preprocessor between the two types of header files is the way the preprocessor searches for them.

- System Header *`<fileName>`* — The preprocessor searches for a system header file in the order: (1) the directories you specify and (2) the standard list of system directories.
- User Header *`“fileName”`* — The preprocessor searches for a user header file in this order:
    1. Current directory—the directory where the source file that has the `#include` command(s) lives
    2. Directories you specify
    3. Standard list of system directories

Refer to “Header Files and #include Command” on page 2-4 for more information.

Syntax:

```
#include <fileName>   // include a system header file
#include "fileName"   // include a user header file
#include macroFileNameExpansion
   /* Include a file named through macro expansion.
   This command directs the preprocessor to expand the
   macro. The preprocessor processes the expanded text,
   which must match either <fileName> or "fileName". */
```

Example:

```
#ifdef __ADSP219X__  /* Tests that __ADSP219X__ has been defined */
#include <stdlib.h>

#endif
```

#line

The `#line` command directs the preprocessor to set the internal line counter to the specified value. Use this command for error tracking purposes.

Syntax:

```
#line lineNumber “sourceFile”
```

where

`lineNumber` — number of the source line that you want to output

`sourceFile` — name of the source file included in double quotation marks. The `sourceFile` entry can include the drive, directory, and file extension as part of the file name.

Example:

```
#line 7 “myFile.c”
```

All assembly programs have `#line` directives after preprocessing. They always have a first line with `#line 1 "filename.asm"` and they will also have `#line` directives to establish correct line numbers for text that came from include files as a result of `#include` directives that were processed.

#pragma

The #pragma is the implementation-specific command that could modify the preprocessor behavior. The #pragma command can take any sequence of tokens. This command is accepted for compatibility with other VisualDSP++ software tools. The pp preprocessor currently does not support pragmas; therefore, it will ignore any information in the #pragma.

Syntax:

```
#pragma any_sequence_of_tokens
```

Example:

```
#pragma disable_warning 1024
```

#undef

The `#undef` command directs the preprocessor to undefine the macro.

Syntax:

```
#undef macroSymbol
```

where

`macroSymbol` — macro created with the `#define` command

Example:

```
#undef BUFFER_SIZE   /* undefines a macro named BUFFER_SIZE */
```

#warning

The `#warning` command is used to cause the preprocessor to issue a warning. The preprocessor uses the text following the `#warning` command as the warning message.

Syntax:

```
#warning messageText
```

where

`messageText` — user-defined text

To break a long *`messageText`* without changing its meaning, place the backslash character (\) at the end of each line except for the last line.

Example:

```
#ifndef __ADSP219X__
#warning \
      MyWarning: \
      Expecting a ADSP-219X . \
      Check the Linker Description File!
#endif
```

# (Argument)

The `#` (argument) “stringization” operator directs the preprocessor to convert a macro argument into a string constant. The preprocessor converts an argument into a string when macro arguments are substituted into the macro definition.

The preprocessor handles white space in string-to-literal conversions by:

- Ignoring leading and trailing white spaces
- Converting any white space in the middle of the text to a single space in the resulting string

Syntax:

`#toString`

where

`toString` — Macro formal parameter to convert into a literal string. The `#` operator must precede a macro parameter. The preprocessor includes a converted string within the double quotation marks (“”).

This feature is "off" by default. Use the “-stringize” command-line switch (on page 2-42) to enable it.

Example:

```
#define WARN_IF(EXP) \
fprintf (stderr, "Warning: " #EXP "\n")
    /* Defines a macro that takes an argument and converts the
    argument to a string */
WARN_IF(current < minimum);
    /* Invokes the macro passing the condition. */
fprintf (stderr, "Warning: " "current < minimum" "\n");
    /* Note that the #EXP has been changed to current < minimum
    and is enclosed in “” */
```

## (Concatenate)

The ## (concatenate) operator directs the preprocessor to concatenate two tokens. When you define a macro, you request concatenation with ## in the macro body. The preprocessor concatenates the syntactic tokens on either side of the concatenation operator.

Syntax:

```
   token1##token2
```

Example:

This is an example of assembly code that handles the interrupt vector table.

```
#define sig_reset      0
#define sig_pwrdwn     1
#define sig_stackint   2
#define sig_kernel     3
#define sig_int4       4
#define sig_int5       5
#define sig_int6       6

#define INTERRUPT_VECTOR(intnr)      \
   .SECTION/CODE      IV##intnr;     \
   .GLOBAL      vector_##intnr;      \
   vector_##intnr:                   \
      jump generic_handler (db);     \
         DM(i4+= -1)=AR;             \
         AR = sig_##intnr

INTERRUPT_VECTOR(reset);
INTERRUPT_VECTOR(pwrdwn);
INTERRUPT_VECTOR(stackint);
INTERRUPT_VECTOR(kernel);
INTERRUPT_VECTOR(int4);
INTERRUPT_VECTOR(int5);
INTERRUPT_VECTOR(int6);
```

For example, `INTERRUPT_VECTOR(int4);` expands to

```
.SECTION/CODE IVint4;
.GLOBAL vector_int4;
vector_int4:
   jump generic_handler (db);
      DM(i4+= -1)=AR;

      AR = sig_int4;
```

? (Generate a Unique Label)

The "?" operator directs the preprocessor to generate unique labels for iterated macro expansions. Within the definition body of a macro (#define), you can specify one or more identifiers with a trailing question mark (?) to ensure that unique label names are generated for each macro invocation.

The preprocessor affixes " _num" to a label symbol, where num is a uniquely generated number for every macro expansion. For example,

```
abcd? ===> abcd_1
```

If a question mark is a part of the symbol that needs to be preserved, ensure that "?" is delimited from the symbol. For example,

"abcd?" is a generated label, while "abcd ?" is not.

Example:

Macro definition

```
#define PAUSE(cycles)\
        cntr = cycles;\
        do pause? until ce;\
        pause?: nop
```

Usage

```
PAUSE(10);
PAUSE(0x20);
```

expands to:

```
cntr = 10;
do pause_1 until ce;
pause_1: nop;
cntr = 0x20;
do pause_2 until ce;
pause_2: nop;
```

The last numeric suffix that was used to generate unique labels is maintained by the preprocessor and is available through a preprocessor predefined macro `__LASTSUFFIX__` (see on page 2-9). This value can be used to generate references to labels in the last macro expansion.

The following example assumes the macro "loop" from the previous example.

```
// Some macros for appending a suffix to a label
#define makelab(a, b) a##b
#define Attach(a, b) makelab(a##_, b)
#define LastLabel(foo) Attach( foo, __LastSuffix__)

// jump back to label in the previous expansion
jump LastLabel(mylabel);
```

The above will expand to (the last macro expansion had suffix of 3):

```
JUMP mylabel_3;
```

Preprocessor Command-Line Reference

The pp preprocessor is the first step in the process of building (assembling and linking) your programs. The pp preprocessor is run before the assembler or linker. You can also run it independently from its own command line.

This section contains:

- "Running the Preprocessor"
- "Preprocessor Command-Line Switches" on page 2-35

Running the Preprocessor

To run the preprocessor from the command line, type the name of the program followed by arguments in any order.

```
pp [-switch1[-switch2 …]] [sourceFile]
```

where:

`pp`	Name of the preprocessor program.
`-switch`	Switch (or switches) to process. The preprocessor offers several switches that are used to select its operation and modes. Some preprocessor switches take a file name as a required parameter.
`sourceFile`	Name of the source file to process. The preprocessor supports relative and absolute path names. The `pp.exe` outputs a list of command-line switches when runs without this argument..

For example, the following command line

```
pp -Dfilter_taps=100 -v -o bin\p1.is p1.asm
```

runs the preprocessor with

`-Dfilter_taps=100` — defines the macro `filter_taps` as equal to 100

`-v` — displays verbose information for each phase of the preprocessing

`-o bin\p1.is` — specifies the name and directory for the intermediate preprocessed file

`p1.asm` — specifies the assembly source file to preprocess

Most switches without arguments can be negated by prepending `-no` to the switch; for example, `-nowarn` turns off warning messages, and `-nocs!` turns off omitting "`!`" style comments.

Preprocessor Command-Line Switches

The preprocessor is controlled through the switches (or VisualDSP++ options) of other DSP development tools, such as the compiler, assembler, and linker. Note that the preprocessor (`pp.exe`) can operate independently from the command line with its own command-line switches.

Table 2-5 lists the `pp.exe` switches. A detailed description of each switch appears beginning on page 2-37.

Table 2-5. Preprocessor Command-Line Switch Summary

Switch Name	Description
`-cstring` (on page 2-37)	Produces "C compiler" style strings
`-cs!` (on page 2-38)	Treats as a comment all text after "`!`" on a single line
`-cs/*` (on page 2-38)	Treats as a comment all text within `/*  */`

Table 2-5. Preprocessor Command-Line Switch Summary (Cont'd)

`-cs//` (on page 2-38)	Treats as a comment all text after `//`
`-cs{` (on page 2-38)	Treats as a comment all text within `{ }`
`-csall` (on page 2-38)	Accepts comments in all formats
`-D`*`macro`*`[=`*`definition`*`]` (on page 2-39)	Defines *`macro`*
`-h[elp]` (on page 2-39)	Outputs a list of command-line switches
`-i|I`*`directory`* (on page 2-39)	Searches *`directory`* for included files
`-M` (on page 2-41)	Makes dependencies only
`-MM` (on page 2-41)	Makes dependencies and produces preprocessor output
`-Mo` *`filename`* (on page 2-41)	Specifies *`filename`* for the make dependencies output file
`-Mt` *`filename`* (on page 2-42)	Makes dependencies for the specified source file
`-o` *`filename`* (on page 2-42)	Outputs named object file
`-stringize` (on page 2-42)	Enables stringization (includes a string in quotes)
`-tokenize-dot` (on page 2-42)	Treats "." (dot) as an operator when parsing identifiers
`-v[erbose]` (on page 2-43)	Displays information about each preprocessing phase
`-version` (on page 2-43)	Displays version information for preprocessor.
`-w` (on page 2-43)	Removes all preprocessor-generated warnings.

Table 2-5. Preprocessor Command-Line Switch Summary (Cont'd)

`-Wnumber` (on page 2-43)	Suppresses any report of the specified warning.
`-warn` (on page 2-43)	Prints warning messages (default).

The following sections describe each of the preprocessor command-line switches.

-cstring

The `-cstring` switch directs the preprocessor to produce "C compiler" style strings in all cases. Note that by default, the preprocessor produces assembler-style strings within single quotes (for examples, '*string*') unless you use the `-cstring` switch.

The `-cstring` switch sets these three "C compiler"-style behaviors:

- Directs the preprocessor to use double quotation marks rather than the default single quotes as string delimiters for any preprocessor generated strings. The preprocessor will generate strings for predefined macros that are expressed as string constants, and as a result of the stringize operator in macro definitions. (See Table 2-1 on page 2-9 for the predefined macros).

- Enables the stringize operator (#) in macro definitions. By default, the stringize operator is disabled to avoid conflicts with constant definitions. See "-stringize" on page 2-42.

- Parses identifiers using C language rules instead of assembler rules. In C, the character "." is an operator and is not considered to be part of an identifier. In the assembler, the "." is considered part of a directive or label. With `-cstring`, the preprocessor will treat '.' as an operator.

The following example shows the difference in effect of the two styles.

```
#define end last
// what label.end looks like with -cstring
label.last     // "end" parsed as ident and macro expanded

// what label.end looks like without -cstring (asm rules)
label.end      // "end" not parsed separately
```

-cs!

The `-cs!` switch directs the preprocessor to treat as a comment all text after "!" on a single line.

-cs/*

The `-cs/*` switch directs the preprocessor to treat as a comment all text within /* */.

-cs//

The `-cs//` switch directs the preprocessor to treat as a comment all text after `//` on a single line.

-cs{

The `-cs{` switch directs the preprocessor to treat as a comment all text within { }.

-csall

The `-csall` switch directs the preprocessor to accept comments in all formats.

-Dmacro[=def]

The `-Dmacro` switch directs the preprocessor to define a `macro`. If you do not include the optional definition string (`=def`), the preprocessor defines the macro as value 1. Similar to the C compiler, you can use the `-D` switch to define an assembly language constant macro.

Some examples of this switch are:

```
-Dinput                // defines input as 1
-Dsamples=10           // defines samples as 10
-Dpoint="Start"        // defines point as “Start”
-D_LANGUAGE_ASM=1      // defines assembly language as 1
```

-h[elp]

The `-help` switch directs the preprocessor to output to standard output the list of command-line switches with a syntax summary.

-i|I directory

The `-idirectory` or `-Idirectory` switch directs the preprocessor to append the specified directory (or a list of directories separated by semicolon) to the search path for included header files (see on page 2-23).

Note that no space is allowed between `-i` or `-I` and the path name.

The preprocessor searches for included files delimited by " " in this order:

1. The source directory, that is the directory in which the original source file resides.
2. The directories in the search path supplied by the `-I` switch. If more than one directory is supplied by a `-I` switch, they will be searched in the order that they appear on the command line.
3. The system directory, that is the `...\include` subdirectory of the VisualDSP++ installation directory.

Current directory is the directory where the source file lives, not the directory of the assembler program. Usage of full path names for the `-I` switch on the command line (omitting the disk partition) is recommended.

The preprocessor searches for included files delimited by < > in this order:

1. The directories in the search path supplied by the `-I` switch (subject to modification by the `-I-` switch, as shown in "Using the -I- Switch". If more than one directory is supplied by a `-I` switch, the directories will be searched in the order that they appear on the command line.

2. The system directory, that is the . . .`\include` subdirectory of the VisualDSP++ installation directory.

Using the -I- Switch

The `-I-` switch indicates where to start searching for include files delimited by < >, sometimes called system include files. If there are several directories in the search path, the `-I-` switch indicates where in the path the search for system include files will begin. For example,

```
pp -Idir1 -Idir2 -I- -Idir3 -Idir4 myfile.asm
```

When searching for

```
#include "inc1.h"
```

the preprocessor will search in the source directory, then `dir1`, `dir2`, `dir3`, and `dir4` in that order. When searching for

```
#include <inc2.h>
```

the preprocessor will search for the file in `dir3` and then `dir4`. The `-I-` switch marks the point where the system search path starts.

-M

The `-M` switch directs the preprocessor to output a rule (generate make rule only), which is suitable for the make utility, describing the dependencies of the source file. The output, a make dependencies list, is written to `stdout` in the standard command-line format.

```
“target_file”:   “dependency_file.ext”
```

where:

> *`dependency_file.ext`* may be an assembly source file or a header file included with the `#include` preprocessor command.

When the “-o filename” option is used with `-M`, the `-o` option is ignored. To specify an alternate target name for the make dependencies, use the “-Mt filename” option. To direct the make dependencies to a file, use the “-Mo filename” option.

-MM

The `-MM` switch directs the preprocessor to output a rule (generate make rule and preprocess), which is suitable for the make utility, describing the dependencies of the source file. The output, a make dependencies list, is written to `stdout` in the standard command-line format.

The only difference between `-MM` and `-M` actions is that the preprocessing continues with `-MM`. See “-M” for more information.

-Mo filename

The `-Mo` switch specifies the name of the make dependencies file (output make rule) that the preprocessor generates when using the `-M` or `-MM` switch. If the named file is not in the current directory, you must provide the path name in the double quotation marks (“ ”). The “-o filename” option overrides default of make dependencies to `stdout`.

-Mt filename

The `-Mt` switch specifies t the name of the target file (output make rule for the named source) for which the preprocessor generates the make rule using the `-M` or `-MM` switch. The `-M`*`fileneme`* switch overrides the default `base.doj`. See "-M" for more information.

-o filename

The `-o` switch directs the preprocessor to use (output) the specified *`file-name`* argument for the preprocessed assembly file. The preprocessor directs the output to `stdout` when no `-o` option is specified.

-stringize

The `-stringize` switch enables the preprocessor stringization operator. By default, this switch is off. When set, this switch turns on the preprocessor stringization functionality (see "# (Argument)" on page 2-29) which is by default turned off to avoid possible undesired stringization.

For example, there is a conflict between the stringization operator and the assembler's boolean constant format in the following macro definition:

```
#define bool_const b#00000001
```

-tokenize-dot

The `-tokenize-dot` switch parses identifiers using C language rules instead of assembler rules, without needing to get other C semantics (see "-cstring" on page 2-37 for more information).

When the `-tokenize-dot` switch is used, the preprocessor will treat "." as an operator and not as part of an identifier. If the `-notokenize-dot` switch is used, it will return the preprocessor to the default behavior. The only benefit to the negative version is that if it appears on the command line after the `-cpredef` switch, it can turn off the behavior of "." without affecting other C semantics.

-v[erbose]

The `-v[erbose]` switch directs the preprocessor to output the version of the preprocessor program and information for each phase of the preprocessing.

-version

The `-version` switch directs the preprocessor to display the version information for the preprocessor program.

ⓘ The `-version` switch on the assembler command line provides version information for both the assembler and preprocessor. The `-version` switch on the preprocessor command-line provides preprocessor version information only.

-w

The `-w` (disable all warnings) switch directs the assembler not to display warning messages generated during assembly. Note that `-w` has the same effect as the `-nowarn` switch.

-Wnumber

The `-Wnumber` (warning suppression) switch selectively disables warnings specified by one or more message numbers. For example, `-W1092` disables warning message `ea1092`.

-warn

The `-warn` switch generates (prints) warning messages (this switch is on by default). The`-nowarn` switch negates this action.

3 ASSEMBLER ENHANCEMENTS AND LEGACY SUPPORT

This chapter concentrates on the assembler and preprocessor features added since DSP development software Release 6.1. Of the new features and enhancements, the following have the most impact on your existing projects developed in Release 6.1:

- Some switches have been modified or removed. If you are using any of these options, you must revise your command-line scripts and batch files.
- Some directives and conventions of syntax have been replaced. These directives and conventions are now referred to as legacy syntax or legacy code. If you are using any of these statements, we recommend that you revise your source code programs.
- The new assembler accepts your source code developed with Release 6.1 assembler software. If you are re-assembling your legacy code program using `easm218x` or `easm219x`, you must select the `-legacy` switch. In some cases you will need to modify your existing source to use the new assembler.
- The Architecture File is no longer supported. If you are re-linking using Release 6.1 object files or object libraries, you must create a Linker Description File for each object or object library before using the new linker.

The following sections contain reference information about Release 6.1 (legacy) and VisualDSP++ 3.5 (new) switches, directives, and rules of syntax, including usage examples. Where a new switch, directive, or rule of syntax has replaced the old one, the text gives a note on the preferred usage and explains the change.

The chapter contains:

Note that the legacy (Release 6.1) directives and conventions of syntax may not be supported in future releases of DSP development software.

Legacy Command Switches

VisualDSP++ support switch selections either via entries on the operating system's command line or specifying options in the **Assemble** tab of the VisualDSP++ environment's **Project Options** dialog box. Using the command switches, you control the assembler's and preprocessor's features, including search and source-level debugging.

Current VisualDSP++ command-line switches used with ADSP-218x and ADSP-219x DSPs are described in "Assembler Command-Line Reference" on page 1-82. Table 3-1 lists obsolete or modified switches not supported by current assemblers.

The new C structs functions (described in "Using Assembler Support for C Structs" on page 1-13) are not available with the `-legacy` switch.

Table 3-1. Obsolete and Modified Switches (Options)

Release 6.1 Switch	Operation under Release 6.1	Change for current VisualDSP++
`-2159`	Assembles instructions unique to the ADSP-21msp5x processors.	Removed
`-2171`	Assembles instructions unique to the ADSP-7x processors.	Removed
`-i`	Shows the contents of the `.INCLUDE` files in the listing file.	Removed
`-l`	Generates a listing file.	Requires the *`filename`* argument: `-l` *`filename`* (see on page 1-92).
`-m`	Expands macros in the listing file.	Removed
`-s`	Disables semantics checking.	Removed
`-ui`	Specifies the directory(ies) to search for included files.	Replaced with `-i` (see on page 1-91).

Legacy Directives

Directives are instructions that you include in your source programs in order to control the assembly process. Current VisualDSP++ 3.5 assembler directives are described in "Assembler Directives" on page 1-40. Current VisualDSP++ 3.5 preprocessor commands are described in "Preprocessor Commands and Operators" on page 2-11.

For compatibility with the Release 6.1 of the assembler software, the current release supports an additional set of legacy directives. lists these directives and their corresponding replacements. A description of each directive appears in the following sections. You can use the provided replacements, preprocessor commands and directives, to update your legacy source code to comply with the ADSP-218x and ADSP-219x DSP's assembler syntax.

Your source code programs, developed with the Release 6.1 assembler development software, may be processed by `easm218x.exe` or `easm219x.exe` assembly programs. To do this, you must use the `-legacy` command-line switch.

Table 3-2. Release 6.1 Legacy Directives

Legacy Directive (Release 6.1)	**Replaced in VisualDSP++ 3.5**
`.CONST` (see on page 3-6)	`#define` (see on page 2-13)
`.DMSEG` (see on page 3-7)	`.SECTION/DM` or `/DATA` (see on page 1-67
`.ENTRY` (see on page 3-9)	`.GLOBAL` (see on page 1-50)
`.EXTERNAL` (see on page 3-10)	`.EXTERN` (see on page 1-46)
`.GLOBAL`	Modified. You can make any symbol glabally available with `.GLOBAL` (see on page 1-50).
`.INCLUDE` (see on page 3-11)	`#include` (see on page 2-23)

Table 3-2. Release 6.1 Legacy Directives (Cont'd)

Legacy Directive (Release 6.1)	Replaced in VisualDSP++ 3.5
`.INDENT` (see on page 3-13)	Removed
`.INIT` (see on page 3-14)	`.VAR` (see on page 1-75)
`.INIT24` (see on page 3-14)	`.VAR/INIT24` (see on page 1-75)
`.INIT & ASCII8` (see on page 3-16)	`.VAR` (see on page 1-75)
`.LOCAL` (see on page 3-17)	`?` (macro label generation) (see on page 2-32)
`.MACRO/.ENDMACRO` (see on page 3-19)	`#define` (see on page 2-13)
`.MODULE/.ENDMOD` (see on page 3-21)	`.SECTION/PM` or `/CODE` (see on page 1-67)
`.PAGE`	Removed. Refer to information on page 1-28
`.PMSEG` (see on page 3-7)	`.SECTION/PM` or `/CODE` (see on page 1-67)
`.PORT` (see on page 3-24)	`.VAR` (see on page 1-75) and `.GLOBAL` (see on page 1-50)
`.VAR/ABS` (see on page 3-25)	`RESOLVE()` linker command (see on page 1-87)
`.VAR/CIRC` (see on page 3-25)	`.VAR/CIRC` (see on page 1-79)

You may need to revise your source files when assembling with the new assemblers. For more information about legacy code support, see the following sections or refer to the publications listed in "Related Documents" in "*Preface*".

.CONST, Declare a Constant

The `.CONST` directive defines assembler constants. Once you declare a symbolic constant, you may use it in place of the actual number.

The `.CONST` directive has the following syntax:

```
.CONST symbol = replacementText;
```

Only an arithmetic or logical operation on two or more integer constants may be given as an expression; symbols are not allowed. For more information on the assembler expressions and operators, see "Assembler Expressions" on page 1-27.

A single `.CONST` directive may contain one or more constant declarations, separated by commas, on a single line. A list of multiple declarations may not be continued on the following line.

To comply with the VisualDSP++ 3.5 release of the assembly language, you use the `#define` preprocessor command to declare a constant symbol and its *replacementText*. For more information on the `#define` command, see `#define` (on page 2-13).

Example:

```
.CONST taps=15, base=H#0D49, sqrt2=H#5A82;
   // This line of legacy code corresponds to the following
      lines:
#define taps 15
#define base 0x0D49
#define sqrt2 0x5A82
```

Note that a single `#define` preprocessor command contains only one constant declaration.

.DMSEG and .PMSEG, Place Data and Code in Memory Sections

The `.PMSEG` and `.DMSEG` directives are similar to the `/`*`type`* qualifier of the `.SECTION` directive.

These directives have the following syntax:

`.PMSEG` *`pmsection_name`*;

`.DMSEG` *`dmsection_name`*;

The `.PMSEG` directive causes the linker to place all of the module's code and data structures in the program memory section *`pmsection_name`*. The `.DMSEG` directive causes the linker to place all of the module's data structures in the data memory section *`dmsection_name`*. The *`pmsection_name`* and *`dmsection_name`* sections must be previously defined in the Linker Description File. The `.PMSEG` and `.DMSEG` directives must precede the `.MODULE` directive in your source code file.

Here is an example that locates only the DM data of a module in a segment named `Audio_Samples`:

```
.DMSEG Audio_Samples;
.MODULE/RAM Sample_Input;

.VAR/DM/RAM/CIRC sample_buffer[15];
.VAR/DM/RAM other_buffer[5];
.VAR/DM/RAM another_buffer[5];
.VAR/DM/RAM variable1;

{…instructions for SAMPLE_INPUT routine}

.ENDMOD;
/* The code for the SAMPLE_INPUT routine is in program memory;
it assembles and links normally */
```

To define placement of code and data objects in program memory and data memory sections using the new assembler syntax, use the `.SECTION/PM` and `.SECTION/DM` directives and the Linker Description File. `SECTION`s define groupings of instructions and data that are set as contiguous memory addresses in the DSP. Each `.SECTION` name corresponds to an input section name in the Linker Description File (`.LDF`).

The `.DMSEG` example may be revised using the `.SECTION/type` directive:

```
.SECTION/DM Audio_Samples;
.VAR sample_buffer[15];

.SECTION/PM Sample_Input;
{…instructions for SAMPLE_INPUT routine}

.SECTION/DATA Audio_Samples;
.VAR other_buffer[5];
.VAR another_buffer[5];
.VAR variable1;
```

For further information on the `.SECTION` directive, see ".SECTION, Declare a Memory Section" on page 1-67.

ⓘ Note that only one program `.MODULE` is allowed per source file, whereas multiple program memory (`.SECTION/PM`) sections define mapping of code and possibly data in a single assembly file.

.ENTRY, Make a Program Label Globally Available

The `.ENTRY` directive allows program labels to be referenced in other modules. By default, a label is only valid in the module it is declared. Once you have changed the label's scope to global using the `.ENTRY` directive, it is available for export. This lets you use the label for subroutine calls or inter-module jumps.

The `.ENTRY` directive uses the syntax:

```
.ENTRY program_label[, … ];
```

A single `.ENTRY` directive may declare one or more global labels, separated by commas, on a single line. A list of multiple declarations may not be continued on the following line.

Once the label is declared as global, other modules or linked files can import (reference) it with `.EXTERNAL` (6.1 release) or `.EXTERN` (current VisualDSP++ release).

To comply with the `easm218x` or `easm218x` syntax, you use the `.GLOBAL` directive to make symbols, including program labels, globally available. For more information on the `.GLOBAL` directive, see ".GLOBAL, Make a Symbol Globally Available" on page 1-50. For more information on the `.EXTERN` directive, see ".EXTERN, Refer to a Globally Available Symbol" on page 1-46.

Example:

```
.ENTRY addcm_encode, adpcm_decode;
   // make labels visible outside current module using the
   // release 6.1 syntax

.GLOBAL addcm_encode, adpcm_decode;
   // make labels visible outside current file using the
   // release VisualDSP++ 2.0 syntax
```

.EXTERNAL, Refer to a Globally Available Symbol

The .EXTERNAL directive allows a code module to reference global data structures (variables, buffers, and ports) and entry labels declared in other modules. The symbol in question must be defined as a GLOBAL or ENTRY symbol in the module in which it originates and must be defined as an .EXTERNAL before it can be referenced in another module.

This directive has the form:

```
.EXTERNAL symbol[, … ];
```

The current version of the assembler software has replaced the .EXTERNAL keyword with .EXTERN. To comply with the easm218x or easm219x syntax, before importing the symbol in question, make sure that it is declared with the .GLOBAL directive in the file to be linked with the current one.

Example:

```
.EXTERNAL fir_start;
   // references the global label using the legacy syntax.

.EXTERN fir_start;
   // references the global label using the new syntax.
```

For more information on the .GLOBAL directive, see “.GLOBAL, Make a Symbol Globally Available” on page 1-50. For more information on the .EXTERN directive, see “.EXTERN, Refer to a Globally Available Symbol” on page 1-46.

.INCLUDE, Include Other Source File

The `.INCLUDE` directive is used to include another source file in the file being assembled. The assembler opens, reads, and assembles the indicated file when it encounters the `.INCLUDE` statement line. The assembled code is incorporated into the output `.DOJ` file. When the assembler reaches the end of the included file it returns to the original source file and continues processing.

The`.INCLUDE` directive has the form:

```
.INCLUDE <filename>;
```

If the file to be included is in the current directory of your operating system, only the filename need be given inside the brackets. If the file is in a different directory, you must give the path of this directory with the filename (or with the `ADII` environment variable). For example, if the file to be included is named newcode.dsp and is located in a subdirectory `C:\218x\filters\` or `C:\218x\filters\`, then the `.INCLUDE` directive must be given in this way:

```
.INCLUDE <C:\218x\filters\newcode.dsp>;
```

This allows the assembler to find the file.

Alternatively, you can specify the path by using the `ADII` environment variable. Setting `ADII` equal to the path also allows the assembler to locate the file. In this case you can give the filename without its path in the `.INCLUDE` directive.Included files may in turn have `.INCLUDE` statements within them; nesting of include files is limited only by memory. Included files may not, however, contain C preprocessor directives, such as `#define`. To include a file that contains C preprocessor directives, use the `#include` command instead of `.INCLUDE`.

The `.INCLUDE` directive allows for modular programming. For example, in many cases it is useful to develop a library of subroutines or macros which are shared between different programs. Rather than rewriting the routines for each program, you can incorporate the macro library into an assembled module using the `.INCLUDE` directive.

The current release of the assembler software has replaced the `.INCLUDE` directive with `#include`, although the source programs that use `.INCLUDE` may be re-assembled with the -legacy switch. Analod Devices recommend that you revise your legacy source code programs in order to avoid incompatibility with a future release of the DSP development tools.

For further information on the `#include` preprocessor command, see "#include" on page 2-23.

.INDENT, Indent a Listing File

The `.INDENT` directive indents the text in the listing file (`.LST`) that the assembler generates when you use the `-l` switch.

The `.INDENT` directive has the following form:

```
.INDENT expression;
```

Example:

```
.INDENT 9;      // 9 spaces are left at the left margin
…
…               // instructions
…
.INDENT 5;      // 5 spaces are left at the left margin
```

The *`expression`* marks the left bound of a row; each text line begins at column *`expression`* + 1. By placing the `.INDENT` directive at the beginning of your assembly source file, you apply the formatting to the entire listing file. The current setting is valid until the assembler encounters the following `.INDENT` statement.

The `.INDENT` directive is omitted in VisualDSP++ 3.5 release. To format your listing file, you use the `.PAGEWIDTH`, `.PAGELENTH`, and `.LEFTMARGIN` directives.

.INIT, Initialize a Variable or Buffer

The `.INIT` initializes variables and buffers. Initialization values may be listed in the directive statement or supplied by an external file.

The `.INIT` directive takes one of the following forms:

```
.INIT   … ;buffer_symbol: constant, constant,
.INIT … ;buffer_symbol: ^other_buffer or %other_buffer,
.INIT buffer_symbol: <filename>;
```

The `^` and `%` operators can be used to initialize the buffer or variable with the base address or length of other buffer(s). Any combination of constants, buffer address pointers, and buffer length values may be given, separated by commas. Here are some examples:

```
.INIT seed_values: 1,2,3,5,7;
//This initializes the buffer seed_values with the listed
//constants.

.INIT buffer_ptr: ^input_buf;
// Here the variable buffer_ptr is initialized with the buffer
// input_buf by referencing its start address.

.INIT cos: <cosines.dat>;
// The assembler establishes a pointer to cosines.dat and the
// linker initializes the buffer cos with the data file contents.

.INIT inputs: ‘ABCD’;
// This initializes the first four locations of the data buffer
// inputs with the ASCII codes for the letters A, B, C, and D.
```

If the initialization file is in the current directory of your operating system, only the filename need be given inside the brackets. Otherwise, you must give the path of this directory with the file name. For example, if `inits.dat` is the initialization file for a buffer named `samples`, and is located in the DOS subdirectory `C:\218x\filter3\`, then the `.INIT` directive should be given as:

```
.INIT samples: <C:\218x\filter3\inits.dat>;
```

A special syntax of the `.INIT` directive, `.INIT24`, lets you store 24 bits of data in a program memory word, rather than the normal 16 bits. This allows you to access the lower 8 bits of each 24-bit program memory word when initializing data buffers or variables in source code. For example,

```
//statement computes a 16-bit address:
.INIT var: ^label + 10;

//statement computes a 24-bit address:
.INIT24 var: ^label + 10;
```

If you are upgrading your code so it adheres to the current version of the assembly language, you must use the `.VAR` directive to declare and initialize variables and buffers. See ".VAR, Declare a Data Variable or Buffer" on page 1-75. for information on the `.VAR` directive and its special case, `.VAR/24`.

This is the example of the revised code.

```
/* Legacy syntax declaration: */
.VAR/DM/SEG=seg_mydata sqrt_coeff[3];
.INIT sqrt_coeff: H#5D1D, H#A9ED, H#46D6;

/* Current syntax declaration: */
.SECTION/DATA seg_mydata;
.VAR sqrt_coeff[3] = 0x5D1D, 0xA9ED, 0X46D6;
```

.INIT and ASCII String Initialization Support

The assembler of Release 6.1 supports 8-bit ASCII string initialization. This allows the full use of the 8-bit ASCII character set (256 characters), including digits, and special characters.

String initialization takes one of the following forms:

```
.INIT symbolString;'initString', 0;
```

Note that the number of initialization characters defines length of an a string (implicit-size initialization).

Example:

```
.VAR/RAM/DM bindwidth[21];
.VAR bindwidth[21]: ‘Rec stat : Play stat’, 0;
```

The assembler also accepts 8-bit ASCII characters within comments.

.LOCAL, Create a Unique Version of the Label

The .LOCAL directive is given with program labels used in macros. The .LOCAL directive instructs the assembler to create a unique version of the label at each invocation of the macro. This prevents duplicate label errors from occurring when a macro is called more than once in a code module.

The .LOCAL directive has the form:

```
.LOCAL label_symbol[, … ];
```

The assembler creates unique versions of label_symbol by appending a number to it; this can be seen in the .LST file if macros are expanded.

To comply with the current version of the assembly language, you can use a trailing '?' to ensure unique label names are generated no matter how many times the same macro is invoked. The preprocessor takes the label_symbol and postpends _num to it, where num is uniquely generated for every macro expansion. For example:

```
abcd? ===> abcd_1
```

The following example demonstrates the described technique. A code example declares a macro named getsLabel with one argument. In the invocation of the macro, the label is concatenated with a number. This concatenated argument varies with each macro invocation. So, the preprocessor outputs three versions of start.

Example:

```
// Macro declaration using the release 6.1 syntax:
MACRO getsLabel(%1);
.LOCAL start;
   start:
   M5=1; I6=1; MODIFY(I6,M4); %1=DM(I6,M5);
.ENDMACRO;

// Macro declaration using the VisualDSP++ 3.5 release syntax:
```

```
#define getsLabel(a) \
start?: \
M5=1; I6=1; MODIFY(I6,M4); a=DM(I6,M5)

// Macro invocation, generate unique labels:
getsLabel(MR1);
getsLabel(MR1);
getsLabel(MR1);

// Macro expansion:
start_1:
   M5=1; I6=1; MODIFY(I6,M4); MR1=DM(I6,M5);
start_2:
   M5=1; I6=1; MODIFY(I6,M4); MR1=DM(I6,M5);
start_3:
   M5=1; I6=1; MODIFY(I6,M4); MR1=DM(I6,M5);
```

.MACRO and ENDMACRO, Define a Macro

Macros are created with the assembler's `.MACRO` directive. Each statement within the macro can be an instruction, directive, or macro invocation. The `.ENDMACRO` directive marks the end of a macro definition.

A macro definition has the following syntax:

```
.MACRO macro_symbol[(%1,%2,…,%n)];
…
…
.ENDMACRO;
```

In the macro's code, the arguments are marked by the placeholders `%1`, `%2`, `%3`, etc. When the macro is invoked, the placeholders are replaced by argument values passed in the call. The correct number of arguments must be passed.

A macro is invoked with its name. The invocation may not contain additional program statements (such as instructions, preprocessor directives, or other macro invocations) on the same line of source code. When the macro is called, the arguments passed may be anything from the following list:

- constant or expression
- symbol (may be any reserved keyword except `MACRO`, `ENDMACRO`, `CONST`, or `INCLUDE`)
- expressions with special address pointer (^) and length of (%) operators

VisualDSP++ 3.5 assembler software has eliminated the `.MACRO` directive, although the source programs that use this directive may be re-assembled with `-legacy` switch. We recommend that you revise your legacy macro declarations in order to avoid incompatibility with a future release of the

DSP development tools. Another way to define macros is with the `#define` C preprocessor command. For more information on this command, see "#define" on page 2-13.

Revise your `.MACRO` declarations as shown below.

```
// MACRO declaration using the release 6.1 assembler syntax:
.MACRO getsfirst(%1);
start:
   M5=1; I6=1; MODIFY(I6,M4); %1=DM(I6,M5);
.ENDMACRO;

// MACRO declaration using the VisualDSP++ 2.0 release
// assembler syntax:
#define getsfirst(a)\
start:\
   M5=1; I6=1; MODIFY(I6,M4); a=DM(I6,M5)

// Macro invocation, common:
getsfirst (MR1);
```

.MODULE and .ENDMOD, Declare a Program Module

The `.MODULE` directive defines the program module's name and marks it beginning, whereas the `.ENDMOD` directive marks the module's end. The assembler stops when it reaches the "end" directive. A source code file may contain only one program module.

This directive has the form:

```
.MODULE/qualifier/qualifier moduleSymbol;
```

where `/qualifiers` are keywords that define memory type and placement of a module in the DSP system. Table 3-3 lists valid qualifiers and provides a brief description of each.

Table 3-3. Module Qualifiers

Qualifier	**Description**
PM or CODE	Memory type — Program Memory.
DM or DATA	Memory type — Data Memory.
RAM	Memory type — Random Access Memory.
ROM	Memory type — Read Only Memory.
ABS=address	Placement of a module at absolute start address.
SEG=secName	Placement of a module in the LDF-declared section secName.
STATIC	A module can not be overwritten during boot page loads.

- **ABS=address**
  The `ABS` qualifier places the module's code at a particular address in program memory, making it non-relocatable. This means that the linker is forced to reserve memory for the module at the specified address. Modules that do not have the `ABS` qualifier are relocatable.

- **SEG=secName**
  The `SEG` qualifier locates the module in a specific memory section, `secName`, which is declared in the Linker Description File. If you use both the `ABS` and `SEG` qualifiers, and specify an absolute address which is not in the named section, you will see an error message when the linker is run.

- **STATIC**

  The `STATIC` qualifier is supported only on ADSP-218x DSPs.

  The `STATIC` qualifier prevents the overwriting of a section when a boot page is loaded. The linker assures this when it determines the placement of your program in memory. If a section is not declared as `STATIC`, it may be partially or completely overwritten by the contents of any boot page.

  When the linker allocates memory to store your program, it considers nine independent time frames of memory: non-booted program, data memory, and boot pages 0-7. Non-booted memory is defined as the initial state of `PM` and `DM` before any boot page is loaded or any code is executed.The code and data of boot page 0 can normally be placed anywhere by the linker, without regard for any pre-existing memory contents (non-booted values), the code and data of boot page 1 can be placed anywhere without regard for the page 0 values, and so on.

The `BOOT` and `STATIC` qualifiers are used only for DSPs with boot memory, which includes all processors of the ADSP-21xx processors (except the ADSP-2100 DSPs).

Example 1:

```
.MODULE/PM/ABS=0x0040 main_prog;
 …
.ENDMOD;
/* This example declares main_prog which is to be located in
   program memory RAM at address 40 (hexadecimal). */
```

Example 2:

```
.MODULE/SEG=fir filter_routine;
 …
.ENDMOD;
/* This statements declare the relocatable module
   filter_routine, located in a memory segment named fir,
   which is defined in the linker description file (.ldf). */
```

Although the `.MODULE/.ENDMOD` directives have been replaced in the current release, `easm218x` and `easm219x` assemblers process your legacy programs when the `-legacy` switch is used.

To mark a program memory section using the VisualDSP++ 3.5 release assembler syntax, you use the `.SECTION/PM` or `.SECTION/CODE` directives. With `.SECTION`, you have advantage of having multiple code sections in a source file and control over data placement. The Linker Description File defines placement of your source sections in the DSP memory. In addition, you can interpret the results of the assembly process via the `elfdump` utility. This utility is included in the DSP development kit and allows you to view the section's size and variable placement.

For more information on the `.SECTION` directive, including syntax and usage examples, see ".SECTION, Declare a Memory Section" on page 1-67. For information on the `.LDF` file and the `elfdump` utility, see the *VisualDSP++ 3.5 Linker and Utilities Manual for 16-Bit Processors*. Note that only one `.MODULE` is allowed per source file, whereas multiple program `SECTION(s)` define mapping of code and data in a single assembly file.

.PORT, Declare a Memory Mapped Port

The `.PORT` directive assigns a port name symbol to I/O port. Port name symbols are global symbols. This port name corresponds to an I/O port that you define in the Linker Description File.

The `.PORT` directive uses the following syntax:

```
.PORT port_name;
```

The `port_name` is a port symbol that is globally available.

To declare a port using the ADSP-218x/ADSP-219x assembler syntax, you use the `.VAR` directive to declare the port-identifying symbol and the Linker Description File to create the corresponding I/O section. The linker resolves port variables in the `.LDF` file.

For more information on the LDFs, see the *VisualDSP++ 3.5 Linker and Utilities Manual for 16-Bit Processors*. For more information on the `.VAR` directive, see ".VAR, Declare a Data Variable or Buffer" on page 1-75.

Examples:

```
// legacy assembly syntax:
.PORT port1;   {declares I/O port port1}
.PORT port2;   {declares I/O port port2}

// current assembly syntax:
.VAR port1, port2;      {declares two port variables}
.GLOBAL port1, port2;   {global scope variables}
```

.VAR/ABS, Place a Variable at the Specified Address

The /ABS qualifier of the .VAR directive places the variable or buffer at a particular *address* in program memory or data memory, making it non-relocatable. This means that the linker is forced to reserve memory for the variable or buffer at the specified *address*. Variables and buffers that do not have the ABS qualifier are relocatable. For more information on the .VAR directive, see ".VAR, Declare a Data Variable or Buffer" on page 1-75.

.VAR/CIRC, Declare a Circular Buffer

The .VAR directive declares a liner buffer unless the /CIRC attribute is applied. The /CIRC qualifier defines the buffer as circular. For more information on the .VAR directive, see ".VAR, Declare a Data Variable or Buffer" on page 1-75.

The following example declares a relocatable circular buffer whose length is the value of the constant taps.

```
.CONST taps=15;
.VAR/DM/CIRC data_buffer[taps];
```

When multiple variables and buffers are declared on the same line, the linker places them in contiguous memory locations. If multiple buffers are declared on one line, and the /CIRC qualifier is used, a single circular buffer is created—the individual buffers will be simple linear buffers only. For example, the following declaration creates one 15-word circular buffer.

```
.VAR/CIRC aa[5],bb[5],cc[5];
```

The base address of the circular buffer is `aa`; this is the symbol used to access the buffer in code. The address of `bb` is `aa+5` and the address of `cc` is `aa+10`. The three five-word buffers can be individually accessed as linear buffers. Since the value 15 requires four bits for binary representation, the circular buffer `aa` is located at an address which is a multiple of sixteen.

The following example uses three `.VAR` directives to declare three different circular buffers.

```
.VAR/CIRC aa[5];
.VAR/CIRC bb[5];
.VAR/CIRC cc[5];
```

This example creates the structure for a `sine/cosine` lookup table.

```
.VAR/CIRC sin[256],cos[768];
```

A single circular buffer is defined which has a length of 1024. To access the buffer in code, you can initialize `DAG` index registers and buffer length registers with the following instructions:

```
I0=^cos;   /* ^ is the Release 6.1 “address pointer” operator */
L0=1024;
I1=^sin;
L1=1024;
```

These instructions load `I0` and `I1` with the base addresses of cos and sin. The corresponding `L` registers are loaded with the length of the circular buffer to enable wraparound addressing. A circular buffer is only implemented when an `L` register is set to a non-zero value.

The following example demonstrate how the assembler operators are used to load `L` (length) and `I` (index) registers when setting up circular buffers.

```
.SECTION/DATA data1;        // data section
.VAR real_data[n];          // n=number of input samples
…
.SECTION/CODE program;      // code section
   I5=real_data;            // buffer’s base address
```

```
      L5=length(real_data);   // buffer’s length
      AR=I5;                  // load address to data register
      REG(B5)=AR;
      M4=1;                   // post-modify I5 by 1
      CNTR=DO loop1 UNTIL CE;
      AX0=DM(I5,M4);          // get next sample
      …
   loop1:  …
```

This code fragment initializes `I5` and `L5` to the base address and length, respectively, of the circular buffer `real_data`. The buffer length value contained in `L5` determines when addressing wraps around the top of the buffer.

For more information on circular buffers, refer to the target DSP’s Hardware Reference Manual.

Syntax Conventions

The assembler supports numeric bases and comments formats within expressions and instructions. You build these expressions and instructions using predefined set of operators and following the assembler's syntax.

This section contains:

- "Modified Operators"
- "Modified Numeric Conventions"
- "Comment Conventions"

Modified Operators

Syntax for the special "length of", "address of", "page of", and preprocessor's division operators have changed. Table 3-4 lists modified operators.

Table 3-4. Modified Operators

Release 6.1 Operator	Description	Change for VisualDSP++ 3.5
\	Division	/
`%symbol`	Length of *`symbol`* in words.	`LENGTH(`*`symbol`*`)`
`^symbol`	Address pointer to symbol	*`symbol`*

`PAGE` *`symbol`*
`PAGEOF` *`symbol`*
	Upper address bits of a page associated with *`symbol`*.	`PAGE(`*`symbol`*`)`

Modified Numeric Conventions

The format for the hexadecimal numeric base has been modified; the usage of the "`0x`" prefix is preferred for hexadecimal numbers. When assembling programs coded with any of numeric conventions listed in Table 3-5, select the `-legacy` switch.

Table 3-5. Hexadecimal Numeric Formats

Release 6.1 Convention	Description	Change for VisualDSP++ 3.5
`0x` *`number`* H#*`number`* h#*`number`*	Hexadecimal base *`number`* formats.	`0x`*`number`*

Comment Conventions

The assembler now supports C++-style format for inserting comments in assembly source code programs:

`//comment` — A pair of slashes (/ /) denote each single-line comment.

The following comment formats are legacy formats:`!comment` — ! begins each single-line comment.

`{ comment }` — a pair of braces "{ }" enclose multiple-line comment.

The current release of development tools allows you to use the `-csall`, `-cs!`, `-cs{`, `-cs//`, or `-cs/*` switch on the assembler's or on the preprocessor's command line to select your comment style format.

Debugging Capabilities and File Format

The assembler and preprocessor include features that allow for debugging of your source code programs. These features include the ability to generate binary data in ELF/DWARF-2 file format and to output line number and the file name of a source file.

ELF File Format

The VisualDSP++ 3.5 assembler creates and supports files in ELF format. The ELF format is derived from the industry standard ELF Specification. The ELF binary format provides host independent object representation and allows for greater flexibility in describing sections.

Object, library, and executable files that were generated by Release 6.1 and prior releases of the tools are in ASCII executable (AEXE) format. If you are using these files in your project builds or find you are rebuilding frequently, you might consider converting them into the ELF format.

You can do this using the `aexe2elf` utility, which is installed in the ADSP-218x DSP and ADSP-219x DSP code generation packages and documented in the *VisualDSP++ 3.5 Linker and Utilities Manual for 16-Bit Processors*. Doing this conversion can potentially save time in your project development cycles.

Although the `aexe2elf` utility will convert your AEXE object files to the ELF object files, it will not convert the AEXE debug information into DWARF-2. As a result, source files that were previously generated in the AEXE format must be reassembled or recompiled in ELF in order to be debugged.

Debug Information

When assembling your source file, either from a command line or within the VisualDSP++ environment, you have the option of generating binary information for source level debugging. You can do it by selecting the `-g` command-line switch or checking the **Generate debug information** check box in the **Assemble** tab of the VisualDSP++ environment's **Project Options** dialog box. The ELF assemblers generate debug information in DWARF-2 format.

For more information on the `-g` switch, see "-g" on page 1-90. For more information on the VisualDSP++ environment, see the *VisualDSP++ 3.5 User's Guide for 16-Bit Processors*.

You also have the option of outputting the line number and file name of your original source file from the assembler by using the `#line` preprocessor command. For more information on the `#line` command, refer to "#line" on page 2-25.

A UTILITIES

Your VisualDSP++ 3.5 development software comes with the comment conversion utility that runs from a command line only. This utility provides support for converting legacy code developed under Release 6.1. This appendix describes the utility and its command-line interface.

Comment Converter

The comment converter program (`commentconverter.exe`) takes an assembler source file and converts legacy comment delimiters to C-style and C++-style comment delimiters.

When converting comments, all occurrences of "{ }" pair interpreted as comments are replaced with "/* */" comment delimiters. All occurrences of "!" interpreted as comments are replaced with "//". The comment converter replaces "{ }" or "!" only when it interpreted as a comment delimiter in the source file. Other occurrences, such as a comment within another comment, are not converted.

The conversion utility has the following command line:

```
C:\Program Files\Analog Devices\VisualDSP>commentconverter
```

Usage: `commentconverter <`*`inputFilename`*`>`

For typical usage, use the `-o` switch to direct the output:

```
commentconverter inputFilename.asm -o outputFilename.asm
```

Additional options can be used to select other comment formats to be interpreted by the converter. These options appear in the help screen (`-help`), as follows in Table A-1.

Table A-1. Commentconverter Command-Line Switches

Convention	Description
`-csall`	Detects all supported commenting styles: `-cs{` "{ }" style comments `-cs/*` "/* */" style comments `-cs!` "!" style comments `-cs//` "//" style comments
`-help`	Displays a list of switches
`-noinfo`	Turns off informational messages
`-nowarn`	Turns off warning and informational messages
`-o` *`filename`*	Outputs named converted file
`-rsall`	Replaces "`{ }`" and "`!`" style comments
`-rs{`	Replaces "`{ }`" style comments
`-rs!`	Replaces "`!`" style comments

By default, the comment converter recognizes all comment delimiters (`-csall`) and replaces both "`{ }`" and "`!`" comment formats (`-rs{, rs!`).

The `-no` prefix preceding the `cs` and `rs` switches turns off recognition of commenting styles.

Example:

```
{ start of a comment
  more comment
  end of a comment
  }
  label: NOP;    // no code here!

  ! start of a comment {single line}
```

Once the utility is run with the default options, the example converts to:

```
/* start of a comment
   more comment
   end of a comment
   */

   label: NOP;   // no code here!

   // start of a comment {single line}
```

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